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and HCL Acid Environment for Corrosion Control of Mild Steel

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COMPARATIVE STUDY OF THE INHIITOR EFFICIENCY OF MAIZE HUSK POLAR EXTRACT IN H₂SO₄ AND HCL ACID ENVIRONMENT FOR CORROSION CONTROL OF MILD STEEL

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Abstract

This research work investigated the comparative study of the inhibitor efficiency of Maize Husk Polar Extract (MHPE) green inhibitor to monitor and control corrosion on mild steel in 1.5M of HCl and 1.5M of H₂SO₄, using gravimetric analysis, Fourier Transform Infrared Spectroscopy (FTIR). The extract was found to efficiently inhibit the corrosion process in 1.5M of HCl and 1.5M of H₂SO₄ as the inhibitor efficiency increased with increase in the concentration MHPE. The maximum inhibition efficiency of MHPE was 93.6% in 1.5m of HCl at 384 hours. However, in 1.5M of H₂SO₄, the maximum inhibition efficiency was 96% at 48 hours in 5ml/litre further increase in inhibitor concentration drastically reduced the efficiency to 28.3% at 25ml/litre for 48hrs. Phytochemical analysis revealed the presence of alkaloid flavonoids, phenolics, phytates, saponins, terpenoids anthocyanins, steroids and tannins. The FTIR of MHPE and the corrosion product shows the variation of the peak numbers and the nature of shift indicates the interaction among the functional groups of extract in the corrosion inhibition process. It also confirmed the presence of C-O functional group as the most dominant in the entire corrosion product. The isotherm parameters were evaluated using Langmuir isotherm model, Temkin isotherm model, Frumkin isotherm model and Flory-Huggins isotherm model and it was observed that Langmuir model gave the best fit with the experimental data because the values of the degree of correlation was found to be about unity which shows a very good fit for the experimental data. Also the adsorption process was physiosorption due to the fact that all the values of ΔG are less than -40KJ/mol. The study clearly shows that by the efficiency of MHPE, gotten from the two media, MHPE is suitable for corrosion control in oil pipelines during pigging, acidizing of reservoirs, hydraulic fracturing and hydro-testing.

KEYWORDS: Corrosion inhibition; Maize Husk; Polar; Mild steel; Adsorption; H_2SO_4 ; HCL; Langmuir isotherm.

Introduction

Corrosion, according to the National Association of Corrosion Engineers, is the deterioration of material caused by its environment. Corrosion control is thus the prevention of this deterioration

by three general ways: Change the environment, Change the material, Place a barrier between the material and its environment. The electro-chemical process where alloys revert back to their naturally occurring Form, e.g. Steel reverting back to Iron oxide which is exactly the way it is found in the earth is called corrosion (Bruce 2004). The problem of corrosion in oil and gas pipelines has led to the death of aquatic lives along with environmental pollution in Escravos-Warri region. This is the reason for the discovery of natural products also known as green inhibitor that is friendly to the eco-system, which is fast replacing the expensive synthetic and hazardous acidic inhibitors. Plant extract constitute numerous natural compounds that can control corrosion and the presence of the compounds depend on the part of the plant. The maize husk polar extract (MHPE) proved the inhibition capacity on mild steel in the following media; diluted hydrochloric acid and sulphuric acid

The behavior and efficiency of maize husk polar extract (green inhibitor) on mild steel in different corrosive media. A corrosion inhibitor is a substance which when added in small concentrations to an environment, effectively reduces the corrosion rate of the metal exposed to that environment (Patni et al., 2013). Corrosion inhibitors are commonly added in small concentrations to acids, cooling water, steam and other environments; either continuously or intermittently to reduce corrosion. Corrosion inhibitors reduce the rate of corrosion by adsorption of ion molecules onto the metal surface, increasing or decreasing the anodic and/or cathodic reaction, decreasing the diffusion rate for reactants to the surface of the metal and decreasing the electrical resistance of the metal surface (Amitha et al., 2012). Chemical based corrosion inhibitors have been successfully used to control the corrosion of metals and alloys in various media (Amuda et al., 2008; Loto et al., 2014; Guzman et al., 2009). However, due to the high toxic nature of chemical based corrosion inhibitors (Ezemonye et al., 2006), there is need to develop environmentally acceptable and inexpensive green corrosion inhibitors. Green corrosion inhibitors are cheap, ecologically friendly and possess no threat to the environment (Umoren et al., 2008). There are numerous reports on the use of extracts from plants to control the corrosion of mild steel in several media. Plants represent a class of interesting source of compounds currently being explored for use in metal corrosion protection in most systems, as possible replacement of toxic synthetic inhibitors. Hence, maize husk polar extract has a good characteristic as a corrosion inhibitor owing to the fact that it contains inhibitive components such as phenols, tannins, saponins, anthraquinones, cardiacglycosides, and phlobatannin. There are virtually little or no reports in literature on the use of maize husk polar extract as a corrosion inhibitor on mild steel comparing in two different media, which necessitated this study.

2. Materials and Method:

Materials

Materials used for the study are mild steel pieces bought from Donasulu Brothers steel company, Warri. The percentage composition of mild steel is 0.0292%C, 0.0062%Si, 0.0152%S, 0.2529%Mn, 0.0096%P, 0.0125%Cr, 0.0869%Cu, 0.0047%Mo, 0.10060%As, 0.0101%Sn, 0.003%Co, 0.0005%Zn and 99.535%Fe, Maize Husk, Digital Weigh Meter, Desiccators, Macerator, Beakers, Measuring Cylinder, Abrasives(sand paper), pH meter, Infrared Spectrometer (FTIR), wall clock and Stop Watch, softbrush, Hand Lens, Vacuum Rotary Evaporator, Manual Blender, Spatula, Filter Paper, Diluted HCL and H₂SO₄, Produce water, Sea water, Fresh water, Methanol, Ethyl Acetate, Ferric Chloride, Distilled Water, Acetone, and Hexane.

Method

Gravimetric analysis (weight loss), FTIR of the corrosion product and the extract, adsorption, phytochemical analysis are the various methods employed for the purpose of this work. The maize husk polar extract is the green inhibitor identified and used for corrosion control in various media, such as; diluted hydrochloric acid (HCL), hydrogen tetraoxosulphate VI acid, (H_2SO_4). The presence of the most inhibitive property was identified. Vacuum rotary evaporator was used to determine the concentration of the extract at 79°C .

The efficiency of the inhibitor is also calculated using the gravimetric analysis

Extraction Process.

Maize husk were bought from Mammy market in Warri, Delta State, Nigeria, washed, cleaned of dirt's and chopped into small pieces, dried in the open air until they were properly dried. This took 5 days. The dry peels were then ground with mechanical blender. 600.52g of maize husk was then put in a liter of macerator containing 80% methanol. The mixture was stirred in macerator for 1 day, and the result was subsequently filtered by using filter paper. The filtrate was put in a vacuum rotary evaporator at a temperature of $54\text{--}55^\circ\text{C}$ to obtain maize husk concentrate. The result of the extract was put in bottles. Analysis to determine the presence of tannin was conducted on the maize husk with a mixture of methanol and ferric chloride. The change of colour on maize husk to olive-green indicates the presence of tannin (Evans 2002). The crude extract of the maize husk was fractionated to obtain the polar extract and a sample of the polar extract was sent to Kappa laboratories in Ibadan for phytochemical analysis. The fractionation was conducted using 15% of hexane, and 15% of ethyl acetate mixture. Finally, the remaining ethyl acetate fraction was obtained as the polar extract of the maize husk. This polar extract was then used as the corrosion inhibitor.

Qualitative Tests for Phytochemicals

FTIR Analysis of Maize Husk Polar Extract

Fourier transform infrared spectrophotometer (SHIMADZU, Model: IR affinity-1) was used for the determination of the functional groups of the MHP extracts. This analysis was carried out at National Centre for Renewable Energy, University of Nigeria Nsukka.

Method Employed in the Research Work

Gravimetric analysis (weight loss), FTIR of the corrosion product and the extract, adsorption, phytochemical analysis were the various methods employed for the purpose of this work. The maize husk polar extract is the green inhibitor identified and used for corrosion control in diluted hydrochloric acid (1.5mole of HCL). The presence of the most inhibitive property was identified. Vacuum rotary evaporator was used to determine the concentration of the extract at 79°C .

The efficiency of the inhibitor was calculated using the gravimetric analysis

The weight loss test method was used to study the corrosion inhibitor. The mild steel (specimens) were manually polished with silicon carbide abrasive paper, greased to avoid further corrosions and degreased with petroleum ether, washed in distilled water and dried. Each metal coupon is size $2\text{cm} \times 3\text{cm} \times 0.12\text{cm}$. Before polishing, a hole of about 0.4cm was drilled on each coupon. The coupon is suspended with the aid of nylon thread and glass rod in a 100ml beaker with 100ml of the 1.5M HCl without and with different concentrations of the inhibitor. To prevent evaporation of solution and contamination, the corrosion vessel was covered with paraffin. At various time intervals in hours, and inhibitor concentrations in HCl

solution at room temperature 30°C dipped in distilled water and immersed in methanol solution which was scrubbed with bristle brush, to remove residual acids, and inhibitors concentration and then washed with washing liquor (NaOH + Zn dust) thoroughly, rinsed with distilled water, and later dried in acetone before reweighed (Nwigbo et al., 2012). The effect of inhibitor concentration on corrosion was investigated by changing the initial inhibitor concentration in the ranges in HCl, at room temperature for different hours. Effect of time of exposure the effect of exposure time on corrosion was investigated in 1.5M HCl concentration.

Test for alkaloids

0.2g of extracts was shaken with 1% HCl for two minutes. The mixture was filtered and drops of Wagner's reagent added. Formation of a precipitate indicated the presence of alkaloids.

Test for phenols

0.2g of extracts was dissolved in ferric chloride solution. A green or dirty green precipitate indicated the presence of phenolic compound

Test for saponins

0.2g of extracts was shaken with 5ml of distilled water in a test tube. Frothing which persists on warming was taken as evidence for the presence of saponins.

Test for tannins

0.2g of extracts was stirred with distilled water and filtered. Ferric chloride was added to the filtrate. A blue- black, green or blue-green precipitate was taken as an evidence for the presence of tannins.

Determination of corrosion rate and inhibitor efficiency

$$H = \frac{(W_1 - W_2)(W_2 - W_1)}{(At)(At)} \quad (1)$$

Where:

H = Corrosion rate

W_1 = initial weight (before immersion)

W_2 = final weight (after immersion)

A = surface area of the sample

t = exposure time

Efficiency (IE) of each sample was calculated by using equation (2).

$$IE = \frac{(V_0 - V_1)}{V_0} (2)$$

V_0 = corrosion rate without inhibitor

V_1 = corrosion rate with the addition of inhibitor

3. Results and Discussion

Table 1 Phytochemical Analysis

PARAMETERS	VALUES
Alkaloids (mg/100g)	++
Cardiac Glycosides (mg/100g)	-
Flavonoids (mg/100g)	+
Phenolics (mg/100g)	+
Phytates (GAE/g)	+++
Saponins (mg/100g)	++
Terpenoids (mg/100g)	+
Anthocyanins (mg/100g)	+
Steroids (mg/100g)	++
Tannins (mg/100g)	++

+++ = highly concentrated, ++ = concentrated, + = in trace; - absent or too little to identified qualitatively.

The presence of the tannins, phenols, saponin, and anthraquinones with functional group containing (nitrogen, Oxygen and carbon), aromatic rings present in phenols constituent in the rubber leave extract chemical structure as depicted by the phytochemical test in Table 1 also enhance the process of corrosion inhibitor adsorption on the mild steel. This also corroborates the work of (Nwigbo et al., 2012; Prithiba et al., 2014; Owate et al., 2014). The presence of these compounds has been reported to promote the corrosion inhibition of mild steel in aggressive acid media (Umoren et al., 2006). Molecules containing nitrogen and acetylenic alcohols are claimed to form a film on the metal surface and can retard the metal dissolution process (an anodic reaction) as well as hydrogen evolution (a cathodic reaction) (Barmatov et al., 2012).

Corrosion Rate Analysis

The graphs shown below are the results of various tests conducted in different corrosion media. Gravimetric analysis, Inhibitor efficiency, corrosion of mild steel at different exposure time in 1.5M of HCL, 1.5M of H₂SO₄.

WEIGHT LOSS TEST IN 1.5M OF HCL

Fig. 1: 5ML⁻¹ concentration of extract in 1.5M of HCL.

Fig.2 : 15ML⁻¹ concentration of extract in 1.5M of HCL.

Fig.3 : 25ML⁻¹ concentration of extract in 1.5M of HCL.

WEIGHT LOSS TEST IN 1.5M OF H₂SO₄

Fig. 4: 5ML⁻¹ concentration of extract in 1.5M of H₂SO₄

Fig.5: 15ML⁻¹ concentration of extract in 1.5M of H₂SO₄

Fig. 6: 25ML⁻¹ concentration of extract in 1.5M of H₂SO₄

Fig.7: Inhibitor efficiency (%), 5ML⁻¹ concentration in 1.5M of HCL

Fig.8: Inhibitor Efficiency (%), 25 ML⁻¹ concentrations in 1.5M of HCL

Fig.9: Inhibitor Efficiency (%), 5ML⁻¹ concentration in 1.5M of H₂SO₄

Fig.10: Inhibitor Efficiency (%), 25 ML⁻¹ concentration in 1.5M of H₂SO₄

Fig.11: 5ML⁻¹ concentration of extract in 1.5M of HCL

Fig.12: 25ML⁻¹ concentration of extract in 1.5M of HCL

Fig.13: 5ML⁻¹ concentration of extract in 1.5M of H₂SO₄.

Fig.14: 25ML⁻¹ concentration of extract in 1.5M of H₂SO₄.

Adsorption Isotherm Parameters

Table 2: Summary tables for Langmuir isotherms for MPHE in all the corrosion environment

Summary tables for Langmuir isotherms for MPHE in 1.5M of HCl					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	0.4539	0.80188	0.83443	0.87231	0.90488
Intercept	0.47864	0.38087	0.31437	0.24755	0.18484
R ²	0.94965	0.97496	0.98298	0.99047	0.99378
K	0.3322	0.4086	0.4849	0.5655	0.6534
ΔGKj/mol	-7.392	-7.917	-8.351	-8.341	-9.017
Summary tables for Langmuir isotherms for MPHE in 1.5M of H ₂ SO ₄					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	1.78857	-1.12069	0.30386	2.10662	0.65994
Intercept	-0.64209	1.86714	0.75706	-0.70233	0.92428
R ²	0.90705	0.01968	-0.32065	0.96929	0.21348
K	4.3867	0.0136	0.1750	5.0388	0.1190
ΔGKj/mol	-13.937	0.713	-5.766	-14.2885	4.7879

Table 3: Summary tables for Frumkin adsorption isotherm for MPHE in the entire corrosion environment

Summary tables for Frumkin adsorption isotherm for MPHE in 1.5M of HCl					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	3.91002	4.75429	5.26849	6.2273	1.17044
Intercept	-1.09009	-1.82631	-2.31509	-3.19251	0.98066
R ²	0.8332	0.9042	0.92612	0.91478	0.91527
a	1.9550	2.3772	2.6343	3.1137	0.5852
K	0.0077	0.0548	0.1012	0.1899	223.0583
ΔGKj/mol	2.1514	-2.8824	-4.3772	-0.2258	-23.9018
Summary tables for Frumkin adsorption isotherms for MPHE in 1.5M of H ₂ SO ₄					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	1.63948	0.36895	2.02337	1.41167	1.23453
Intercept	0.4877	1.52339	0.05799	0.42022	0.47314
R ²	0.97566	0.6235	0.9932	0.95394	0.92147
a	0.8197	0.1845	1.0117	0.7958	0.6173
K	52743.05	32.4908	5.173x10 ³⁹	302317.03	73702.3073
ΔGKj/mol	-37.7647	-19.0156	-242.1186	42.1923	-36.6133

Table 4: Summary tables for Temkin adsorption isotherm for MPHE in all corrosion environments

Summary tables for Temkin adsorption isotherm for MPHE in 1.5M of HCl					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	0.38751	0.32295	0.29071	0.23377	0.18588
Intercept	0.21601	0.33798	0.42191	0.52739	0.62878
R ²	0.58705	0.62353	0.6225	0.62861	0.5711
α	-0.3365	-0.2805	-0.2525	-0.2030	-0.1614
K	0.8647	0.8273	0.8081	0.8073	0.81863

$\Delta G_{Kj}/\text{mol}$	-9.8182	-9.7060	-9.6465	-9.6438	-9.6721
Summary tables for Temkin adsorption isotherms for MPHE in 1.5M of H_2SO_4					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	-1.02441	-1.87441	-0.40202	-1.05267	-0.95875
Intercept	1.79801	2.50159	2.07697	1.61752	1.51081
R^2	0.69863	0.62803	0.71172	0.92936	0.90942
α	0.8896	1.6278	1.2176	0.9142	0.8326
K	24.4971	3438.1945	157.0806	19.2373	12.3713
$\Delta G_{Kj}/\text{mol}$	18.2994	-30.8393	-23.0124	-17.6863	-16.5666

Table 5: Summary tables for Flory-Huggins adsorption isotherm for MPHE in all the corrosion environment

Summary tables for Flory-Huggins adsorption isotherm for MPHE in 1.5M of HCl					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	0.59847	0.77164	-0.60255	0.87023	0.75648
Intercept	-0.01939	-0.85055	-1.60414	-0.60649	-0.57026
R^2	0.02262	0.27539	0.50452	0.35907	0.3017
K	0.0956	0.1411	0.0249	0.2475	0.2690
$\Delta G_{Kj}/\text{mol}$	-4.2335	-5.2195	-0.8185	-0.6449	-6.8565
Summary tables for Flory-Huggins adsorption isotherms for MPHE in 1.5M of H_2SO_4					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	-0.93567	0.67341	-0.27416	-1.22097	-1.4864
Intercept	-1.99292	-0.21146	-1.23924	-1.98926	-2.03231
R^2	0.94094	0.16624	-0.29431	0.77063	0.76661
K	0.0102	0.6145	0.0576	0.0103	107.7234
$\Delta G_{Kj}/\text{mol}$	1.4520	-8.9519	-2.9496	1.4306	-22.0557

Fig.15: FTIR of MHPE

Fig.16: FTIR of Corrosion Product of H_2SO_4

Fig.17: FTIR of Corrosion Product of HCL

Discussion:

The results display that the Maize Husk Polar Extract (MHPE) has the character of a mixed inhibitor in H_2SO_4 medium. The metal samples (coupons) in the inhibited and un-inhibited (control) medium exhibit a progressive increase in weight loss with time. The increase of extract concentration significantly affects the rate of weight loss.

The efficiencies of the inhibitor in H_2SO_4 and HCL show progressive increase in the percentage efficiencies of the inhibitor with time. The more the concentration of MHPE in H_2SO_4 and HCL, the less the rate of weight loss. Conclusively, the extract is compatible and effective in the H_2SO_4 and HCL. The analysis of FTIR Spectra Test result indicates the presence of the following (-OH, (Alcohols, Phenols), $-\text{NH}_2$, (Amines), $-\text{CHO}$, (Aldehyde), $-\text{COOH}$, (Carboxylics), $-\text{NO}_2$, (Nitriles), etc. Essential organic inhibitors substituent or functional groups in $\text{H}_2\text{SO}_4 + \text{MHPE}$, HCL + MHPE, River water + MHPE, Reservoir formation water + MHPE, and Saline water + MHPE. Corrosion inhibitor of organic origin in various corrosive media decreases or prevents the reaction of the metal with the media. They reduce the corrosion rate by adsorption of ions/molecules onto metal surface, increasing or decreasing the anodic and/or cathodic reaction, decreasing the diffusion rate for reactants to the surface of the metal, decreasing the electrical resistance of the metal surface.

($-\text{NH}_2$, $-\text{NO}_2$, $-\text{CHO}$, or $-\text{COOH}$) replacing H-atom attached to the C- central atom improve inhibition. However, the presence of a hydrophilic functional group (OH, NH, and NO) in the molecule increases the solubility of the inhibitors.

The inhibitive characteristics of such compounds derive from the adsorption ability of their molecules, with the polar group acting as the reaction center for the adsorption process. The resulting adsorbed film acts as a barrier that separates the metal from the corrodent, and efficiency of inhibition depends on the mechanical, structural, and chemical characteristics of the adsorption layers formed under particular conditions.

The MHPE appears to be a good inhibitor in HCL, but not as effective in H_2SO_4 . The order of amount of detectable functional organic inhibitors (substituent) is as follows: $\text{RW} + \text{MHPE} > \text{HCL} + \text{MHPE} > \text{RFW} + \text{MHPE} > \text{SW} + \text{MHPE} > \text{H}_2\text{SO}_4 + \text{MHPE}$.

Conclusion

This research work investigated the comparative study inhibitor efficiency of Maize Husk Polar Extract (MHPE) green inhibitor to monitor and control corrosion on mild steel in 1.5M of HCL and 1.5M of H_2SO_4 , using gravimetric analysis, Fourier Transform Infrared Spectroscopy (FTIR). The extract was found to efficiently inhibit the corrosion process in 1.5M of HCL and 1.5M of H_2SO_4 as the inhibitor efficiency increased with increase in the concentration MHPE. The maximum inhibition efficiency of MHPE was 93.6% in 1.5m of HCL at 384 hours. However, in 1.5M of H_2SO_4 , the maximum inhibition efficiency was 96% at 48 hours in 5ml/litre further increase in inhibitor concentration drastically reduced the efficiency to 28.3% at 25ml/litre for 48hrs. Phytochemical analysis revealed the presence of alkaloid flavonoids, phenolics, phytates, saponins, terpenoids anthocyanins, steroids and tannins. The FTIR of MHPE and the corrosion

product shows the variation of the peak numbers and the nature of shift indicates the interaction among the functional groups of extract in the corrosion inhibition process. It also confirmed the presence of C-O functional group as the most dominant in the entire corrosion product. The study clearly shows that by the efficiency of MHPE, gotten from the two media, MHPE is suitable for corrosion control in oil pipelines during pigging, acidizing of reservoirs, hydraulic fracturing and hydro-testing.

References

- [1] Amitha, B. A., Basu B. J (2012). Green inhibitors for corrosion protection of metals and alloys. *International Journal of Corrosion* (ISSN: 1687-9333(E)/11pages (O)), 2012,doi:10.1155/2012/380217.
- [2] Amuda, M.O.H., Soremekun, A.O.O., Oladoye, A (2008). Improving the corrosion inhibitive strength of sodium sulphite in hydrogen cyanide solution using sodium benzoate. *Leonard Electronic Journal of Particles and Technologies* (ISSN: 1583- 1078(E)/75 – 63(O)), 13.
- [3] Bruce, D.C. (2014). *Textbook of Oilfield Metallurgy and Corrosion*, Third Edition, Published by MetCorr, ISBN 10 09760400X.
- [4] Ezemonye, L.I.N., Ogeleka, D.F., Okeimen, F.E (2006). Toxicity of negate (industrial detergent) and norust cr 486(corrosion inhibitors) to earthworms (*Aporrectodea longa*) in naturally spiked soil. *African Journal of Biotechnology* (ISSN: 1684 – 5315(E)/1117
- [5] Guzman, M., Lara, R., Vera, L (2009). 5 – amino – 1, 3, 4 – thiadiazole – 2 – thiol corrosion current density and adsorption thermodynamics on ASTM A – 890 – 1B stainless steel in a 3.5% NaCl solution. *Journal of the Chilean Chemical Society* (ISSN: 0717 – 9707(E)/18 – 1(O)), 549(2), doi: 10.4067/S0717 – 97072009000200005.
- [6] Loto, R.T., Loto, C.A., Popoola, P.A (2014). Corrosion inhibition of 2- amino – 5 ethyl – 1, 3, 4 – thiadiazole on mild steel in hydrochloric acid. *Canadian Journal of Pure and Applied Sciences* (ISSN: 1920 -3853(E)/3103 -3091(O)), 8(3).
- [7] Umoren, S. A., Ogbobe, O., Ebenso, E. E., and Ekpe, U. J. (2006). Effect of halide ions on the corrosion inhibitor of mild steel in acidic medium using polyvinyl alcohol, pigment and Resin Technology, Vol. 35, Issue 5, 284-292.
- [8] Umoren, S. A., Eduok, U. M., and Oguzie, E. E. (2008). Corrosion Inhibition of mild steel in 1M H₂SO₄ by polyvinyl pyrrolidone and synergistic iodide additive, *Portugaliae Electrochemica Acta*, Vol. 26, Issue 6, pp 533-546.
- [9] Umoren, S. A., Obot, I.B., Ebenso, E.E., Okafor, P.C (2008). Eco – friendly inhibitors from naturally occurring exudates gums for aluminium corrosion inhibition in acidic