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Anti-corrosive Properties of *Centella asaitica* (Gotu Kola) and *Alternanthera sessiles* (Joyweed) Extracts in Acidic and Basic Medium

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ABSTRACT

Corrosion in the oil and gas industry causes major economic losses, prompting this study to assess the effectiveness of *Centella asiatica*(AGotu kola) and *Alternanthera sessilis* (Dwarf joyweed) plant extracts as corrosion inhibitors for mild steel in acidic and basic media. Phytochemical screening confirmed both plants contain saponins, tannins, steroids, terpenoids, alkaloids, glycosides, and anthraquinones.The weight loss method was used to evaluate inhibition efficiency after immersing mild steel in 0.5 M HCl and 0.5 M NaOH with the extracts. In acidic medium, C. asiatica showed inhibition efficiencies of 37.50–85%, while A. sessilis ranged from 64.30–85.7%. In basic medium, C. asiatica achieved 37.50–65% and A. sessilis achieved 16.70–46.70%. A 1:1 blend of both extracts yielded 64.30–85.70% efficiency in acid and 37.50–65% in base.Scanning electron microscopy of the coated metal surfaces revealed that C. asiatica produced a rough film with puff-wool-like structures on mild steel, whereas A. sessilis formed a rough, cracked surface. FTIR analysis identified functional groups including nitrile, carbonyl, alkyne, ether, ester, hydroxyl, and alkane, confirming the presence of active phytochemicals responsible for inhibition.The results demonstrate that both plant extracts effectively inhibit mild steel corrosion, particularly in acidic environments. A. sessilis showed superior performance in acid, making it the more effective inhibitor overall. The study supports the potential of these eco-friendly plant extracts as alternatives for corrosion control in oil and gas applications.

Keywords: Corrosion, Centella asiatica (Gotu Kola), Alternanthera sessilis (Dwarf joyweed), Acidic Medium, Mild steel & Basic Medium.

1.0 INTRODUCTION

Corrosion is defined as the degradation of materials due to chemical or electrochemical attack in the workplace [1]. It may also be considered an unintentional deterioration of materials as a result of their interactions with the environment, which have an adverse effect on the material's predetermined qualities. Corrosion weakens pipelines structurally and causes them to deteriorate and overflow their contents into the environment, making them an unsafe transmission channel [2]. A pure metal can incur irreversible surface damage in a corrosive environment whether solid, liquid, or gaseous due to chemical processes that convert it into its most stable forms, such as sulfides, oxides, or hydroxides. Corrosion is typically regarded as a global phenomenon [3].

According to [4], corrosion is an everyday occurrence that has an impact on our society on a daily basis. The deterioration and destruction of home appliances, motorcycles, aircraft, highways, buildings, energy manufacturing and distribution systems, and more are among the issues brought on by corrosion. Corrosion is an environmental factor that causes metal to modify its natural viewpoint or surface as a result of oxidation reaction alongside mixture in the environment.

Oil and gas fields use a lot of metallic components such as pipe, tubing, valves, pumping equipment, and sucker rods [5]. Because of the use of metals and the problems associated with corrosion, scientists are always looking for ways to reduce corrosion. Multiple approaches and methods have been constructed and are currently being employed to minimize corrosion. Industries around the world use protective coating to protect pipelines from corrosion. Paint is a mastic or flammable product consisting of pigment and changes into protective opaque film upon application. One of the most basic and important methods for protecting pipelines is still painting them with protective coating [6]. Galvanization is an additional method of stopping the corrosion of metal surfaces. Using both an anodic and cathodic component, this approach creates a corrosion response at particular locations on the metal surface [7].

While galvanization and painting have proven successful in stopping corrosion on the exterior of metals, their costs are rising. As an alternative, some plant extracts with anticorrosive qualities are currently being used [8]. When introduced in small amounts to a corrosive environment, corrosion inhibitors reduce the rate of corrosion by either delaying the cathodic and anodic processes or serving as a barrier by creating an adsorbed layer [9]. Because they are inexpensive, efficient, and simple to employ in acidic solutions, many substances that inhibit corrosion have recently gained popularity [10].

In order to find a natural, environmentally friendly, affordable, and easily accessible corrosion inhibitor, [11] used Grade 304 austenitic material stainless steel in a 1.0 M HCl solution to test the corrosion inhibition capacity of Terminalia catappa leaf extract. Gravimetric measurements and scanning electron microscopy (SEM) data on microstructural surface alterations were used to examine the extract's corrosion-inhibiting properties. Both Terminalia vcatappa inhibitor and no inhibitor were used during the investigation (0.01-50 ºC). Terminalia catappa leaf extract inhibited stainless steel corrosion in acidic conditions by 96.6 percent at 300C, according to data from weight loss assays and isotherms for adsorption. This data also supports the physisorption adsorption process. The results showed that the extract's inhibitory efficacy rose with increasing extract concentrations but fell with rising temperature. Weight loss, electrochemical impedance spectroscopy (EIS) potentiodynamic polarization, were used to assess the potential of Tinospora crispa extracts as a mild steel corrosion inhibitor in 1 M HCl. For Tinosporacrispa water extract (TCDW) and Tinosporacrispa acetone water extract (TCAW), the greatest inhibition was seen at 800 and 1000 ppm. With a maximal inhibition of around 70–80%, the impedance and polarization experiments of Tinosporacrispa extracts shown good concordance in their inhibitory efficacy. According to research employing potentiodynamic polarization measurements, Tinospora crispa extracts mostly function as an anodic inhibitor. [12] reported that Langmuir's adsorption model was seen in the adsorption process of Tinosporation crispa extracts.

The corrosion resistance of stainless steel with low carbon (LCS) in an acidic medium (0.5 M sulfuric acid) using an extract of Cannabis sativa leaves was tested in a distinct study utilizing the weight loss method, Tafel, and electrochemical spectroscopy (EIS) [14].

Potentiodynamic polarization on the surface of Low Carbon Steel (LCS) reveals the heterogeneous inhibitor deposition condition. Cannabis sativa demonstrated an astounding 97.31% inhibitory efficacy at a 200 mg/L inhibitor dosage. The thin layer that formed on the outermost layer of local carbon steel (LCS) to prevent corrosion was identified using atomic force microscopy (AFM) and scanning electron microscopy (SEM), and UV-visible spectroscopy demonstrated that the inhibitor had been adsorbed [13].

The influence of heteroatoms and functional groups in the inhibitor was verified using the FT-IR technique. The Langmuir's adsorption isotherm was used to compare the inhibitory chemicals' adsorbance on the surface of local carbon steel (LCS). The outcome of computational hypothetical investigations was a very useful report. According to all of the evidence, cannabis sativa leaf extract can effectively form a protective layer and prevent corrosion. The inhibitory efficiencies discovered by experiments are consistent with the outcomes of the molecular dynamics (MD) simulations [14].

Electromagnetic impedance spectroscopy (SEM), Potentiodynamic polarization (PDP), and the weight loss method were used to assess how well Cuscutare flexa fruit extract, which belongs to the Piperaceae family, inhibited mild steel corrosion in 0.5 M H2SO4. A 3-methoxy-3, 4, 5, 7-tetrahydroxy flavone found in Cuscutare flexa extract slows down mild steel corrosion in acidic environments. At a 500 mg/L inhibitor dosage, the best corrosion inhibition and efficiency was found. The adsorption of Cuscutare flexa extract on mild steel surfaces has been studied using UV-visible spectroscopy, Fourier transform infrared spectroscopy (FT-IR), atomic force microscopy (AFM), SEM, and density functional theory (DFT) [15]. The weight loss technique, EIS, and PDP with water and ethanol extracts of Spondias mombin leaves were used to assess the corrosive inhibition of mild steel in 1M HCl solution. The effect of temperature on inhibitor behavior was also examined. According to the Freundlich and Langmuir isotherms, both extracts stopped mild steel from corroding by adsorption. The inhibitory efficiency (IE) increased along with the extract concentration. 500 ppm of extracts produced the highest efficiency of 94.44% and 76.52% for ethanol and 51.52% and 58.57% for water after being exposed to an acid solution for 24 and 72 hours at 250 C in an acid solution, 500 ppm of extracts yielded the maximum efficiency of 94.44% and 76.52% for ethanol and 51.52% and 58.57% for water. The effectiveness of the water extract was significantly increased by increasing the temperature to 400 and 600 degrees Celsius (after a day), which promoted inhibition by a combination of chemical and physical adsorption. In contrast, the performance of the ethanol extract was reduced.

The extracts are suggested as environmentally friendly substitutes for the current hazardous ones since they offer mild steel good protection in acidic environments [16]. It is observed that corrosion has caused a lot of problems in our society, such problems include; destruction and degradation to household gadgets, automobiles, airplanes, highway bridges, energy production and distribution systems and so on causing accidents, injuries and even death [17]. One of the most prevalent types of material degradation that presents significant obstacles to various businesses and may even have an effect on human health is corrosion. For example, degradation of artificial implants (such as hips and knees) due to corrosive body fluid and wear may necessitate their premature replacement, which alone can cost any economy enormously [18]. It has been reported that corrosion has effect on the desirable properties of iron and steel causing them to lose strength and become unsuitable for use. Moreover, corrosion can lead to the deterioration of water pipelines resulting in water that is unsuitable for consumption and other domestic purposes. These outcomes can ultimately result in poisoning and fatalities. Corrosion causes considerable economic losses around the world, it has a significant impact on the production of gas and oil as well as how they are transported. Corrosion is causing costly issues for the sectors. The majority of corrosion-related issues can arise from exposure to electronic parts, materials, corroded chemical leaks, oil pipeline breakdowns, and even fire [19]. Barrier coating and painting of metal surfaces are some of the ways used to prevent metals from corrosion. However, the high cost of coating and painting, is now a concern. The research focuses on the investigation of plants with anti-Corrosive properties that are cheaper and alternative to those practices of painting and galvanizing.

The study is aimed at investigating the anti-corrosive properties of the Leaf extract of *Centella asiatica* (Gotu kola) and *Alternanthera sessilis* (Dwarf joyweed) in acidic and basic medium.

The objectives are to;

i. Extract and identify the phytochemical constituents in the leaves extracts of *Centella asiatica* (Gotu kola) and *Alternanthera sessilis* (Dwarf joyweed).

ii. Examine the functional groups of the leave extracts using Fourier Transform Infra- red Spectroscopy (FTIR)

iii. Asses the anti-corrosive properties of the leave extracts on the metal in acidic and basic medium using weight loss technique.

iv. Compare the inhibition efficiencies of the blend of the both extracts in different ratios with individual properties of the extract.

v. Assess the morphology of the plant on the metal using a Scanning Electron Microscopy(SEM).

2.0 MATERIALS AND METHODS

2.1 Study Area

The plant utilized in this study was gathered from the Bukan Sidi community in the Lafia Local Government Area of Nasarawa State, Nigeria (Figure 3.1). Its coordinates are latitude 80.540 East and longitude 80.540 North. The Gwandara, Eggon, and Fulani are the three main ethnic groupings. Hausa migrants and other minor tribes live side by side in the area. The town is bustling with business and educational activities. Farming is one of the other economic activities.

2.2 Sample Collection

The plant Centella asiatica(Gotu kola) and Alternanthera sessilis (sessile joyweed) was collected from Bukan Sidi in Lafia Local Government Nasarawa State, Nigeria. Then, it was identified at the Herbarium of the Department of Plant Science and Biotechnology, Federal University of Lafia, Nasarawa State, Nigeria.

Figure 1:Map of Lafia representing plant collection site (Source: Google)

2.3 MATERIALS AND METHOD

All chemicals used were purchased without any further purification. Distilled water, Acetone, Sodium Hydroxide (NaOH), Ethanol (CH3CH2OH), Hydrochloric Acid (HCl), Mayer's reagent, Wagner's reagent, Q235 steel with dimension of 7cm3 x 4cm3 was abraded using silicon emery paper, 100 ml standard flask, Aluminium foil, Analytical weighing balance, Water bath, Autoclave, Filter paper, Petri-dishes, 250ml beaker , Test tubes, Magnetic stirrer, Leaves extracts of the plants, Mortar and pestles, Cary 630 machine and PhenomProX Scanning Machine.

2.4 Preparation of Plant Extracts

To get rid of dust and other undesirable particles, the leaves were carefully cleaned with distilled water after being plucked out. Using a mortar and pestle, the leaves were pounded into a finely ground powder after being allowed to dry for seven days at room temperature.

2.5 Sample Extraction

After weighing 500 grams (500g) of each powder into a sterile conical flask, 1000 milliliters of 100% ethanol were added. It was filtered after being left for 72 hours, or three days. After air drying, the extracts were kept for later usage (Omotioma et al., 2015).

2.6 Phytochemical Screening of the Plant Extracts

The Phytochemical screening of the plant was carried out for centella asiatica(Gotu kola) and alternanthera sessilis (Dwarf joyweed) using standard procedures as described by [37] as follows:

2.6.1 Test for Tannins

Each portion of the plant extract was dissolved with 2mL of deionized water and warmed in a water bath. Three (3) drops of 0.1% ferric chloride were added stepwise to the filtrate after the mixture was filtered, the dark green color formed indicate the presence of tannins.

2.6.2 Test for Saponins

In a test tube with five milliliters of distilled water, 1 mL of each plant extract was dissolved and forcefully agitated. The liquid developed astable, long-lasting foam, indicating the presence of saponins.

2.6.3 Test for Flavonoids

After dissolving 0.5g of each plant extract in 5 cm3 of distilled water, lead acetate aqueous solution was added dropwise to 2cm3 of the solution. The yellow precipitate that developed indicated the presence of flavonoids.

2.6.4 Test for Alkaloids

After cooling, 0.5g of each plant extract was heated with 1% HCl and filtered. Two (2) drops of Mayer's reagent were added to the filtrate. The presence of alkaloids was suggested by the production of a thick precipitate.

2.6.5 Test for Terpenoids

To create a layer, 0.5g of each plant extract was combined with 2mL of chloroform, and then 3mL of concentrated H2SO4 was carefully added. The presence of terpenoids was indicated by the formation of a reddish-brown color interface.

2.6.6 Test for Steroids

5g of the sample's ethanolic extracts were mixed with two milliliters (2 ml) of H2SO4 and two cubic centimeters (2 cm3) of acetic anhydride. Steroids are present because the color does not shift from violet to green.

2.6.7 Test for Glycosides

0.5g of each plant extracts was dissolved in 1mL of distilled water and then aqueous 1% NaOH solution was added. A yellow color was formed color which indicated the presence of glycosides

2.6.8Test for Anthraquinones

In a water bath, 0.5g of each plant extract was cooked for a few minutes with 2 mL of 10% HCl. After filtering, the resulting solution was left to cool. The filtrate was mixed with an equal volume of chloroform. The mixture was heated after a few drops of a 10% NH3 solution were added. The presence of anthraquinones in the extracts was suggested by the rose pink color that was seen.

2.6.9 Preparation of metal coupon for analysis

The soft steel sheets were sliced into thirty coupons, each measuring seven centimeters by four centimeters. To reveal the gleaming polished surface, it was scrubbed and polished with emery paper. The coupons were then stored in a dehydrator after being degreased with acetone, cleaned with distilled water, and allowed to air dry [20].

2.6.10 Preparation of inhibitor

Several concentrations of the inhibitor from *Centella asiatica* (Gotu kola) extract (2ml, 4ml, 6ml, and 8ml) were prepared in 0.5 M NaOH. The reference was 0.5 M NaOH which was without inhibitor. Similar concentrations of the inhibitor was prepared in 0.5 HCl and 0.5 M HCl as a reference [21].These was repeated for the extract of *Alternanthera sessilis* (Sessile joyweed).

To prepare 100 mLs solution of 0.5M NaOH in the alkaline medium

Molarity = wt of solute ÷ wt of solute × 1000 ÷ vol of solvent taken …Eq (2.1)

1M of NaOH = 40g of NaOH

Therefore, M =m ÷ MM × 1000 ÷ v (in moles) …Eq (2.2)
Where:
MM = molar mass, V= volume in mLs, m= mass in grams
Mole = 0.5
m= ?
MM=40g

V=100mL

0.5 = m÷40
M = 0.5(10 × 4) = 20g

Therefore; 20g of NaOH was dissolved in 100 mL of distilled water.
To prepare 100 mLs solution of 0.5 HCl
1M HCl=1000mL= 83.5 mL

Molecular weight of HCl= 36.5g/mL

Density = 1.18g/cm3

% Assay = 37%

1M HCl= 1000 mL

D = Density, M = Mass, V= Volume

Density = Mass ÷ Volume

Therefore, V =36.5/1.18 = 30.9mL ..Eq(3.2)
1M HCl 37% =37.90 mL of HCl
100% = 30.9 × 100 ÷37 = 83.5 mL

1ml HCl= 1000 mL = 83.5 mL

Therefore; 0.5 ml HCl= 100mL = 8.35mL

6.11 Anti-Corrosion testing
These were done as reported by [22] One hundred (100 ml) militer of 0.5M NaOH each was poured into five (5) 250 ml beakers. These volumes were the same for all beakers. The inhibitor (*Centella asiatica* plant extract) was added to the diluted base in the beakers in varying volumes: 0 ml, 2 ml, 4 ml, 6 ml, and 8 ml, respectively. Each beaker included the coupons for mild steel plates. After a day, the first coupon was taken off. Subsequently, the second, third, fourth, and fifth were immersed at room temperature for 48, 72, 96, and 120hours, respectively. Each coupon were removed from the solution and immediately brushed, cleaned and rinsed in 34.4% ethanol to remove the corrosion product on the surface. The same process was repeated for 0.5 HCl. And for the extract of alternanthera sessilis, the above process was repeated, Their weights were measured after it had dried and recorded.

2.6.12 Determination of weight loss

The weight loss was determined using the formula below;

W = Wb – Wa …Eq(4.2)

Where ;

Wb = Weight before immersion test
Wa = Weight after immersion test

2.6.13 Determination of corrosion rate (CR)

The weight loss of the coupons at room temperature (33^{o}C) at different concentrations and immersion test was used to compute the corrosion rate (CR) in millimeters per year (mm/year) using an equation.

Cr = K × Wt. loss/A × T × D …Eq(5.2)

Where;

K = Corrosion constant 8.76x104 g/cm^3

Wt. loss= Weight loss in grams (g) after exposure in corrosive medium
D = Density of the mild steel
A = surface area of the specimen in cm3
T = the end time of each experiment

2.6.14 Evaluation of Percentage Inhibitory Efficiency of the plant extracts (IE%)

The percentage inhibition efficiency (IE%) was calculated using

IE% = CRuN - CRiN÷CRuN×100 …Eq(6.2)

Where CRuN is the corrosion rate in the absence of the inhibitor, and CRiN is the corrosion rate in the presence of inhibitor.

2.6.15 Determination of Functional Group of plants extracts using FT-IR

The extracts of each plant was labelled A (Centella asiatica) and B for (Alternanthera Sessilie) were prepared for analysis and taken to the Ahmadu Bello University Zaria, Kaduna State for Fourier Transform Infrared Spectroscopy (FT-IR) analysis (Cary 630 machine was use for the analysis)

2.6.16 Determination of the coated metal sample using Scanning Electron Microscope (SEM)

The mild steel metal surface was coated with the sample extract solution labelled C (Centella asiatica) and D (Alternanthera Sessilie), were also sent to Ahmadu Bello University Zaria, Kaduna State for analysis (PhenomProX machine was use for the analysis).

3.0 RESULTS AND DISCUSSIONS

3.1 Phytochemical Properties of Plant Extracts

Table 1.The table presents the results of the phytochemical analysis conducted Centella asiatica(Gotu kola) and Alternanthera Sessilis(Dwarf joyweed) aimed to identify and quantify the presence of various phytochemicals. Qualitative analysis was done to detect the presence or absence of the phytochemicals while quantitative analysis was carried out to determine the concentration of the phytochemical present in the plants.

Table 1. Phytochemical analysis of *Centella asiatica* (Gotu kola) and *Alternanthera Sessilis* (Dwarf joyweed)

Phytochemicals	*Centella asiatica*			*Alternanthera sessilis*
Qualitative	Quantitative (mg/g)		Qualitative	Quantitative (mg/g)
Saponin	+	0.440	+	2.50
Tannis	+	4.644	+	11.25
Glycoside	+	2.150	+	1.75
Flavonoids	+	1.830	+	12.75
Alkaloids	+	0.51	+	3.25
Steroids	+	0.23	+	0.50
Anthraquinones	+	0.067	+	0.20

KEY: "+" = indicates present of compound, "-" indicates absence of compoun

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Table 1 shown the results of qualitative and quantitative analysis of phytochemical screening of the extracts of Centella asiatica (Gotu kola). From the results in (Table 1) it was observed that tannins, cardiac glycoside, flavonoids, saponin, alkaloids, steroids and Anthraquinones were all suspected in the two plant extracts. The quantitative analysis indicate a high concentration of Tannins at 4.644 mg/g, 2.150 mg/g of Cardiac glycoside, Flavonoid at 1.830 mg/g, Alkaloids at 0.518 mg/g, Saponin at 0.440 mg/g and Anthraquinones at 0.067 mg/g concurrently.

From Table 1.Phytochemicals like saponin tannins, , alkaloids, cardiac glycoside, flavonoids, steroids and Anthraquinones were confirmed in the extract of Alternanthera Sessilie. These phytochemicals have been reported in several study by researchers. [23] revealed the presence of these phytochemicals in aqueous solution of acetone, methanol and ethanol extracts of Alternanthera Sessilie.

Quantitative phytochemical result revealed high quantity of flavonoids (12.75 mg/g), followed by tannins (11.25 mg/g), alkaloids (3.25 mg/g), saponins (2.50 mg/g), cardiac glycosides (1.75 mg/g), steroids (0.50 mg /g), anthraquinones (0.2 mg/g).

The two extracts contain high concentration of tannins which have been reported to have inhibitory activity against corrosion. [24] reported 72% inhibition efficiency. Another phytochemical presented in this study is flavonoids with high concentration in the extract of Alternanthera Sessilie but low in Centella asiaticawas also reported to have inhibitory activity against metals because of their carbonyl carbon with their ability to chelate metals [25].

3.2 Corrosion rate and inhibition efficienciences of plant extracts

The rate of corrosion in both 0.5 M HCl and 0.5M NaOH for Centella asiatica(Gotu kola) is presented in Figure 2 below. The data in the figure indicated a decreasing trend in the corrosion rate over the 120 hours period of the experiment. The initial rate of corrosion at 24 hours in 0.5 M HCl was the highest at 0.6642 g/cm3. This indicated a rapid corrosion rate in the early-stage of the corrosion process. At 48 hours, the rate dropped to 0.4153g/cm3 followed by a slight increase at 72 hours to 0.4981. The corrosion rate reduced significantly at 96 hours to 0.1426 g/cm3 and to 0.0997 at 120 hours. Similar trend was also observed in 0.5 M NaOH medium, in which the highest corrosion rates of 0.6642 g/cm3 was observed at 24 hours. This is because no inhibitor was used at the period of 24 hours. Following this, the corrosion rate consistently decreased, 0.4151 g/cm3 at 48 hours, 0.3874 g/cm3 at the end of 72 hours, 0.2599 g/cm3 at 96 hours, and 0.2324 at 120 hours, respectively. This was most likely caused by the Gotu kola extract. When the rates of corrosion in the two media were compared, it was found that 0.5 M HCl corroded more quickly than 0.5 M NaOH. This could be because acidic media are more corrosive than basic ones.

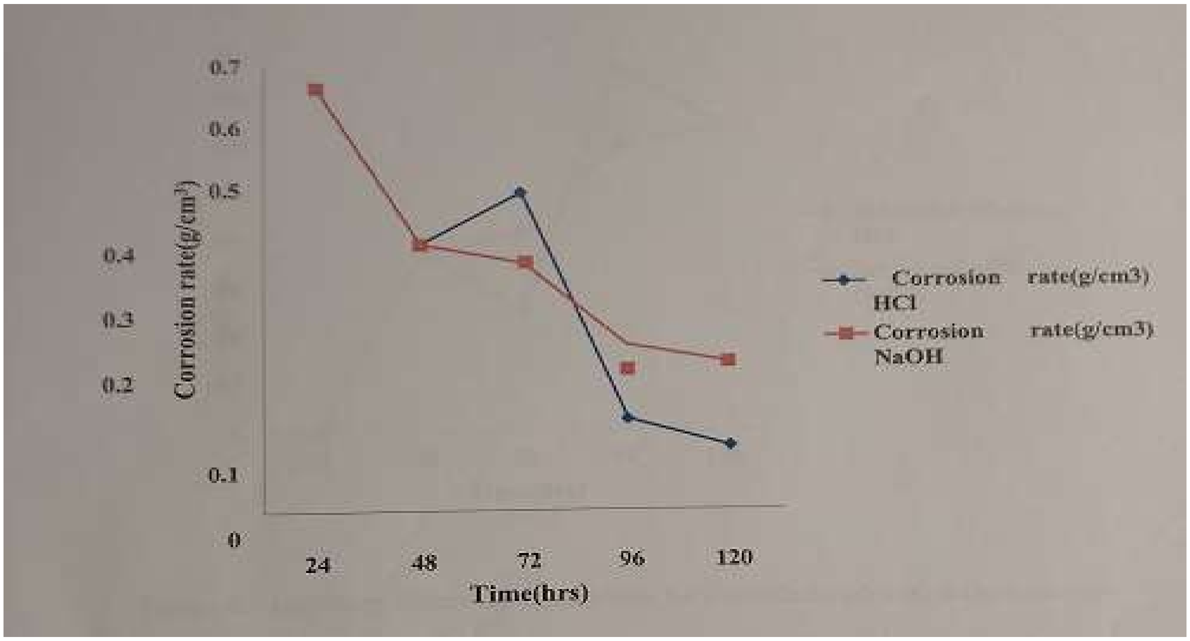

Figure 2: Corrosion rate against time for Centella asiatica(Gotu kola) extract

Figure 3 below Presented inhibition efficiency of Centella asiatica(Gotu kola). From the result it was observed that Centella asiatica(Gotu kola) in both HCl and NaOH has ability to inhibit corrosion at different concentrations. At 48, 72, 96, and 120 hours, respectively, the results indicated inhibition efficiency of 37.50, 25.0, 78.50 percent, and 85.0 in the HCl medium. At 48, 72, 96, and 120 hours, the % corrosion inhibition for the NaOH medium was 37.5, 41.7, 60.90, and 65.0. The extract exhibited the same inhibitory efficiency at 48 hours at the extract concentration, according to the comparative examination of the inhibition efficiency. At 72 hours, the inhibition efficiency rose to 41.7% in the basic medium whereas it dropped to 25% in the acidic media. Inhibition efficiency rose dramatically to 78.50 percent in HCl and was high at 60.9% in NaOH at 96 hours.

At 120 hours, the inhibition efficacy rose to 85.0% in HCl and reached a maximum of 65.0% in NaOH. Up to an optimal point, inhibition efficiency rises with immersion or exposure duration, indicating improved inhibitor molecule adsorption and surface coverage on the metal, which eventually lowers the corrosion rate more successfully (Haris et al., 2021). Based on the overall result, it can be inferred that as the extract concentration increases, the Centella asiatica extract showed a higher inhibitory efficacy in HCl over a longer length of time than NaOH.

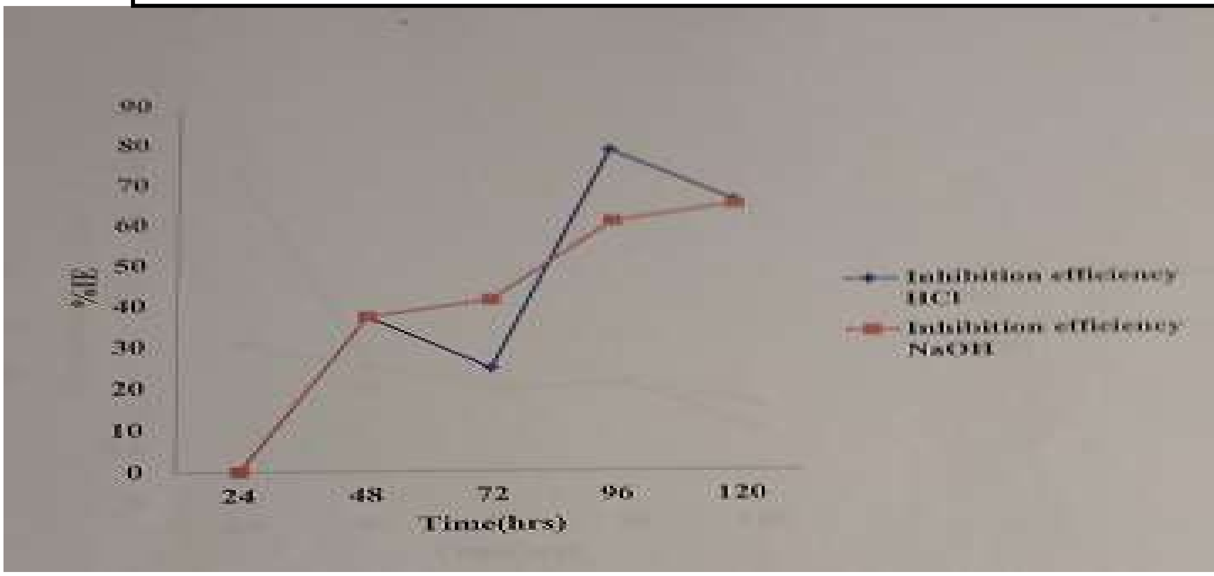

Figure 3: Inhibitory efficiency against time for Centella asiatica(Gotu kola) extract

Figure 4 below displays the corrosion rate (g/cm3) vs time (hrs) of Alternanthera sessilis leaf extracts in 0.5 M HCl and 0.5 M NaOH.According to the results, the corrosion rate peaked at 1.1624 g/cm3 and then dropped to 0.1660 g/cm3 over the course of 120 hours.
The high corrosion rate at the initial stage of the process can likely be attributed to the aggressive nature of the HCl in promoting metal dissolution [26[. The development of hydroxides of metal or oxides that stick to the metal surface may be the cause of the basic (NaOH) medium's lower and more constant corrosion rate, which reached an upper limit of 0.4981 g/cm3 [27]. The declining rate of corrosion could indicate that corrosion-preventing agents are being exhausted as the inhibitor's activity rises.

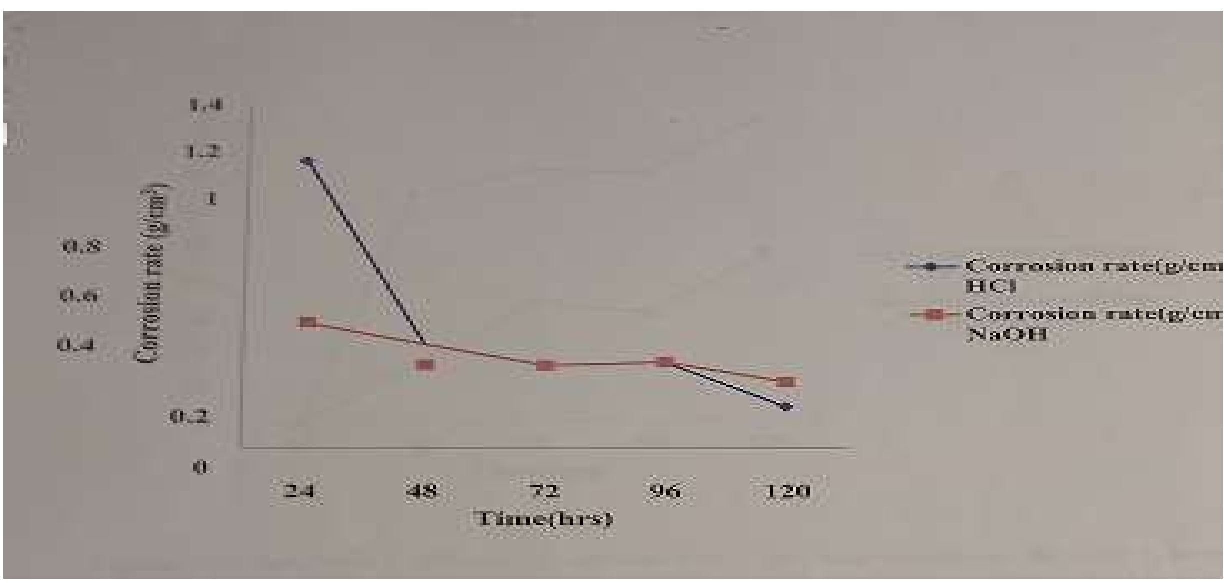

Figure 4: Corrosion rate against time for *Alternanthera sessilis*(Dwarf joyweed) extract

Figure 5 below displays the *Alternanthera Sessilis* extract's inhibitory efficiency (%IE) versus time (hrs) in 0.5 M HCl and 0.5 M NaOH. As the content of the leaf extract increased, the rate of corrosion reduced. Under the same conditions, the highest efficiency was recorded at 120 hours, with an inhibition effectiveness of 85.7% in the acidic medium and a lower inhibition efficiency of 46.7% in the basic medium. This outcome demonstrated that *Alternanthera Sessilis* inhibits more effectively in an acidic media than in a basic one. The increased inhibition efficiency suggests that the corrosion inhibitor is very successful in lowering the metal's rate of corrosion. As a result, the metal constructions' lifespan and durability are increased [28]. While, lower inhibition efficiency means that the corrosion inhibitor was not effectively reducing the corrosion rate.

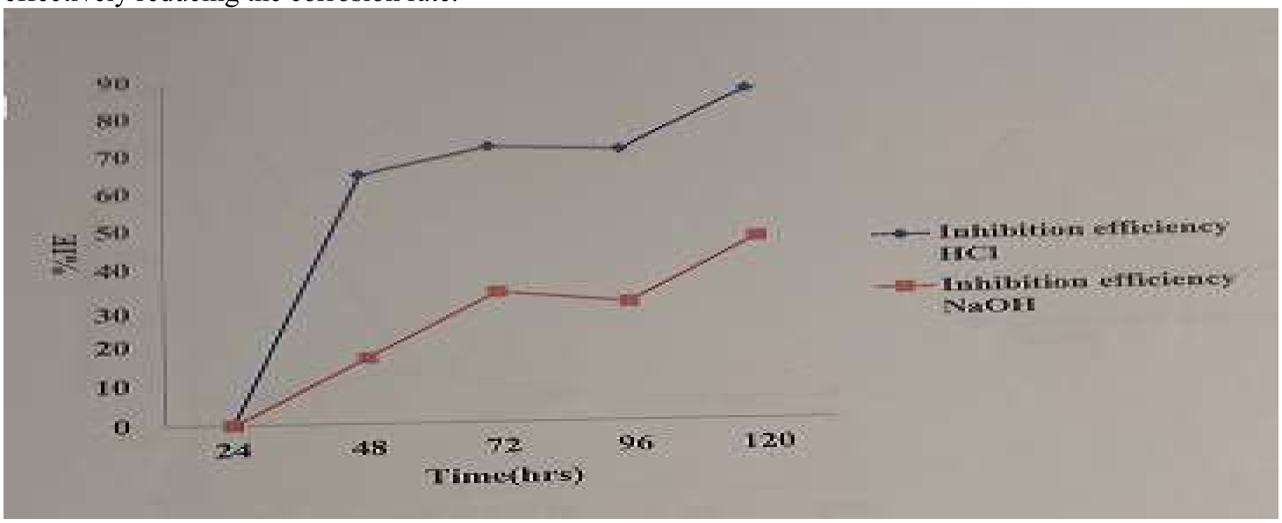

Figure 5: Inhibitory efficiency against time for Alternanthera Sessilis(Dwarf joyweed) extract

Figure 6 below displays the corrosion rate (g/cm3) versus time (hrs) graph of the combination of the two extracts of Alternanthera sessilis and Centella asiatica in 0.5 M HCl and 0.5 M NaOH. In the acidic media, a greater corrosion rate was seen after 24 hours and then sharply decreased, suggesting that the inhibitor had formed a protective layer. In the basic media the oxidation rate started with a lower degradation rate but rapidly grew to 0.4151 g/cm3. Followed by a steady reduction. As the extract content rose, the corrosion rate gradually decreased in both media, indicating that the extract had created a barrier that prevented the corrosion agent from coming into direct contact with the mild steel coupon. The report of [28] is consistent with the little decrease in corrosion rate.

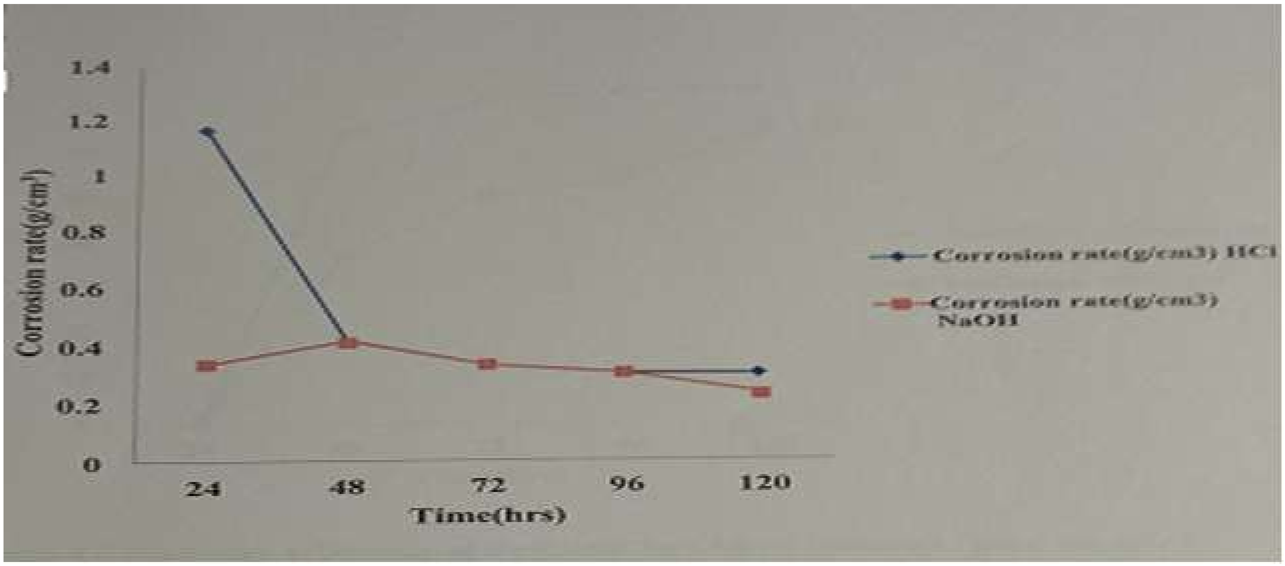

Figure 6: Corrosion rate (g/cm^3) against time for a blend mixture of plant extracts 1:1

For the combination of extracts of Centella asiatica and *Alternanthera sessilis* in 0.5 M HCl and NaOH, the graph of inhibition efficiency (%IE) against time (hrs) as displayed in (Figure 4.7 below) showed an increasing inhibition effectiveness as the extract concentration increased. At 120 hours, the two mediums showed the highest effectiveness of 74.3% and 65%, respectively. contrasting the outcomes with the inhibitory efficiency results for specific plants, as shown in Figures 4.2 and 4.4. At 120 hours in the acidic medium, Alternanthera sessilis has the maximum inhibitory efficacy of 85.7%. This demonstrated that they function best when they are fully focused. Additionally, it was noted that the plant extract's inhibitory efficacy rises as its concentration does. These plants' capacity to suppress corrosion can be linked to the phytochemicals they contain, particularly flavonoids and tannins, which have been shown to have corrosion-inhibiting properties.

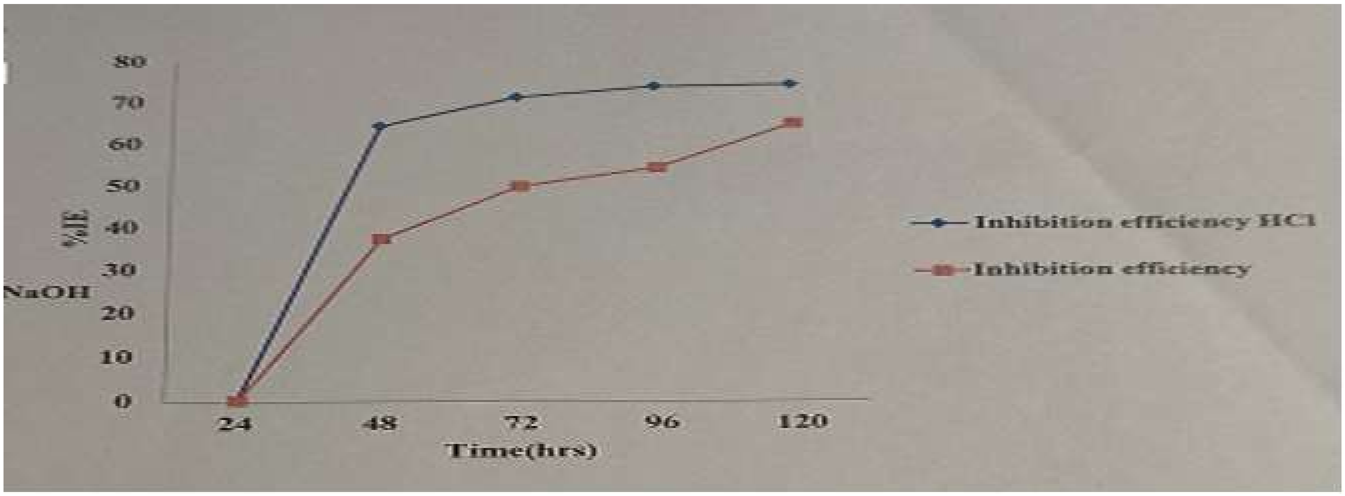

Figure 7: Inhibitory efficiency against time for a blend mixture of plant extracts 1:1

3.3 FTIR Analysis of Plant Extracts

They spectrum of Alternanthera sessilis(Dwarf joyweed), Centellaa siatica (Gotu kola) and mixture blend of both plant extracts reveals the transmittance and wavenumber and the chemical compounds present in the plant extracts.

3.3.1 FTIR Spectroscopy of Alternanthera sessilis(Dwarf joyweed)

FTIR spectrum of Alternanthera sessilis(Figure 4.7) showed fourteen (14) peaks with various functional groups. The wavenumber present are 3332.2 cm-1, 2922.2 cm-1, 2855.1 cm-1, 2124.6 cm-1, 1707.1 cm-1, 1636.3 cm-1, 1457.4 cm-1, 1379.1 cm-1, 1244.9 cm-1, 1166.7 cm-1, 1036.2 cm-1, 834.9 cm-1, 719.4 cm-1 and 674.6 cm-1 (as shown in Figure 4.7) corresponding to O-H stretch, C-H stretch, C-H stretch, -C=C stretch, C=O stretch, N-H bend, C-C stretch, C-H rock, C-O stretch, C-O stretch, C-O stretch, C-Cl stretch, C-Cl stretch and C-Cl stretch bonds, respectively. Alcohols, aromatics, alkanes, alkynes, ketones, carboxylic acids, alkyl halides, alkyl halides, esters, ethers, and ten amines are the corresponding functional groups. Functional group at 2855, 2922.2 cm-1.1 cm-1, 1707.1 cm-1, 1244.9 cm-1, 1166.Functional groups at 3332.2 cm-1 and 2124.6 cm-1 have large transmittance peaks, whereas 7 cm-1 and 1036.2 cm- 1 have significant transmittance peaks. By forming a strong contact with the metallic surface, organic hetrocyclic compounds with polar functional groups, like –OR, SH, CONH2, COOH, COOR, COR, COCl, COBr, PO4, e. t. c, provide great inhibitory efficiency [36]. The anticorrosive qualities of the plant extracts may be due to the existence of O-H stretching, C-H stretching, -C=C stretching, C=O stretching, and N-H bending.

[29] made similar findings while analyzing the FTIR spectra of extracts from Alternanthera sessilis leaves and stems. The following peaks are visible in the leaf extract: 3395 cm-1 (O-H stretching), 3011 cm-1 (=C-H stretching), 2924 cm-1 (C-H stretching), 2853 cm-1 (C-H stretching), 1736 cm-1 (C-O stretching), 1645 cm-1 (C-C- stretching, N-H bending), 1461 cm-1 (C-H bending, C-C stretching(in ring)), 1408 cm-1 (C-C stretching(in ring)), 1167 cm-1 (C-H wag –CH2X, C-N stretching), 887 cm-1 (N-H wag, C-H stretching), and 721 cm-1 (C-Cl stretching).

This is consistent with the findings of [30]. They identify the bioactive substances in Alternanthera sessilis leaf extract using FTIR. The following peaks are visible in the spectrum: The stretching measures 3294.4 cm-1 for O-H, 2918.3 cm-1 for -CH, 2850.7 cm-1 for C-H, 1624.1 cm-1 for N-H, 1315.5 cm-1 for C-O, 1238.3 cm-1 for C-O stretching (esther), 1101.3 cm-1 for C-O stretching (ethers), and 1018.4 cm-1 for C-Br.

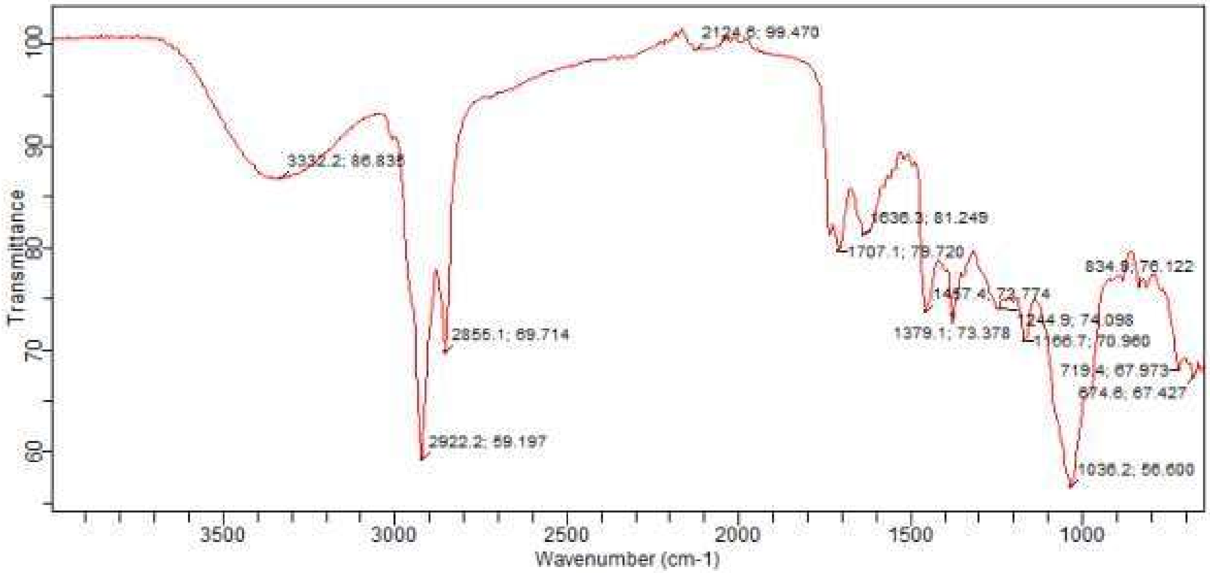

Figure 8: Fourier Transform Infrared (FTIR) spectra of Alternanthera sessilis(Dwarf joyweed)

3.4 FTIR Spectrum of Centella asiatica(Gotu Kola).

The FTIR spectrum of Centella asiatica(Figure 4.8) showed sixteen (16) peaks. The frequencies of the peaks located at 337.3, 2922.2, 2855.1, 2091, 1994 , 1688.5, 1625.1 , 1457.4,1375.4, 1312, 1274.7, 1241.2 cm-1 , 1148, 1028.7, 924.4 and 812.6 cm-1 have corresponding bonds of O-H stretch, C-H stretch, C-H stretch, -C=C stretch, C=O stretch, N-H bend, C-C stretch (in-ring), C-H rock, N-O symmetric stretch, N-O symmetric stretch, C-H wag, C-H wag, C-O stretch, O-H bend and C-Cl stretch. Functional groups present due to the nature of the bond were alcohols, aromatics, alkanes, alkynes, carboxylic acid 10 amines, Nitro compounds, alkyl halides, ethers and esters. Both extracts exhibit corrosion prevention properties, as demonstrated by the oxygen- containing functional groups such as carboxylic acid, esters, and ethers at 1244.9 cm-1, the nitrogen-containing functional group (amines) at 1636.3 cm-1, and the halogen-containing functional group (alkyl halides) at 834.9 cm-1. As a result, when organic compounds including atoms of sulfur, nitrogen, halogen, phosphorous, and oxygen are adsorbed on the metal's surface, corrosion is prevented [31]. [32] reported similar findings. The FTIR spectrum of Centella asiatica leaf extract reveals the following peaks: 1447.50 (C-C stretching (in ring)), 1441.05 (C=O stretch carbonyls), 2988.09 (C-H stretching), 1233.23 (C-O stretch alcohol, carboxylic acids, esters, ethers), 1098.24 (C-N stretching), 2940.95 (O-H stretch carboxylic acids), 937.54 cm-1 (O-H bend carboxylic acids), and 849.69 cm-1 (C-Cl stretch alkyl halides). Additionally, the outcomes matched those of Verma et al. (2023). They use FTIR to conduct comparative analyses of Centella asiatica. 3289.27 cm-1 (O-H stretching), 2919.72 cm-1 (C-H stretching), 2847.30 cm-1 (- CH synthetic stretching), 1731. 80 cm-1 (C=O stretching), 1605. 68 cm-1 (C=O stretching), 1307.11 cm-1 (CN stretching), and 1214. 70 cm-1 (C-H in-plane bend) are among the peaks displayed.

[33] schooling from 2023. Centella asiatica leaf extract revealed that the leaves contain the following: 3550-3200 cm-1, (O-H stretching, N-H stretching), 2960- 2850 cm-1, (C-H stretching, N-H stretching), 1650-1600 (C=C stretching), 1470-1430 cm-1, (C=C stretching), 1300-1250 cm-1, (C-O stretching, alkyl ether, aromatic ester), 1085-1050 cm-1, (C-O stretching, primary alcohol, acid), 69-515 cm-1, (C- Br (halo compound)). In a particular context, both extracts demonstrated good quality for inhibiting corrosion. Alternanthera sessilis lacked the additional functional group (nitro compound) seen in Centella asiatica-based extract, suggesting that Centella asiatica extract may have superior corrosion inhibition capabilities. Strong transmittance is present in three peaks (2922.2 cm-1, 1688.5 cm- 1, and 1028.7 cm-1).

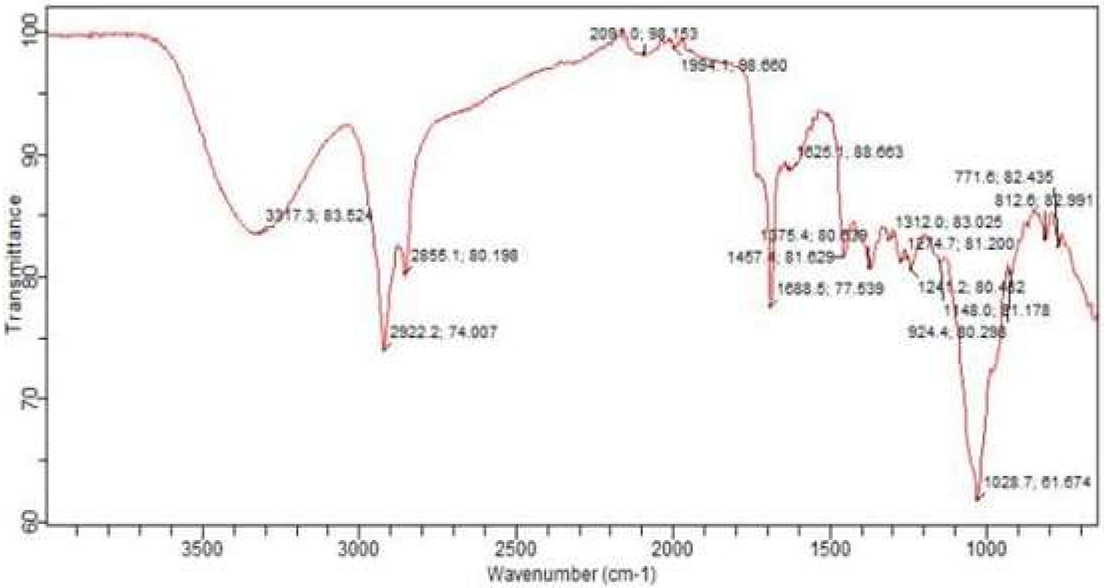

Figure 9: Fourier Transform Infrared (FTIR) spectra of Centella asiatica(Gotu kola)

3.4 Morphology of the coated film on the metal using Scanning Electron Microscopy

3.4.1 Elementary Analysis of the Mild Steel

Elemental analysis of the mild steel (Table 2) shows the following chemical composition; Fe (98.823%), C (0.182%), Mn (0.717%), Si (0.228%), P (0.031%), S (0.010%), Cr (0.007%).

It was observed that Fe has the largest proportion in the Metal matrix of the mild steel and Cr has the lowest proportion. When the material is coated with corrosion inhibitor, the percentage of the inhibitor atoms do increase together with anti-corrosion rich sites [34].

Table 2: Elementary composition of the Mild steel.

Atomic Number	Symbol	Element Name	% Composition
26	Fe	Iron	98.823
6	C	Carbon	0.182
25	Mn	Manganese	0.182
14	Si	Silicon	0.228
15	P	Phosphorus	0.031
16	S	Sulphur	0.010
24	Cr	Chromium	0.007

Figure 10a: Mild steel's morphological structure displays the mild steel coated with dwarf joyweed, Alternanthera sessilis. the micrograph reveals a rough, bunch of puff wool stretched across the sample's surface, suggesting that the leaf extract shields the metal's surface from deterioration. According to the observation, dwarf joyweed, Alternanthera sessilis, inhibits rusting. By sticking to the metal's surface and forming a protective coating, the inhibitor lowers the rate of corrosion and protects the metal's surface from the hostile atmosphere [35].

The Energy dispersive spectroscopy (EDS) spectrum of the sample is presented in Figure 10 below, and the percentage of the chemical composition of mild steel coated with Alternanthera sessilis extracts shown in Table 4 shows that phosphorous and sulphur, which promote corrosion inhibition increased by 287% (0.031% to 0.12%) and 4400% (0.010% to 0.45%), respectively.

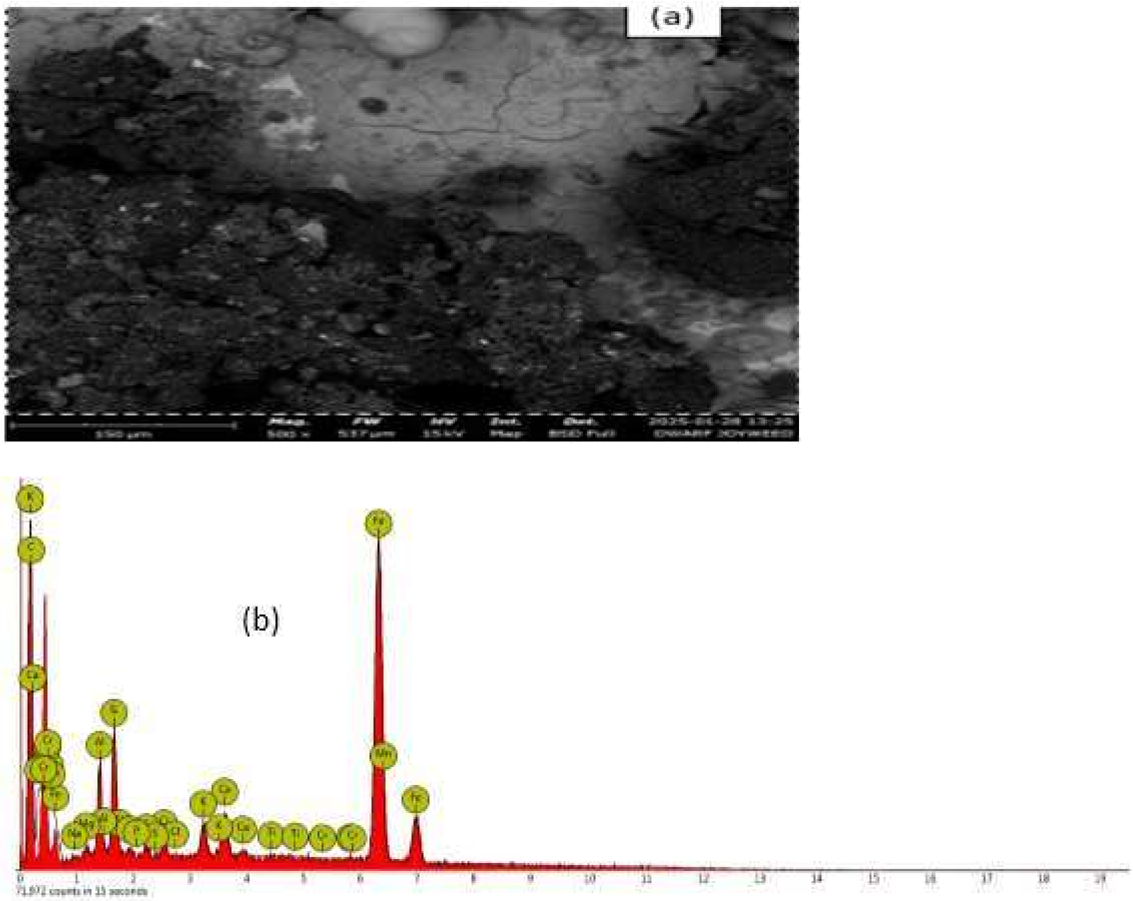

Figure 10 (a) SEM image and (b)EDS spectrum of mild steel with Alternanthera sessilis Extract.

Table : 3 Chemical composition of mild steel coated *Centella asiatica* (Gotu kola)

Atomic Number	Symbol	Element	Atomic Conc.	Weight Conc.
26	Fe	Iron	52.26	74.40
6	C	Carbon	24.55	7.52
14	Si	Silicon	7.66	5.48
13	Al	Aluminium	7.06	4.85
20	Ca	Calcium	3.06	3.12

19	K	Potassium	2.11	2.10
12	Mg	Magnesium	1.26	0.78
17	Cl	Chlorine	0.80	0.73
16	S	Sulphur	0.45	0.37
11	Na	Sodium	0.49	0.29
25	Mn	Manganese	0.18	0.26
15	P	Phosphorus	0.12	0.10
22	Ti	Titanium	0.00	0.00
24	Cr	Chromium	0.00	0.00

Figure 11a shows SEM image of mild steel coated Centella asiatica extracts. SEM micrograph was observed to have rough surface with cracks. Addition of Centella asiaticaon the surface of the mild steel inhibits corrosion of the sample. It was due to adsorption of aggregate of particles which form inhibitor film on the sample. The electronegative atoms (Cl, S and P) in the Centella asiatica chemical composition occupy the active sites and reduced aggressive destruction of the mild steel thereby proving efficient corrosion inhibitor.

Therefore, the centella asiatica and alternanthera sessile leaves extracts are good inhibitors that can be used to prevent or reduce corrosion which are environmental friendly, available, cost effective and low cost. The Energy dispersive spectroscopy (EDS) spectrum of the sample and tabulated percentage of chemical composition of Centella asiatica on mild steel demonstrated presence of chlorine, phosphorous and sulphur. It shows that the percentage of sulphur after coating Centella asiaticaon the mild steel. The increase in percentage atomic concentration of sulphur demonstrates presence of films on the steel slowing down corrosion process of the metal. However, the atomic concentration of phosphorous in the sample reduced after coating compared with the atomic concentration of mild steel.

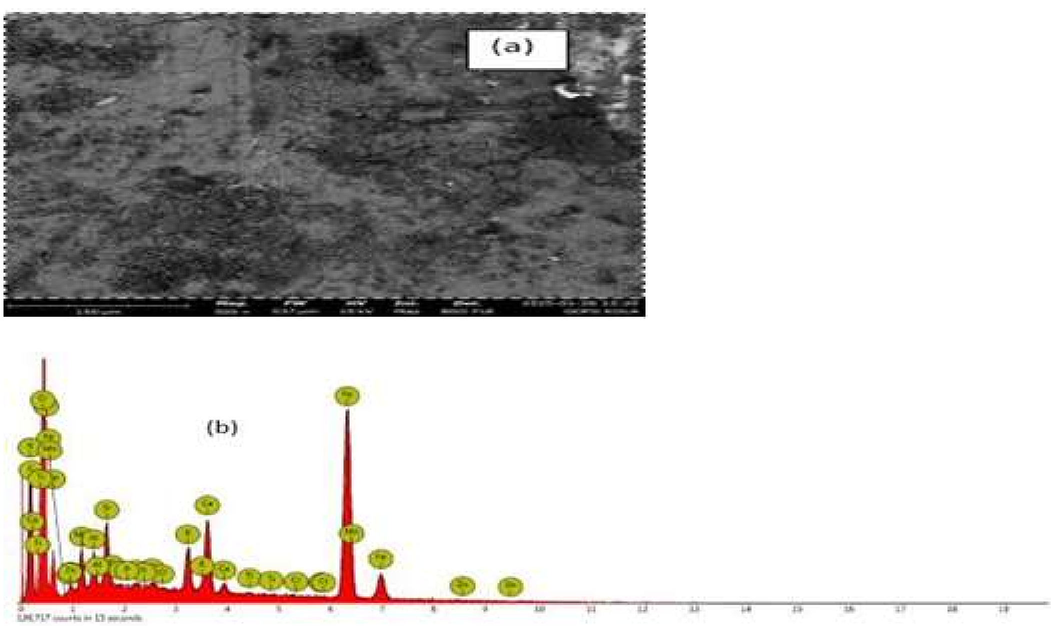

Figure 11: (a) SEM image and (b) EDS spectrum of mild steel with Centella asiatica extracts

Table 4. Chemical composition of mild steel coated Centella asiatica(Gotu kola)

Table 4. Chemical composition of mild steel coated *Centella asiatica*(Gotu kola)

Atomic Number	Symbol	Element	Atomic Conc.	Weight. Conc.
26	Fe	Iron	50.36	68.81
20	Ca	Calcium	8.42	8.26
12	Mg	Magnesium	8.02	4.77
6	C	Carbon	14.78	4.34
19	K	Potassium	4.51	4.32
14	Si	Silicon	6.20	4.26
13	Al	Aluminium	4.23	2.80
11	Na	Sodium	2.29	1.29
17	Cl	Chlorine	0.52	0.45
22	Ti	Titanium	0.33	0.39
16	S	Sulphur	0.21	0.16
25	Mn	Manganese	0.12	0.16
24	Cr	Chromiun	0.00	0.00
30	Zn	Zinc	0.00	0.00
15	P	Phosphorus	0.00	0.00

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The plant used in this study are Centella asiatica(Gotu kola) and althernanthera sessilis(Dwarf joyweed), in acidic and basic media. These plants were extracted and the phytochemical screening were conducted both qualitative and quantitatively. Centella asiatica(Gotu kola) and althernanthera sessilis(Dwarf joyweed) extracts indicated the presence of Saponin (0.440 mg/g), Tannis (4.644 mg/g), Glycoside (2.150 mg/g), Flavonoids (1.830 mg/g), Alkaloids (0.518 mg/g), Strereoids (0.23 mg/g), Anthraquinones (0.067 mg/g) and Saponin (0.50mg/g), Tannis (11.25 mg/g), Glycoside (1.75 mg/g), Flavonoids (12.75 mg/g), Alkaloids (3.25 mg/g), Strereoids (0.50 mg/g), Anthraquinones (0.20 mg/g) respectively.

Weight loss measurements to determine the corrosion rates and inhibitory efficiencies of the individual and blend mixture (1:1) plant extracts indicated the individual plant extracts have higher inhibitory efficiencies particularly in acidic media than the blend mixture and can be used as corrosion inhibitor.

The morphology of the extracts' pictures on the metal surfaces was revealed by scanning electron microscopy. The findings revealed that the mild steel metal's surface was covered in a bundle of puff wool, giving the impression that Centella asiatia is rough. Sessilis for alternanthera were found to be rough, with surface flaws in the mild steel alloy. Additionally, a basic analysis of the delicate steel metal was carried out. Fe (98.823%), C (0.182%), Mn (0.717%), Si (0.228%), P (0.031%), S (0.010%), and Cr (0.007%) were the chemical compositions revealed by the results. The metal matrix of mild steel was found to contain the highest proportion of Fe and the lowest fraction of Cr.

The extracts' functional group makeup was shown by the FTIR analysis. Alkynes, nitrile, carbonyl, ether, esthers, hydroxyl, alkanes, ketones, and alkenes were among the functional groups found in the plant extracts. The inhibitory efficiency of the functional groups included in specific plant extracts has been attributed to their anticorrosive properties. This is because the extracts bond and neutralize in the media (basic and acid) to produce a protective layer on the metal surface.

Conclusion

This study has highlighted the anticorrosive properties of the leaf extracts of centella asiatica(Gotu kola) and althernanthera sessilis(Dwarf joyweed) in acidic and basic media. The leaves of these plants were subjected to qualitative and quantitative analysis, the results obtained for centella asiatica(Gotu kola) and althernanthera sessilis(Dwarf joyweed) are Saponin (0.440 mg/g), Tannis (4.644 mg/g), Glycoside (2.150 mg/g), Flavonoids (1.830 mg/g), Alkaloids (0.518 mg/g), Strereoids (0.23 mg/g), Anthraquinones (0.067 mg/g) and Saponin (0.50mg/g), Tannis (11.25 mg/g), Glycoside (1.75 mg/g), Flavonoids (12.75 mg/g), Alkaloids (3.25 mg/g), Strereoids (0.50 mg/g), Anthraquinones (0.20 mg/g) respectively.

Weight loss measurements determined the corrosion rate and the inhibitory efficiencies of the studied plants. The inhibition efficiency of centella asiatica(Gotu kola) plant ranged from 37.5 – 85% in the acidic medium and ranged from 37.5 - 65% in the basic medium as compared to althernanthera sessilis(Dwarf joyweed) which ranged from 64.30 – 85.70% and 16.70 – 46.70% in the basic media.

Lastly, comparing the corrosion inhibitory efficiencies of both the individual and mixture of the of the plant extracts, centella asiaticawas efficient in both the acidic and basic media while, althernanthera sessilis was more efficient in acidic media and higher than that of the centellaasiatica. The blend mixture of the plant extracts was efficient in acidic media. Althernanthera sessilis showed the highest inhibition efficiency in the range of 64.30 – 85.70%.

The form and structure of the extracts coated on the metal plates was revealed by the study using SEM. The SEM picture of Centella asiatica revealed a rough surface covered in a bundle of puff wool. The metal's morphology revealed fissures and a rough surface in Althernanthera sessilis. Additionally, the elements Fe (98.823%), C (0.182%), Mn (0.717%), Si (0.228%), P (0.031%), S (0.010%), and Cr (0.007%) are revealed by the mild steel's chemical makeup. The mild steel's metal matrix was found to contain the highest concentration of Fe and the lowest proportion of Cr.

The chemical makeup of the protective coatings deposited on the metal plates was revealed by FTIR analysis. It was observed that centella asiatica showed the characteristic peaks which indicated the presence of aromatics, alkanes, carboxylic acid, amine, nitro compounds, ethers, alkynes and alkyl groups. In the extracts of Althernanthera sessilisits showed ketones, alkynes, alkanes, aromatics, carboxylic acids, esters, ethers, alcohols, amines and alkyl groups. When applied on metal surfaces, these chemical compositions effectively suppress aqueous corrosion. They are adsorbed, producing a high inhibition effectiveness by forming a strong link with the metallic surface.

RECOMMENDATIONS

The following recommendations were made bases on the finding of the study;

i. The individual plants and blend mixture extracts in the ratio of 1:1 in acidic media should be used as corrosion inhibitors as they have high inhibitory efficiency and cheaper when compared to usual practices of painting and galvanization in chemical industries, pipe lines, metal implants for surgery operation, iron materials in our bridges, machines e. t. c.

ii. More research should be done on the plant extracts, specifically on how the blend mixture affects mild steel at various ratios and concentrations.

Contribution to Knowledge

Centella asiatica, Althernanthera sessilis, and a blend mixture of plant extracts in a 1:1 ratio have been demonstrated to be efficient in this study, especially in acidic medium. Althernanthera sessilis, on the other hand, has demonstrated the highest inhibitory efficiency, ranging from 64.30 to 85.70%. Important pictures of the protecting coated film's morphology, including its shapes, areas, and elements, are also provided by this study.

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