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Parametric Study and Measure of the Orange Leaves Extract Using Frtir Spectrophotometer

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ABSTRACT

This work on green corrosion inhibition of buried steel sheet in acidified soil is limited to the use of weight loss method and electrochemical cell (Tafel and OCP investigations) to determine the corrosion rate in different molarities of acid (1M, 2M HCl, and 1M, 2MH$_2$SO$_4$) and characterization of the extract using FTIR Spectrophotometer and to determine the compounds responsible for inhibition. The green corrosion inhibition of buried low carbon steel (LCS) (in different molarities of acid) using orange leaves extract (OLE) as inhibitor has successfully been carried out. The soil sample was characterized to determine its resistivity, chloride and sulphate content, oxidation-reduction potential (ORP) and corrosively towards buried structural material while the absorbed film on LCS surface was characterized using FTIR spectrophotometer to determine the functional groups weight loss measurement, tafel technique were used to determine the corrosion behavior of the metal in the composed medium. . Result show that OLE is a good corrosion inhibitor of low carbon steel in acidic medium over the time interval of study, the inhibition efficiency of the OLE increased with increase in inhibitor concentration. The highest inhibition efficiency obtained was 89.61% in 1.0m H2SO4, it follows that OLE as better as inhibitor in H2S04 than in HCL. Also, the effectiveness of OLE as an inhibitor is higher at lower acid concentration.

1. INTRODUCTION

Corrosion is the irreversible deterioration of metals by chemical attack. It occurs when metal interact with its environment causing it or its alloys to return to their unrefined natural forms as minerals and ores (Ogunleye et al., 2019). Metals generally tend to corrode as they always prefer to return to the stable oxide form as a result of corrosion. Low carbon steel is one of the most important metals in existence and has a wild variety of industrial applications. However, it corrodes due to pH, oxidation-reduction potential, chloride and sulfate contents in the acidified moisture in the environment (Popoola et al., 2013, Bhattarai et al., 2016). The Studies on LCS surface reactions in acidified moisture have been the subject of investigation due to areas of applications of LCS for durability in performance and in service (Cheng et al., 2007). Typical situations abound where Synthetic inhibitors have been widely applied to protect metal surfaces against corrosion in the chemical industries, textile wet processing plants, marine, oil and gas industries (Uchenna et al., 2019); Zhang et al., 2012; Markhali et al., 2013). Most synthetic organic inhibitors contain nitrogen, sulphur or oxygen atoms in their structures (Chigondo and Chigondo 2016). The costs of these synthetic inhibitors are high.This is not withstanding, they could be toxic to the environment and human lives. Presently, corrosion scientists and engineers are exploring the use of plant extracts inhibitors that are inexpensive, readily available, environmentally friendly and ecologically acceptable, and renewable. The plant extracts are primarily organic compounds composed of carbon, nitrogen, oxygen and sulphur atoms. They are environmentally friendly and constitute a good displacement for the toxic synthetic inhibitors and consequently promote greenness to the environment Frederick et al., (2020). These readily available green inhibitors are nontoxic, inexpensive and can be extracted from various plant parts (Okafor et al., 2011, Oguzie et al., 2013).

This work on green corrosion inhibition of buried steel sheet in acidified soil is limited to the use of weight loss method and electrochemical cell (Tafel and OCP investigations) to determine the corrosion rate in different molarities of acid (1M, 2M HCl, and 1M, 2MH$_2$SO$_4$) and characterization of the extract using FTIR Spectrophotometer and to determine the compounds responsible for inhibition.

II. Theoretical background of technique used

Corrosion measurement techniques

Several corrosion measurement tests are employed to the study of corrosion processes and corrosion characteristics of various metals and alloys in aqueous environments. They provide important information on the corrosion rate, corrosion mechanism, passivity and coatings by measuring the potential-current relations under certain conditions. This section explains the theories of the corrosion techniques, which were employed in this research project.

III. Weight loss measurement

Weight loss measurement is one of the oldest and the most convenient method for determining corrosion. The technique works by measuring the weight loss of metal samples before and after the immersion in acid and inhibited solution (Obi-Egbedi et al., 2012). One of the preliminary techniques to measure corrosion inhibition is to calculate the weight loss of metal sample on its immersion in uninhibited and inhibited solution (Kumar& Bashir, 2015, Daudaet al., 2013). Two parameters viz, immersion time and concentration of the inhibitor have been evaluated and inhibition efficiency was calculated correspondingly. Plots and tables will be used to show the dependence of inhibition efficiency on immersion time (25-125hours), concentration (0.5, 1.0 and 2.5g/L) respectively. Metal coupons (low carbon steel) with dimensions 0.3×0.2cm will be taken to be immersed in a test solution. Three concentrations of inhibitors will be used ranging from 0.5, 1.0, 2.5g/L in 1M HCl, 2M HCl, 1M H_2SO_4 and 2M H_2SO_4 for low carbon steel respectively. The metal coupons were thoroughly graded with emery papers from range of 150-1500 to achieve a smoother surface, washed with acetone and then air dried. The weight loss measurement was started by recording the initial weight of metal coupon (W_1) at the 0th hour. Then, it was immersed in acid solution (1M HCl, 2M HCl, 1M H_2SO_4 and 2M H_2SO_4) for 25 hours. It was taken out and the weight of coupon was again recorded which was marked as the final weight (W_2) (Abiola& James, 2010, Abdallah, 2002). Similarly, the procedure was repeated for the inhibitor compounds and the study was carried out at all concentrations. The experiment was performed at five hours; 25, 50, 75, 100, 125 hours.

IV. FTIR Spectroscope Analysis

Fourier transform infrared (FTIR) spectroscopy is one of the most widely used methods to identify the chemical constituents and elucidate the compound structures to propose in medicinal purposes (Hari and Vandana, 2019). IR spectroscopy provides valuable and practical information about the identification of both organic and inorganic materials. The information about a simple background, given by each compound's IR spectrum, can be used to characterize unknown materials, as well as determine the molecular structures. An IR spectrum show detector response and is sketched in absorbance or % transmittance (%T) versus IR frequency (in number wave numbers cm^{-1}). A frequency of radiation that interacts with the sample produces an absorption band that is characteristic of the energy required for a particular molecular group.The use of IR spectroscopy for the analysis of biological samples was first suggested in 1940s, the technique was being successfully explored for the study of biological materials. IR spectroscopy has become an accepted tool for the characterization of biomolecules (Hari and Vandana, 2019).

V. Electrochemical cell (Tafel plots and OCPT)

A Tafel plot is a graphical plot (usually logarithmic) showing the relationship between the current generated in an electrochemical cell and the electrode potential of a specific metal and open circuit potential established between the working (the metallic surface to be studied) and the environment, with respect to reference electrode which will be placed in the electrolyte close to the working electrode. These plots are usually generated based on electrochemical experiments performed under controlled conditions.All electrochemical techniques were carried out using a standard three cell electrodes system, The CH1604E electrochemical analyzer was used to conduct the corrosion test. The ASTM G199-09 standard was confirmed during the testing (Electrochemical measurement standard Guide, 2014), at normal room temperature. The polarization resistance used for testing of corrosion typically consists of three electrodes, which includes the counter or auxiliary electrode, saturated calomel or reference electrode (SCE) and working electrode (Imoh et al., 2018). The surface of the metal (low carbon steel) is coated and it acts as a working electrode. For the supply of cathodic current to working electrode, an inert material such as graphite rod is used which also acts as an auxiliary (counter) electrode. Reference electrode which is made up of silver/silver chloride (Ag/AgCl) is used to measure the potential of a working electrode and the current of potentiometer is measured by an ammeter (Sumayah, 2019). Luggin capillary is used to connect reference electrode to the test solution. The potential drop that takes place because of the solution resistance is minimized by placing the capillary tip close to the surface of working electrode. To avoid the screening of working electrode from current flow, distance between luggin capillary and metal surface is kept less than the twice of peripheral diameter of capillary. For a reaction to attain a steady state, the three electrode cells were kept in water baths for duration of 1 to 2 hours until a constant open circuit potential was achieved. The potential balances the anodic and cathodic reactions. The Corrosion Potential (E_{corr}) or open circuit potential can be defined as the potential of metal when no net current flows through it. The potential was scanned from initial E to final E using potentiodynamic polarization method. As time depends, the potential waveform was used. The logarithm of current was employed for determination of voltage -1.0 to +1.0(V). This investigation comprised potential studies with potential settings ranging from -1.0V to 1.0V. Open circuit test as well as the potentiodynamic polarization method to tafel investigations, took 3600 seconds to complete the process.

Working electrode (WE)

Low carbon steel coupons with composition; P(0.35%), Si(0.27%), C(0.20%), Cu(0.30%), S(0.35%), Mn(0.65%), Cr(0.85%) and Ni(0.30%) and the remaining being Fe were enclosed in epoxy resin (Araldite) with $1cm^2$ exposed and were used as working electrodes. The surface of theses WE's was scarped with emery papers with the grades ranging from 100 to 1500. By doing so, a uniform surface of metals was achieved. Acetone was used to degrease the electrodes followed by washing with double distilled water (Sumayah, 2019).

Fig 1.0: Metal encapsulated in epoxy resin serves as working electrodes (Sumayah, 2019).

Reference electrode

Figure 2.13 represents the reference electrode which was used as saturated Calomel Electrode (SCE). This electrode was Connected to the luggin capillary which was filled with the test solution. Reference electrode measures the potential of the half cell 43 by itself being used as the other half cell thus, forming the electrochemical, cell when no net current is flowing through the circuit (Sumayah, 2019).
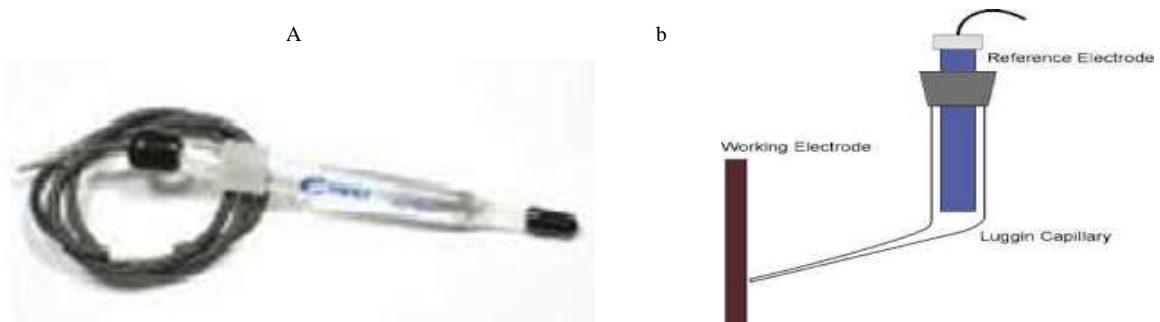

Fig 1.1: (a) Reference electrode and (b) Luggin capillary (sumayah, 2019)

Auxiliary electrode

The auxiliary electrode, also called as platinum electrode or counter electrode (CE) is used for potentiometric analysis in a three electrode chemical cell. It is also used for the analysis of reactions where a flow of current is expected. For performing electro analytical chemistry, an auxiliary electrode, along with reference electrode and the working electrode in three electrode electrochemical cell, provides circuit over which current is either applied or measured (Sumayah, 2019).

Fig 1.3: Standard platinum counter electrode (Sumayah, 2019).

Fig 1.4: Electrochemical standard corrosion test (Sumayah, 2019).

Empirical reviews of the related work

Low-carbon steel possesses excellent ductility because of the low carbon it contains, which is essential for the deep drawing of sheet but their strength is low. As the percentage of carbon is increased (0.30%) the majority of this class of steel is flat-rolled products like sheet or strip. Reduction in carbon percentage and addition small amount of other alloying elements can achieve this, LCS possess the desirable properties as good tensile strength. With the above properties along with relative cheapness has made LCS a desirable material for the use in industry for many mechanical and structural engineering purpose of bridge work, reactors, boiler plates, parts of various components and engines.

A great deal of study has been devoted to corrosion in the multidiscipline area of different. With the help of certain materials, including eco-friendly extract a number of organic compounds have been used as potent corrosion inhibitor.

There were several empirical literatures that were sourced and formed the foundation for this work.

Janaina Cardozo Da Rochaa et al., (2014)

Observed that the aqueous extracts of mango and orange peels were shown to be good corrosion inhibitors for carbon steel in a 1 M HCl solution. In the presence of 400 mg of mango and orange peel extracts, the weight loss measurements showed an increase in the inhibition efficiency with immersion time, where the best results after 24 h of immersion were 97% and 95%, respectively. The inhibitory effect was performed via the adsorption of compounds present in the fruit peel extracts on the steel surface. The inhibition efficiency obtained from this new extraction procedure, which contains more polar hetero-sides, is extremely similar to that obtained from a simple infusion. Thus, the more polar hetero-sides are likely responsible for the corrosion inhibition in both extracts. Due to the hydroxyl presence in these molecules, the adsorption on the metal surface could occur through H-bonding, which involves the displacement of water molecules from the metal surface.

NitinMathurand R .C. Chhipa (2015)

Investigated the corrosion of mild steel IS: 432 (Part I)-1982 in various concentrations of hydrochloric acid and sulphuric acid using Mass Loss method in the absence and presence of the extracts of Pennisetum glaucum seeds. In their work, water played an important role in enhancing corrosion. Results show that corrosion inhibition increased with concentration of the extract. It was found that seed extract of Pennisetum has high corrosion inhibition efficacy. It was also observed that mild steel is very susceptible to corrosion in HCl and H_2SO_4 solution.

Salami, L., Wewe, T.O.Y, Akinyemi, O.P. And Patinvoh, R.J. (2009)

Investigate the use of local wastes which are organic in nature for the production of green corrosion inhibitor is no doubt the trend of the day. Which evaluate to produce corrosion inhibitor from Musa Sapientum peels extract with a view of determining the effectiveness of the corrosion inhibitor? Musa Sapientum peels extract produced was used as a corrosion inhibitor on mild steel in concentrated tetraoxosulphate (VI) acid using weight loss method. The results of the study showed that as the concentration of the produced inhibitor increases, the rate of corrosion decreases. It also showed that as the concentration of the inhibitor increases, the inhibitor efficiency also increases up to an optimum of approximately 71 % for 0.8 g/l extract in 2.0M H_2SO_4which is encouraging.

V. MATERIALS AND METHOD

EQUIPMENT AND MATERIALS

Equipment

The equipment used were: Electronic weighing balance, stamping machine, measuring cylinder (1000ml), volumetric flask (250ml), plastic containers, nylon thread, blender, emery papers, and digital pH meter.

Analytical equipment includes working electrode low-carbon steel (LCS), Reference electrode (RE) made of silver/silver chloride (Ag/Agcl), counter electrode (graphite rod). CH1604E electrochemical analyzer used. Materials: LCS, Orange leaves, HCl and H_2SO_4 acid.

Sources of Materials

LCS was sourced from new site market in Nsukka, Enugu State, Nigeria and the chemical analyses was carried out at quality assurance and research control express laboratory,Ajaokutasteel Company Limited.

Orange leaves were obtained from a local garden in Amokwe at Nsukka Local Government Area, Enugu State. HCl, H_2SO_4, acetone, distilled water, ethanol were sourced from University of Nigeria Nsukka. Plastic containers, emery paper, thread, paper tape (for labeling) were sourced from Ogige market

Nsukka. **Table 1.0: Design of experiment**

Acid type	Volume of Acid(ml)	Volume of(H_2O) (ml)	Conc. of Inhibitor (g/L)		
1M HCl	83·6ml	916·4ml	0·5g/L	1·0g/L	2·5g/L
2M HCl	167·2ml	832·8ml	0·5g/L	1·0g/L	2·5g/L
1M H_2SO_4	54·35ml	945·65ml	0·5g/L	1·0g/L	2·5g/L
2M H_2SO_4	108·7ml	891·3ml	0·5g/L	1.·0g/L	2·5g/L

Preparation of sample for infrared spectroscope (FTIR) spectrum analysis

1.2.   The extract was encapsulated separately in KBr pellet, to prepare translucent sample discs. The sample was loaded in FTIR spectroscope with IR range from 500 to 4000cm^{-1} (NICOLET IS5, made by thermo scientific). 1.0g of OLE was put in a small blender and a small quantity of KBr was added to it and stirred. The extract was compressed inside a sample disc to be like pellet and then was put inside FTIR to monitor the functional groups and the directions of peaks.

1.3.   **FTIR spectrum analysis of OLE**

The FTIR spectrum analysis was used to detect the characteristic peaks and their functional groups. The FTIR spectra of OLE adsorbed on LCS is shown in fig 4.1. The OLE exhibits broad and strong peaks ranging from 3550-3200cm^{-1} confirming the presence of Alcohols (O-H stretch). A carboxylic acid has similar O-H stretch so it has a broad signal due to that, but there is no carbonyl. C-H stretch ranging from 2900-2800cm^{-1} confirms the presence of Alkanes and Aldehydes, C=O stretch strong peaks ranging from 1815-1630cm^{-1} confirms the presence of Acid chlorides, Anhydrides, Amides, Ester and Ketones. The strong NO_2 stretch peaks ranging from 1570-1490cm^{-1} suggests the stretching vibration of Nitro compound. This result shows that OLE contained nitrogen and oxygen in its functional group which agrees with the structures of corrosion inhibitors.
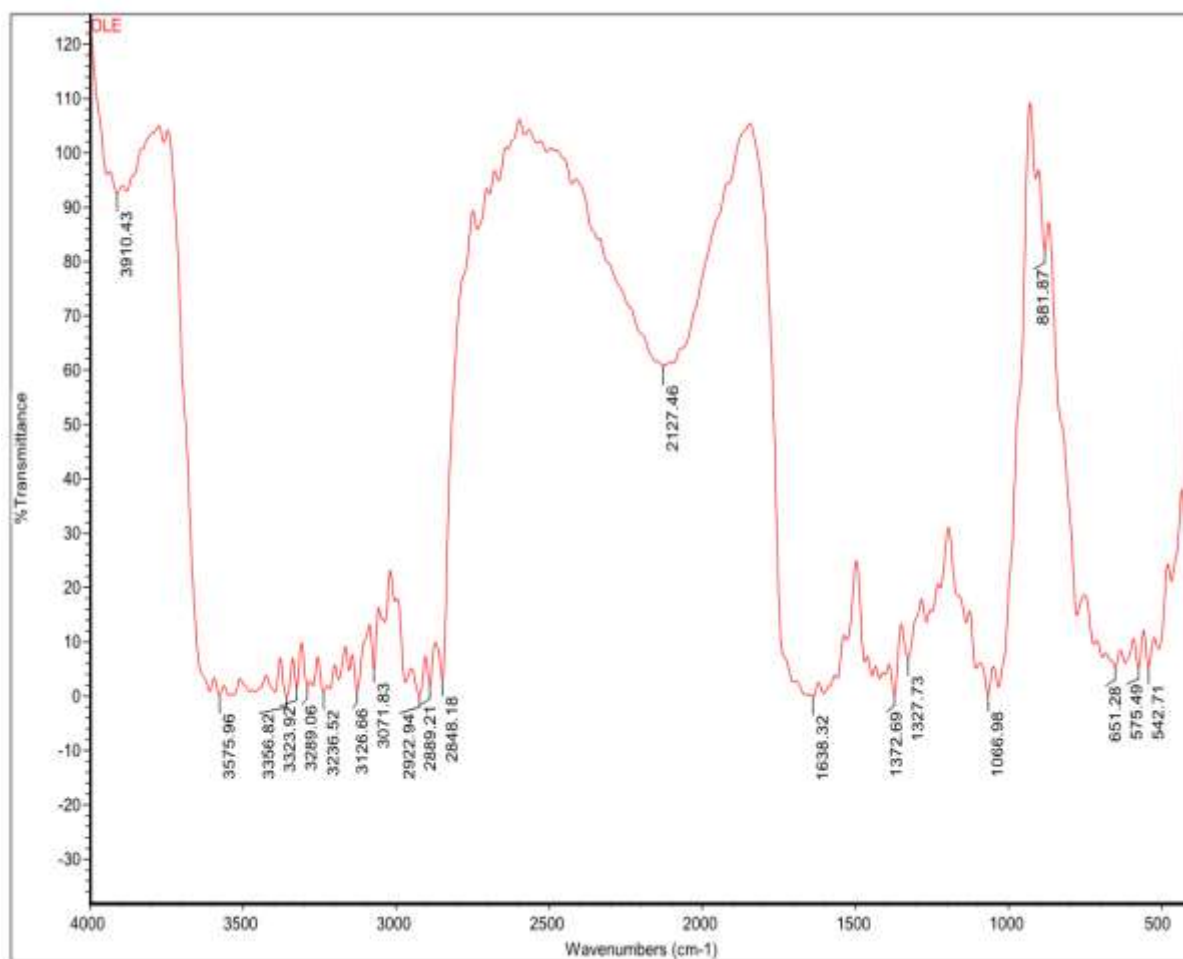

Fig 1.5: IR analysis for OLE

Table 1.2: Characteristics of IR Absorption peaks of functional groups

| Vibration	Position (cm^{-1})	Intensity
Alcohols (O-H)	3550-3200	br, s
Alkanes(C-H stretch)	2990-2850	m to s
Alkenes(C=C stretch)	1680-1620	w to m
=C-H bend	995-685	s
Alkynes(C≡C stretch)	2250-2100	m to w
Aromatic compound(C=H stretch)	3100-3000	m to w
C=C stretch	1625-1440	m to w
C-H bend	900-680	s
Amines (N-H stretch)	3550-3250	br, m
Aldehydes (C-H stretch)	2900-2800	s
Nitriles(C≡N stretch)	2280-2200	s
Ketones(C=O stretch)	1750-1705	s
Esters(C=O stretch)	1765-1735	s
Carboxylic Acids (O-H stretch)	3200-2500	br,m to w
C=O stretch	1715-1680	s
Amides (N-H stretch)	3500-3150	m
C=O stretch	1700-1630	s
Anhydrides (C=O stretch)	1850-1800	s
	1790-1740	s
Acid chloride (C=O stretch)	1815-1770	s
Nitro compound (NO$_2$ stretch)	1570-1490	s
	1390-1300	s
Alkyl Halides (C-F stretch)	1000-1400	Hidden in fingerprint region
C-Cl stretch	< 600-840	
C-Br stretch	< 700	
C-I stretch	< 600	

FTIR analysis of OLE adsorbed on buried LCS in 1M, 2M HCl and 1M 2M H₂SO₄.
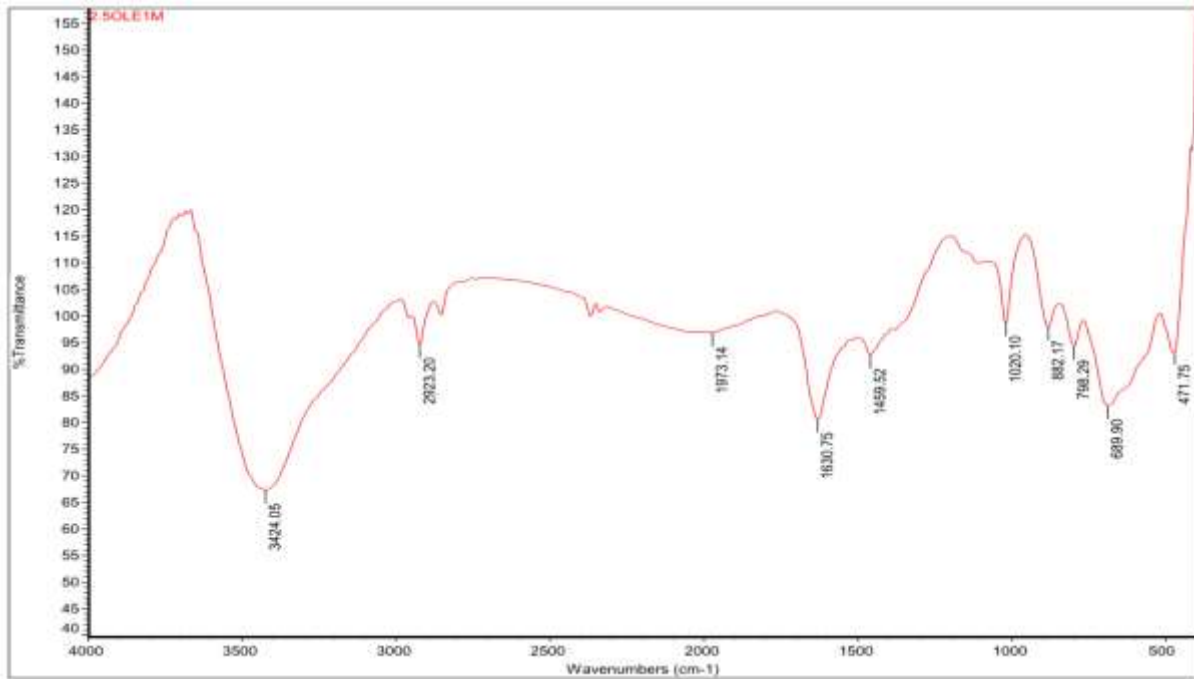
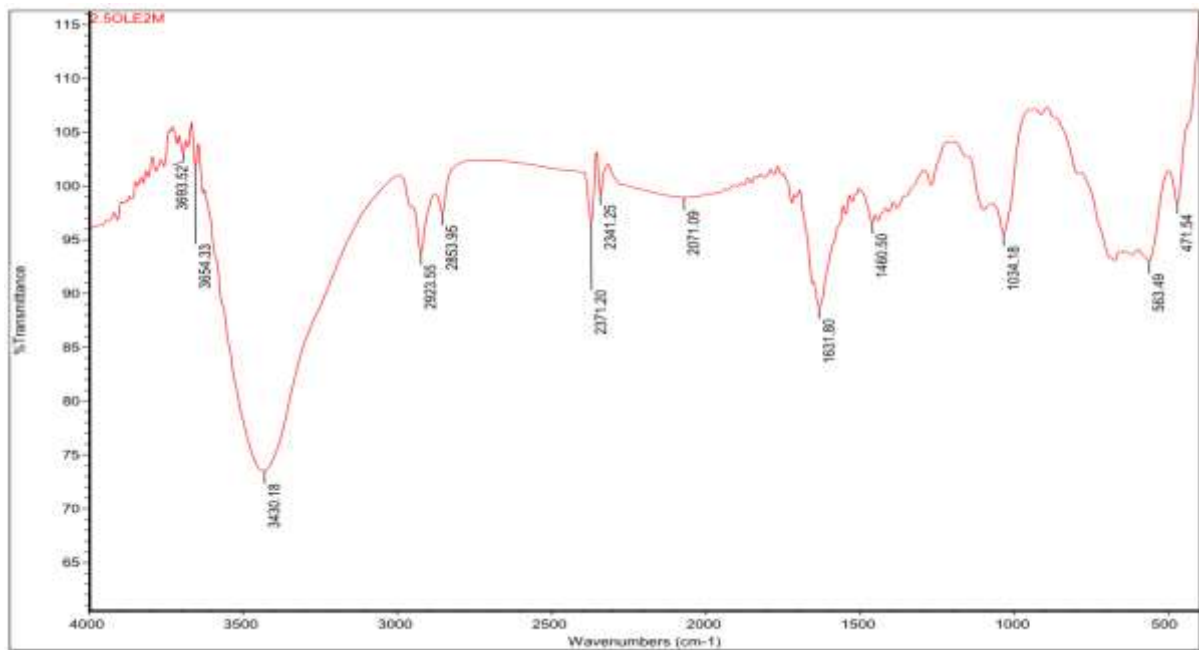Fig 4.2 (a); IR analysis of 2.5g/L OLE on buried LCS in 1MHCl

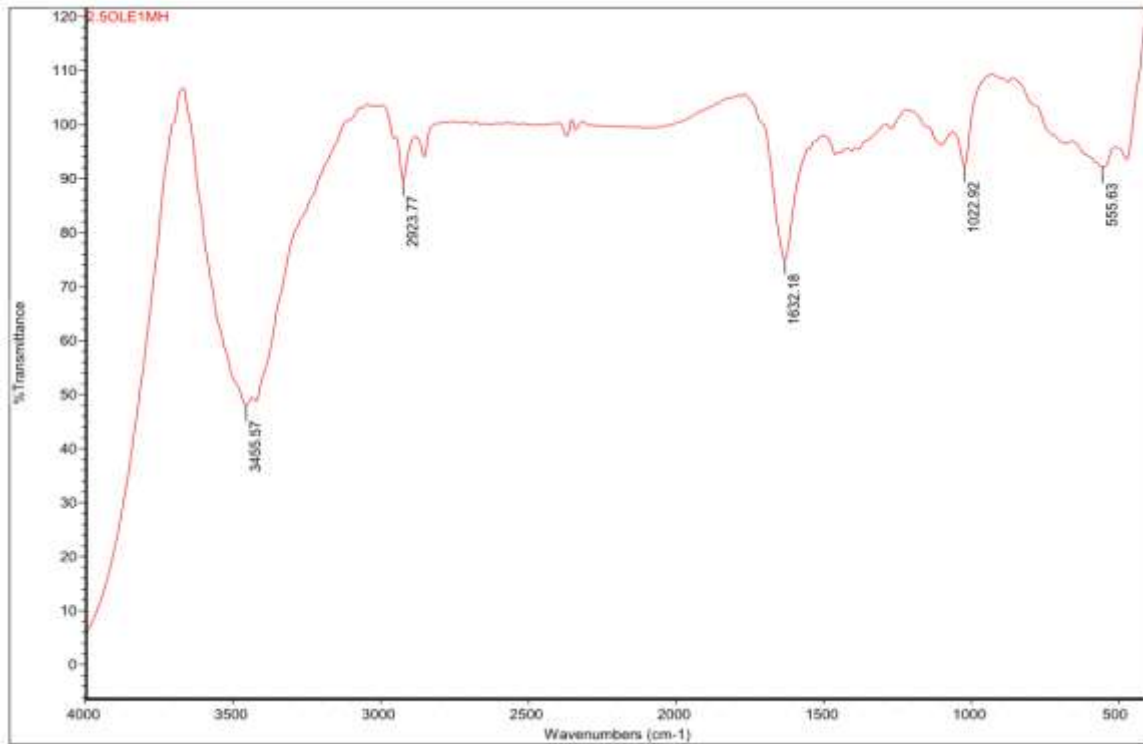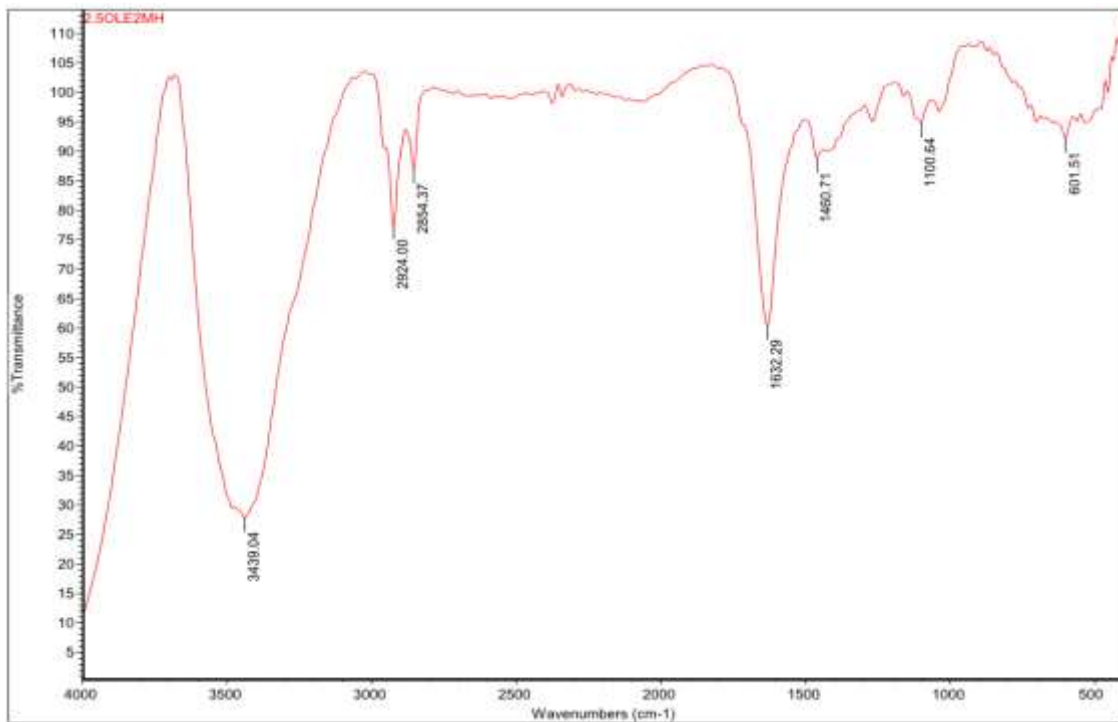Fig 4.2(b); IR analysis of 2.5g/L OLE on buried LCS in 2MHCl

Fig 1.5:(a); IR analysis of 2.5g/L OLE on buried LCS in 1MH$_2$SO$_4$

Fig 1.6:(b); IR analysis of 2.5g/L OLE on buried LCS in 2MH$_2$SO$_4$

Fig 1.5 (a) and (b), show that the OLE O-H stretch exhibits strong peaks at 3424.05 and 3430.18cm^{-1} and it confirms the presence of Alcohols and Amines. The strong peaks of C-H stretch at 2923.20 and 2923.55cm^{-1} confirms the presence of Alkanes and fig 4.2(b) confirms the presence of Aldehydes at strong peaks of 2853.95cm^{-1} and strong peaks value 2371.20 and 2341.25cm^{-1} C=N stretch in fig 4.2(b) confirms the presence of Nitriles. Then in fig 4.2(a) and (b). C=C and C=O stretch in the peaks at 1630.75 and 1631.80cm^{-1} confirms the presence of Alkenes and Amides. NO$_2$ stretch of strong peaks at 1459.53 and 1460.50cm^{-1} confirms the presence of Nitro compound. At the peaks in the range above 600cm^{-1} confirms the presence of Alkyl halides; it is hidden in fingerprint region.

Fig 1.6(a) and (b), the OLE exhibits strong peaks at 3455.57 and 3439.04cm^{-1} as O-H stretch, confirms the presence of Alcohols and Amines. The strong peaks of C-H stretch at 2923.77 and 2924.00cm^{-1} confirms the presence of Alkanes and fig 4.3(b) confirms the presence of Aldehydes at strong peaks of 2854.37cm^{-1}. Then C=C stretch in the peaks at 1632.18 and 1632.29cm^{-1} confirms the presence of Alkenes and Amides. In the fig 4.3(b) the strong absorption bands at 1460.71cm^{-1} shows NO_2 stretch, it confirms the presence of Nitro compounds. At the peaks in the range above 600cm^{-1}, confirms the presence of Alkyl halides; it is hidden in fingerprint region. This result suggests that OLE contain mixtures of compounds; Alkyl halides, alkaloid and Nitro compounds that acted as as effective inhibitors for buried LCS in the acidified soil (Udoh et al., 2016, Ogunlye at el., 2019).

VII. CONCLUSION

From the results of this study,the following conclusion could be drawn.

1. Soil collected from Ngwo has moisture content of 37.05%, pH 7.2, soil resistivity of 15000 ohm.cm, ORP of 250mV, sulfate content of 170ppm and chloride content of 80ppm which generally would be "mildly corrosive" to the buried LCS used for underground structures like petroleum tanks.

2. The addition of acid to the soil increased the pH values of the soil to -0.10 for 1MHCl, 2.89 for 2MHCl, -0.35 for $1MH_2SO_4$and1.03 for $2MH_2SO_4$, thereby making the soil more corrosive in nature.

3. The OLE contains essential compounds necessary for corrosion inhibition of buried LCS surface in acidicenvironment according to FTIR.

4. The inhibition Efficiency increasedwhile corrosion rate decreasedwith increase in extract concentrations for buried LCS used for underground structures like petroleum tanks. OLE is good corrosion inhibitors for buried LCS in acidic soil.

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5. **APPENDIX**

6. **Calculated values of corrosion rate and inhibition efficiency of OLE on buriedlow carbon steel in acid soil.**

Time in Hours	Acids	Inhibitor concentration (g/L)	Initial wt M_1 (g)	Final wt M_2 (g)	Weight(M_1-M_2)(g)	$CR_{(mm/yr)}$	Inhibition Efficiency (IE %)
25	1M HCl	Control/Blank	16.94	16.81	0.13	9.6837	0.00
		0.5	17.00	16.90	0.10	7.4490	23.71
		1.0	16.76	16.68	0.08	5.9592	39.76
		2.5	16.84	16.78	0.06	4.4694	50.00
	2M HCl	Control/Blank	16.91	16.76	0.15	11.1735	0.00
		0.5	16.87	16.75	0.12	8.9388	18.75
		1.0	16.89	16.80	0.10	7.4490	33.69
		2.5	16.89	16.80	0.09	6.7041	39.55
	1M H$_2$SO$_4$	Control/Blank	17.01	16.85	0.16	11.9184	0.00
		0.5	16.90	16.77	0.13	9.6837	24.27
		1.0	17.04	16.94	0.10	7.4490	42.18
		2.5	17.00	16.92	0.08	5.9592	55.40
	2M H$_2$SO$_4$	Control/Blank	16.99	16.81	0.18	13.4082	0.00
		0.5	17.01	16.86	0.14	10.4286	20.56
		1.0	16.91	16.78	0.12	8.9388	31.69
		2.5	17.02	16.92	0.10	7.4490	46.39

		Control/Blank	16.90	16.73	0.17	6.3316	0.00
50	1M HCl	0.5	17.03	16.92	0.11	4.0900	36.84
		1.0	16.80	16.71	0.09	3.3520	47.06
		2.5	16.93	16.85	0.08	2.9796	57.78
	2M HCl	Control/Blank	17.04	16.85	0.19	7.0765	0.00
		0.5	16.89	16.77	0.13	4.8418	30.43
		1.0	16.92	16.81	0.11	4.0970	40.23
		2.5	16.95	16.85	0.10	3.7245	48.83
	1M H$_2$SO$_4$	Control/Blank	16.96	16.78	0.18	7.7041	0.00
		0.5	17.00	16.89	0.11	5.0969	37.27
		1.0	17.04	16.94	0.10	3.7245	47.78
		2.5	16.92	16.84	0.08	2.9796	57.78
	2M H$_2$SO$_4$	Control/Blank	16.85	16.62	0.23	8.5663	0.00
		0.5	17.05	16.89	0.16	5.9592	31.03
		1.0	16.85	16.71	0.14	5.2143	42.58
		2.5	16.87	16.76	0.11	4.0969	52.29
75	1M HCl	Control/Blank	16.98	16.79	0.19	4.7177	0.00
		0.5	16.85	16.74	0.11	2.7313	43.36
		1.0	17.00	16.92	0.08	1.9864	56.52
		2.5	17.04	16.97	0.07	1.7381	63.38
	2M HCl	Control/Blank	17.02	16.79	0.23	5.7109	0.00
		0.5	16.90	16.77	0.14	3.4762	38.46
		1.0	17.05	16.93	0.12	2.9796	48.08
		2.5	17.06	16.96	0.10	2.4830	57.22
	1M H$_2$SO$_4$	Control/Blank	16.96	16.75	0.21	5.2143	0.00
		0.5	16.90	16.90	0.10	2.7830	46.19
		1.0	16.90	16.81	0.09	2.2347	57.89
		2.5	16.86	16.79	0.07	1.7381	65.23
	2M H$_2$SO$_4$	Control/Blank	16.96	16.69	0.27	6.7041	0.00
		0.5	17.03	16.87	0.16	3.9728	40.74
		1.0	17.00	16.86	0.14	3.4762	48.76
		2.5	16.88	16.76	0.11	2.7313	61.90
100	1M HCl	Control/Blank	16.94	16.72	0.22	4.0969	0.00
		0.5	16.80	16.70	0.10	1.8622	50.00
		1.0	16.98	16.90	0.08	1.4898	63.83
		2.5	16.97	16.07	0.07	1.3036	68.29
		Control/Blank	16.98	16.73	0.25	4.6556	0.00

	2M HCl	0.5	16.94	16.81	0.13	2.4209	46.34
		1.0	16.90	16.80	0.10	1.8622	55.84
		2.5	16.93	16.86	0.07	1.3036	67.86
	1M H$_2$SO$_4$	Control/Blank	17.04	16.82	0.22	4.0940	0.00
		0.5	16.98	16.90	0.08	1.8898	57.64
		1.0	17.00	16.93	0.07	1.5036	69.28
		2.5	16.95	16.89	0.06	0.9173	76.73
	2M H$_2$SO$_4$	Control/Blank	16.87	16.59	0.28	5.2143	0.00
		0.5	16.94	15.80	0.14	2.6071	48.91
		1.0	16.97	16.86	0.11	2.0485	61.83
		2.5	16.87	16.78	0.09	1.6760	73.16
125	1M HCl	Control/Blank	17.01	16.76	0.25	3.7436	0.00
		0.5	17.00	16.91	0.09	1.3177	62.07
		1.0	16.89	16.83	0.06	0.8985	75.35
		2.5	16.87	16.83	0.04	0.4990	86.57
	2MHCl	Control/Blank	16.91	16.62	0.29	4.3426	0.00
		0.5	17.00	16.89	0.11	1.6472	61.15
		1.0	16.90	16.81	0.09	1.3177	70.00
		2.5	17.04	16.99	0.05	0.7487	82.76
	1M H$_2$SO$_4$	Control/Blank	16.94	16.68	0.26	3.8933	0.00
		0.5	17.01	16.95	0.06	1.5985	70.00
		1.0	16.90	16.82	0.08	1.2487	80.77
		2.5	16.91	16.87	0.04	0.5990	89.61
	2M H$_2$SO$_4$	Control/Blank	16.90	16.57	0.33	4.8415	0.00
		0.5	16.80	16.68	0.12	1.8969	61.15
		1.0	16.93	16.84	0.09	1.3177	72.78
		2.5	17.00	16.96	0.04	0.5990	85.79