ANALYSIS

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DISCOVERY

The rate of corrosion inhibition of mild steel in fresh water using maize husk polar extract

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ABSTRACT

The rate of corrosion and inhibition efficiency of Maize husk polar extract was investigated in Fresh water at room temperature of 29^{o}C by weight loss method. The green inhibitor's concentration was achieved through Vacuum rotary evaporator at 79^{0}C. The result gotten from the vacuum rotary evaporator is 24.00% concentration (mg/100g) from 600.50grams of the extract. The extract contains Alkaloids, Flavonoids, Phenolics, Phenolics, Phytates, Saponins, Terpenoids, Anthocyanins, Steroids, and Tannins. The extract shows spontaneous characteristics with the physical adsorptions submits to Langmuir isotherm. The results signal the inhibition efficiency attained 96.5% for 840hours in Fresh water. MHPE is a good inhibitor for the corrosion control in fresh water. FTIR analysis reveals the detectable functional organic inhibitor.

Keywords: Maize husk polar extract; FTIR analysis; corrosion inhibition; mild steel

1. INTRODUCTION

Corrosion control is a task that encompasses so many professions. Its importance has a significant effect to environmental resource protection and management. Natural inhibitors have been proven to be the surest means of combating corrosion with little or no effect to the environment. Biodegradable inhibitors are eco-friendly because they are product of the environment. By comparing the negative effect of organic and inorganic inhibitors; there is every reason to rely so much on organic inhibitors to save our planet (Amitha, 2011). The reduction in the rate of correction is a response to the molecules found in the extract (Emeka, 2008). Leaves extract act as a good corrosion inhibitor for mild steel in concentrations of the extract. The inhibition action depends on the concentration of leaves extract in the acid solution (Jamiu, 2013). Inhibition efficiency is the corresponding increase in the molecules responsible in slowing down the effect of corrosion found in the corrosion product (Chuan, 2017).

Corrosion environment is the determinant factor to the type of inhibitor (Erebugha, 2020). The use of corrosion inhibitors has proven to be the easiest and cheapest method for corrosion protection and prevention. These inhibitors slow down the corrosion rate and thus prevent monetary losses due to metallic corrosion on industrial vessels, equipment, or surfaces (Marko, 2016).

The Electrochemical impedance spectroscopy (EIS) measurement of inhibition on mild steel reveals the formation of barrier layer on mild steel surface (Tsoeunyane, 2019).

2. PROCEDURE

Materials

Percentage composition of mild steel; 0.0869% Cu, 0.0047% Mo, 0.10060% As, 0.2529% Mn, 0.0096% P, 0.0125% Cr, 0.0101% Sn, 0.0292% C, 0.0062% Si, 0.0152% S, 0.003% Co, 0.0005% Zn and 99.535% Fe. Maize Husks, Digital Weighing Meter, Desiccators, Macerator, Beakers, Measuring Cylinder, Abrasives (sand paper), pH meter, Infrared Spectrometer (FTIR), wall clock and Stop Watch, soft brush, Hand Lens, Vacuum Rotary Evaporator, Manual Blender, Spatula, Filter Paper, Diluted HCL, H_2SO_4, Methanol, Ethyl Acetate, Ferric Chloride, Distilled Water, Acetone, Hexane and Fresh water.

Method

Weight loss, phytochemical analysis, FTIR, adsorption was used in this research. The green inhibitor is maize husk polar extract. The concentration of the extract at 79^0C was gotten via Vacuum rotary evaporator. Calculated inhibitor efficiency was gotten using weight loss.

Experimental Method

Extraction Process

Maize husks were washed, chopped to small pieces and dried for 5 days and ground with mechanical blender. 600.50g 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 54-55 ^{0}C to obtain maize husk concentrate. The crude extract of the maize husk was fractionated to obtain the polar extract and phytochemical analysis.

3. RESULTS

Graphs of Corrosion Rate

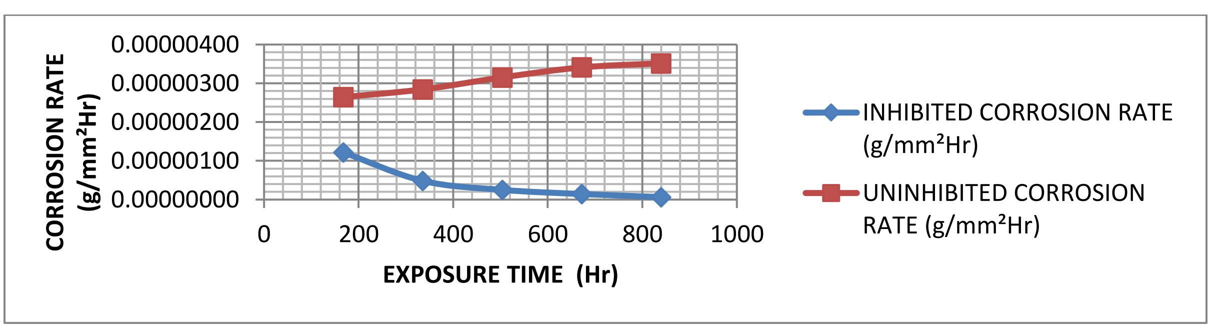


Fig.1: 5ML CONCENTRATION OF EXTRACT IN FRESH WATER

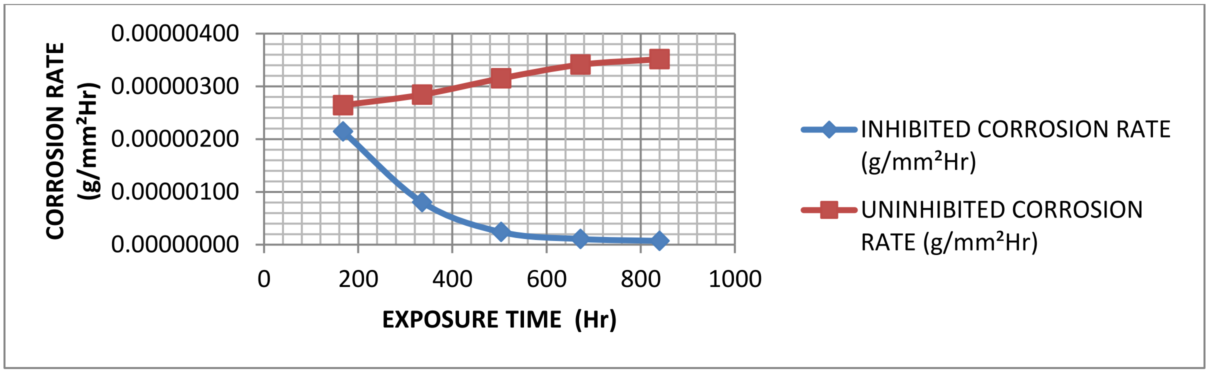


Fig.2: 10ML CONCENTRATION OF EXTRACT IN FRESH WATER

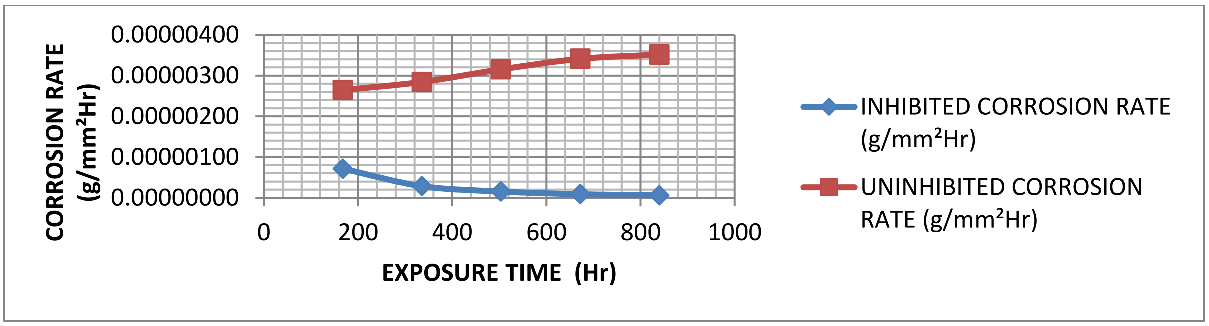


Fig.3: 15ML CONCENTRATION OF EXTRACT IN FRESH WATER

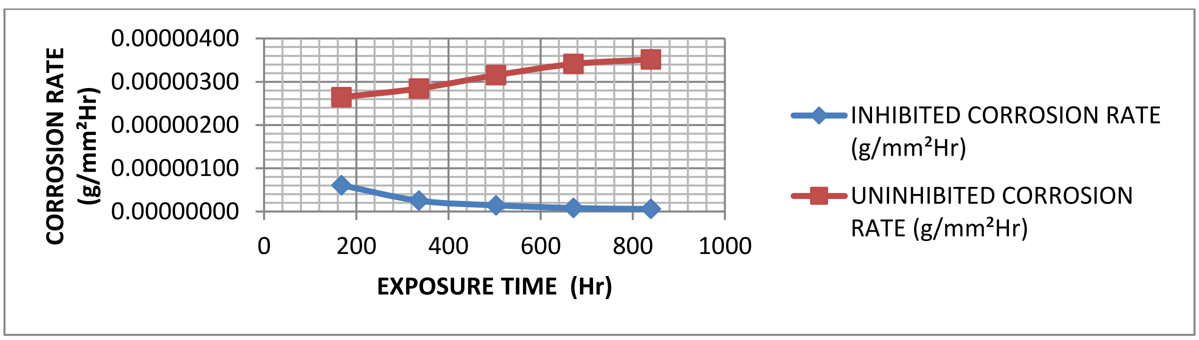


Fig.4: 20ML CONCENTRATION OF EXTRACT IN FRESH WATER

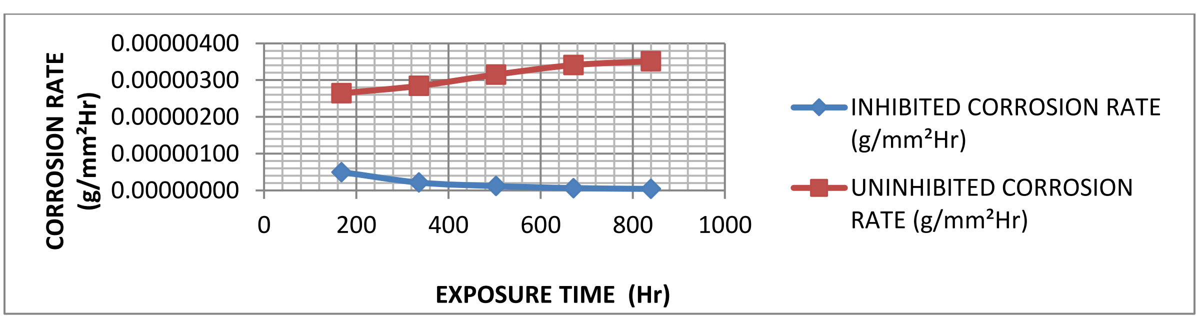


Fig.5: 25ML CONCENTRATION OF EXTRACT IN FRESH WATER

Graphs of weight loss

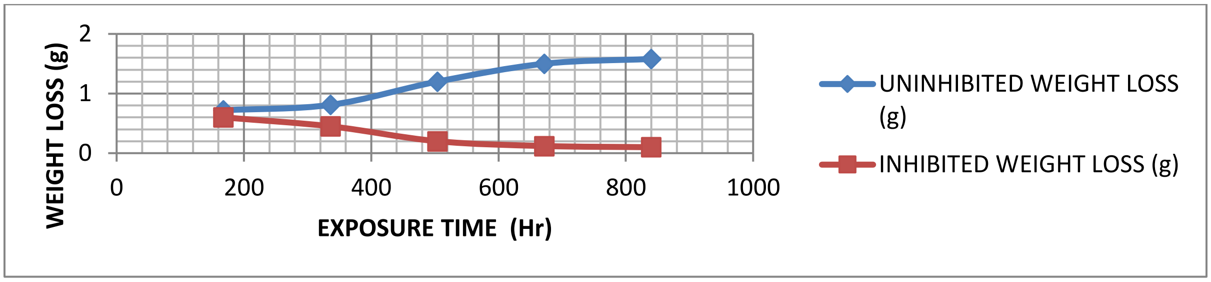


Fig.6: 5ML CONCENTRATION OF EXTRACT IN FRESH WATER (RIVER WATER)

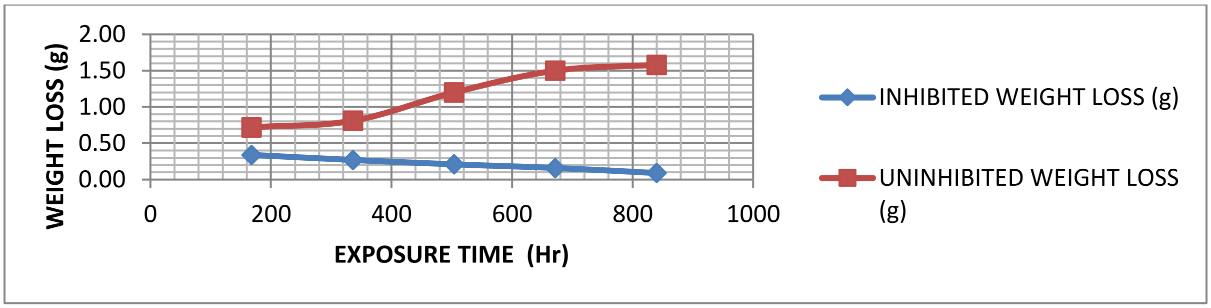


Fig.7: 10ML CONCENTRATION OF EXTRACT IN FRESH WATER (RIVER WATER)

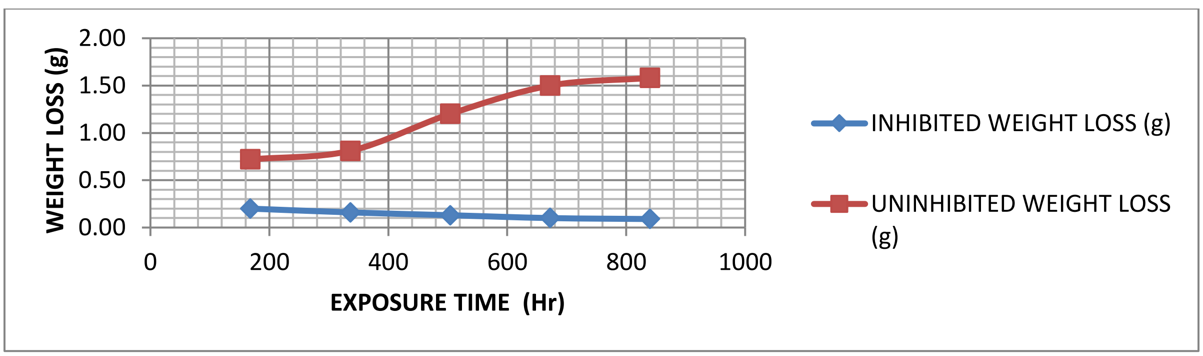


Fig.8: 15ML CONCENTRATION OF EXTRACT IN FRESH WATER (RIVER WATER)

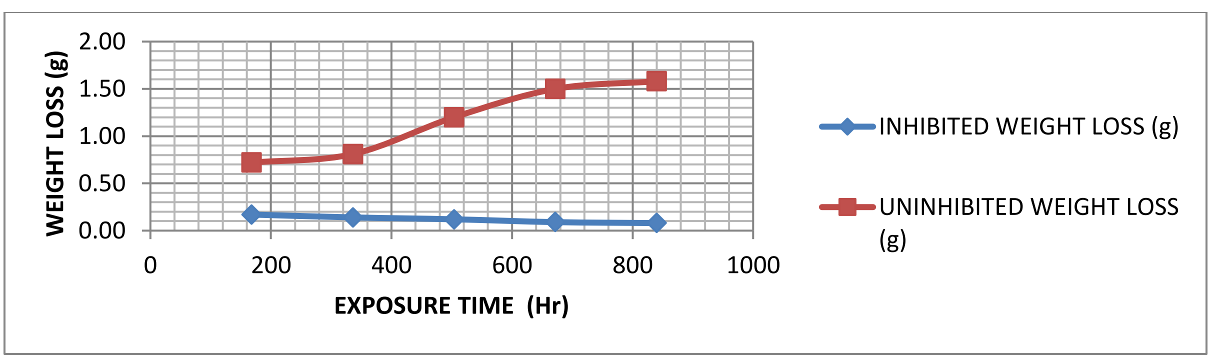


Fig.9: 20ML CONCENTRATION OF EXTRACT IN FRESH WATER (RIVER WATER)

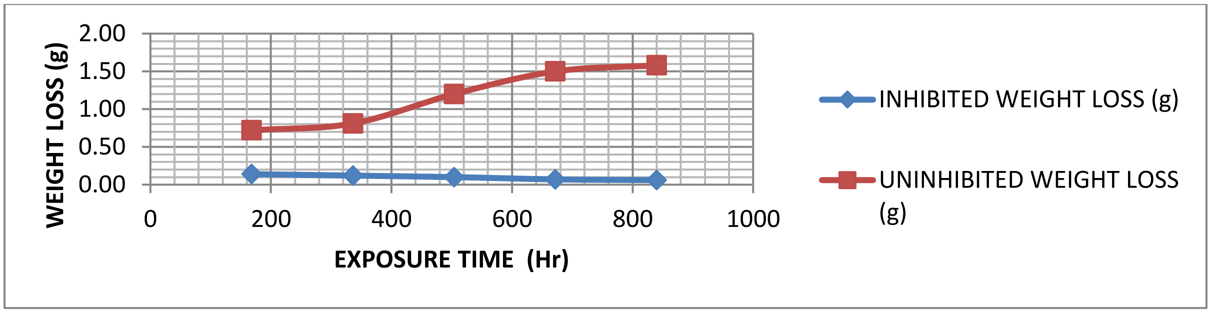


Fig.10: 25ML CONCENTRATIONS OF EXTRACT IN FRESH WATER (RIVER WATER)

Graphs of Inhibition efficiency

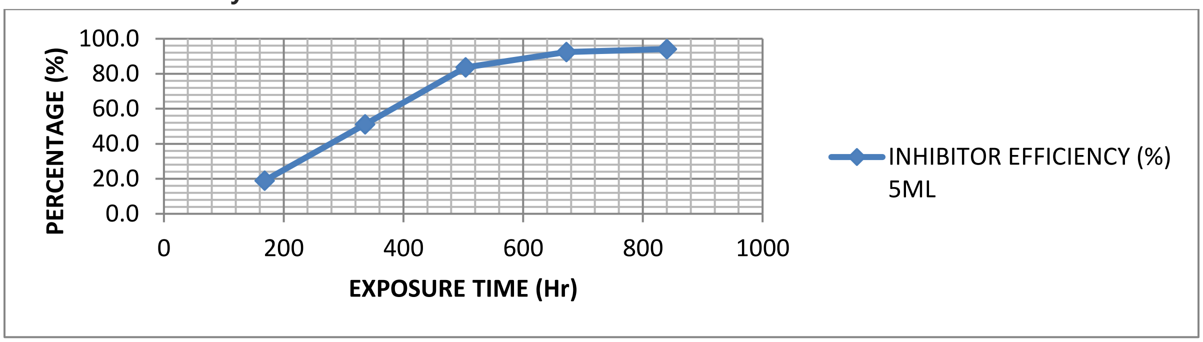


Fig.11: INHIBITOR EFFICIENCY (%), 5 ML CONCENTRATION IN FRESH WATER

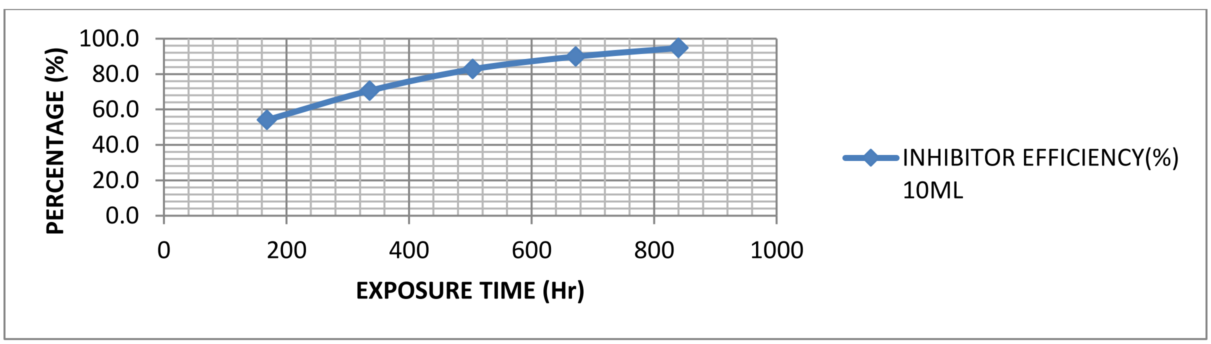


Fig.12: INHIBITOR EFFICIENCY (%), 10ML CONCENTRATION IN FRESH WATER

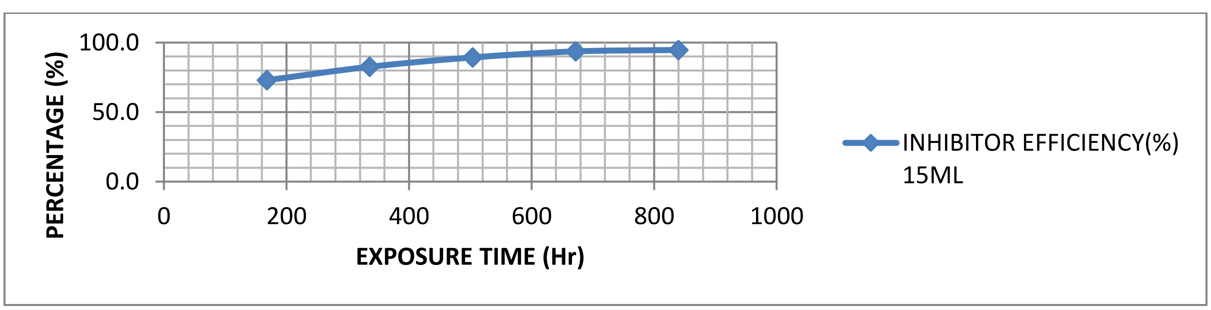


Fig.13: INHIBITOR EFFICIENCY (%), 15ML CONCENTRATION IN FRESH WATER

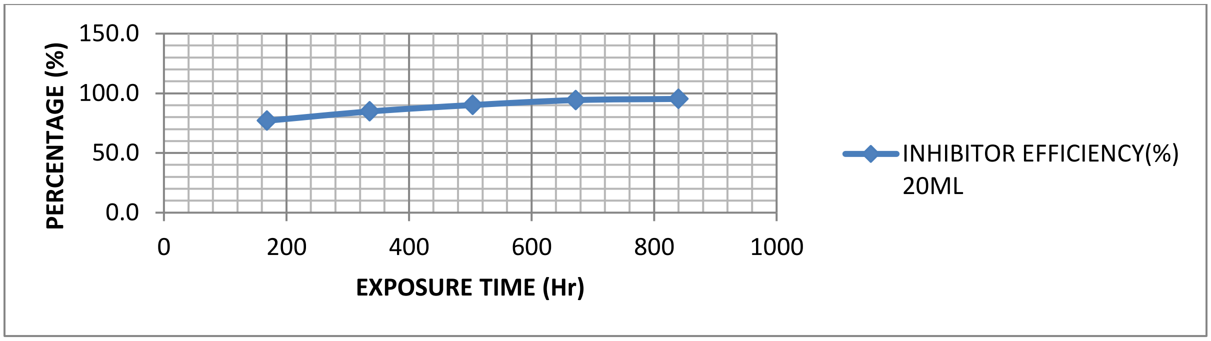


Fig.14: INHIBITOR EFFICIENCY (%), 20ML CONCENTRATION IN FRESH WATER

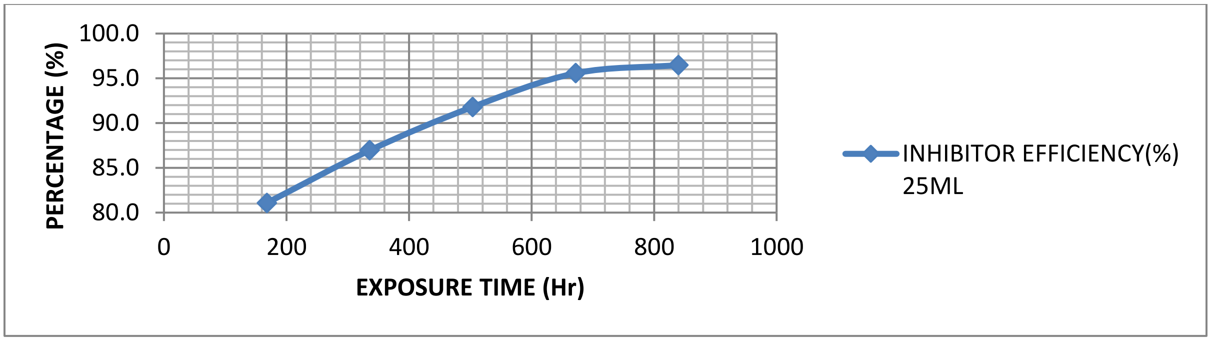
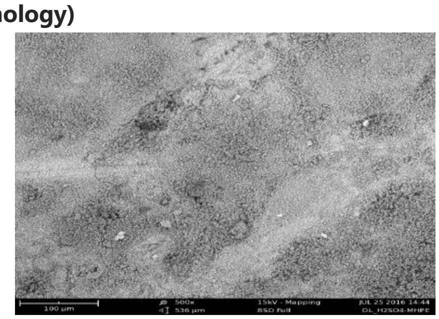


Fig.15: INHIBITOR EFFICIENCY (%), 25ML CONCENTRATION IN FRESH WATER

SEM (Coupon Morphology)



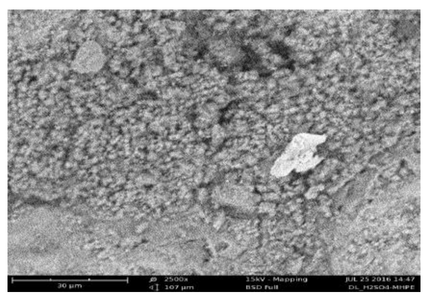


Plate 1. Mild steel in River water with MHPE **Plate 2.**Mild steel in River water.

Adsorption Isotherm Parameters

Table 1: Summary tables for Langmuir isotherms for MPHE in Fresh water

Summary tables for Langmuir isotherms for MPHE in Fresh Water					
	168hrs	336hrs	504hrs	672hrs	840hrs
Slope	0.09686	0.66691	0.93147	0.97219	0.98946
Intercept	1.27302	0.50393	0.1324	0.0618	0.03395
R^2	-0.21324	0.97614	0.99789	0.999	0.99997
K	0.0533	0.3134	0.7372	0.8674	0.9248
ΔGKj/mol	-2.751	-7.244	-9.414	-9.826	-9.989

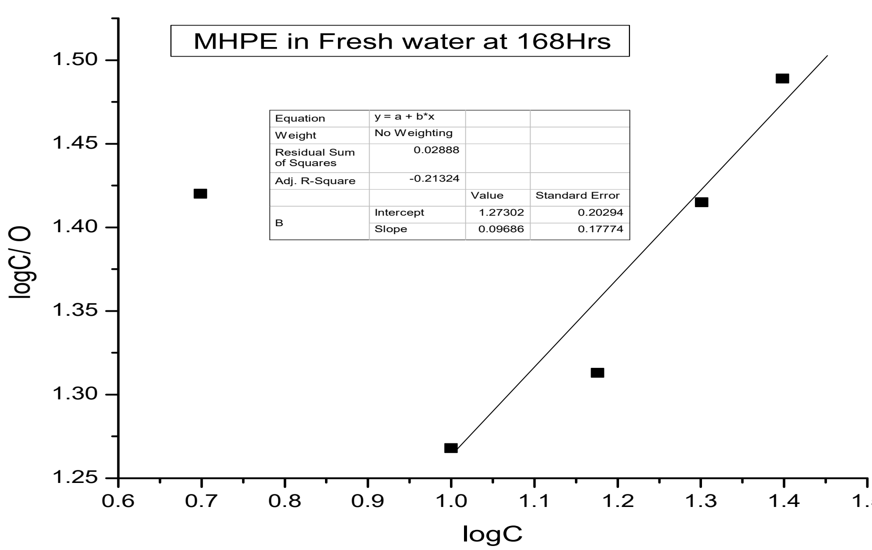
Table 2: Summary tables for Frumkin adsorption isotherm for MPHE in Fresh water

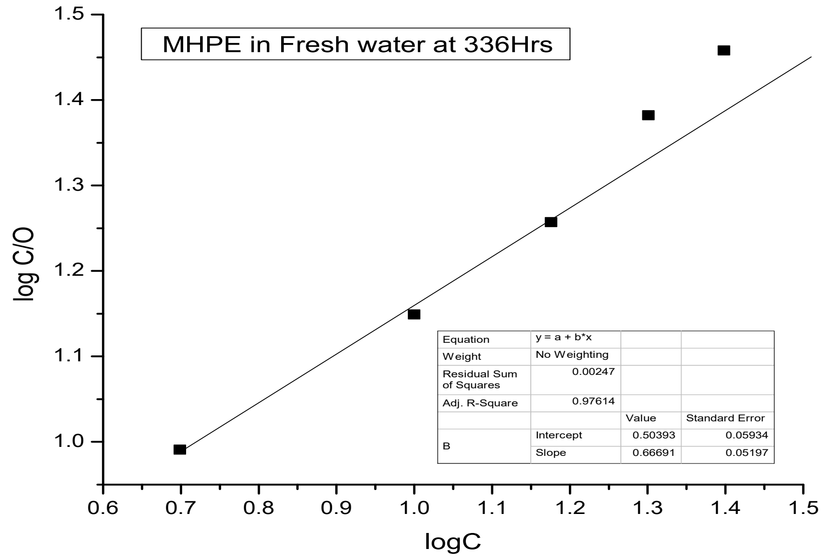
Summary tables for Frumkin adsorption isotherms for MPHE in Fresh Water					
	168hrs	336hrs	504hrs	672hrs	840hrs
Slope	3.06201	4.02639	9.79324	15.9	44.2
Intercept	-0.5415	-1.38299	-6.61545	-12.547	-39.5928
R^2	0.99027	0.97185	0.87516	0.69883	0.8271
A	1.5317	2.0132	4.8966	7.9500	22.1000
K	0.000057	0.0216	0.4486	0.6553	0.8747
ΔGKj/mol	14.6511	-0.4617	-8.1537	-9.1148	-9.8471

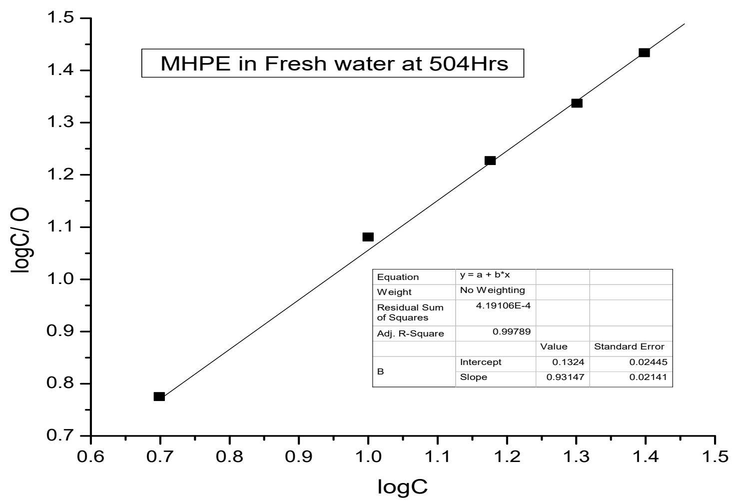
Table 3. Summary tables for Temkin adsorption isotherm for MPHE in Fresh water

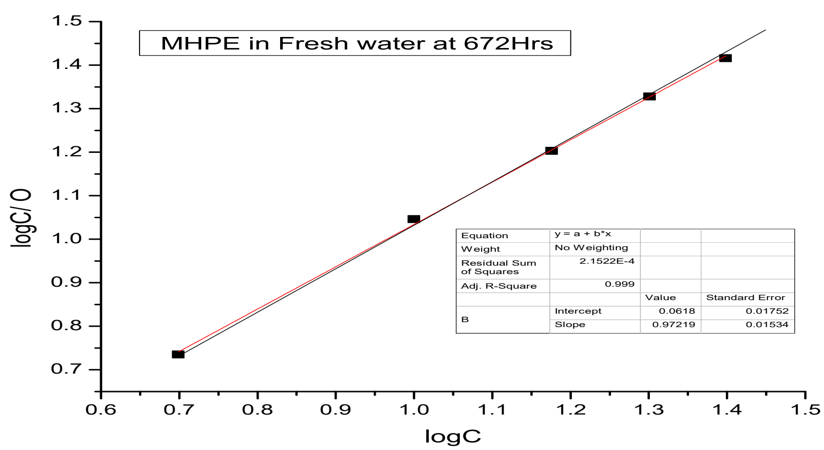
Summary tables for Temkin adsorption isotherms for MPHE in Fresh Water					
	24hrs	48hrs	96hrs	192hrs	384hrs
Slope	0.90732	0.51909	0.13706	0.06095	0.10516
Intercept	-0.40348	0.17132	0.72721	0.86405	0.74476
R^2	0.94665	0.93363	0.69794	0.39234	0.7164
α	-0.7879	-0.4508	-0.1190	-0.0529	-0.0913
K	1.8884	0.8569	0.8411	0.9126	0.8728
ΔGKj/mol	-11.7992	-9.7951	-9.7478	-9.9549	-9.8419
Summary tables for Flory-Huggins adsorption isotherms for MPHE in Fresh Water					
	168hrs	336hrs	504hrs	672hrs	840hrs
Slope	0.10083	0.62611	1.41847	1.23118	3.361
Intercept	-1.33347	-0.5526	0.16795	0.32566	3.25986
R^2	-0.2216	0.5569	0.672	0.41149	0.63644
K	0.0464	0.2802	1.4721	2.1167	1819.1143
ΔGKj/mol	-2.3992	-6.9596	-11.1677	12.0887	-29.2247

Langmuir, Flumkin, Temin and Flory-Huggins Isotherm Plot for Adsorption of MHPE on Mild Steel, Temperature at 311K




MHPE in Fresh water at 336Hrs
log C/O
logC
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.00247
Adj. R-Square 0.97614
Value Standard Error
B Intercept 0.50393 0.05934
Slope 0.66691 0.05197


MHPE in Fresh water at 504Hrs
logC/ O
logC
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 4.19106E-4
Adj. R-Square 0.99789
Value Standard Error
B Intercept 0.1324 0.02445
Slope 0.93147 0.02141


MHPE in Fresh water at 672Hrs
logC/ O
logC
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 2.1522E-4
Adj. R-Square 0.999
Value Standard Error
B Intercept 0.0618 0.01752
Slope 0.97219 0.01534

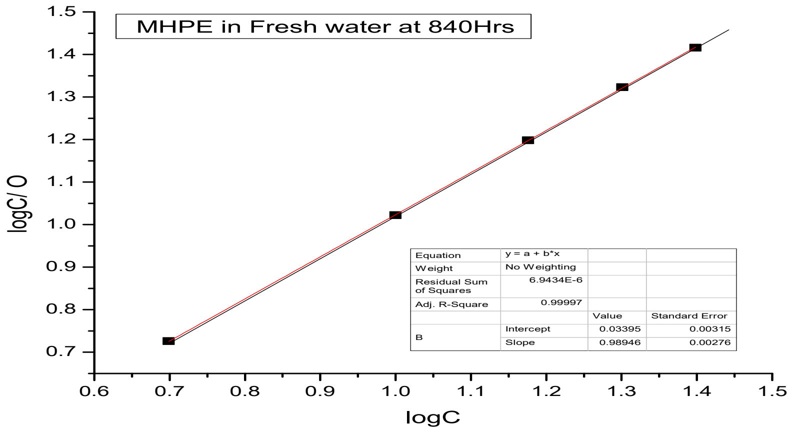
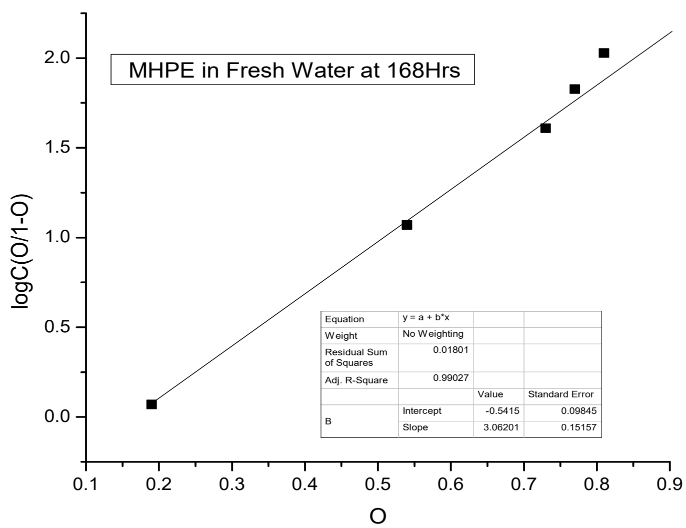
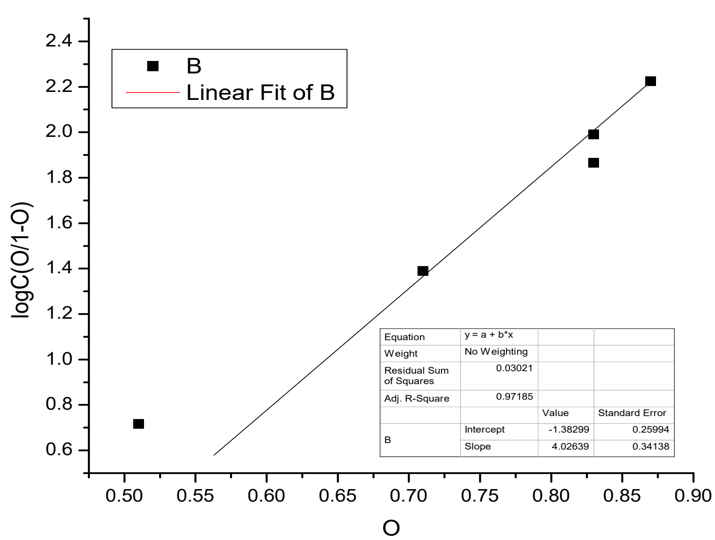


Fig.16: Langmiur adsorption isotherm plot





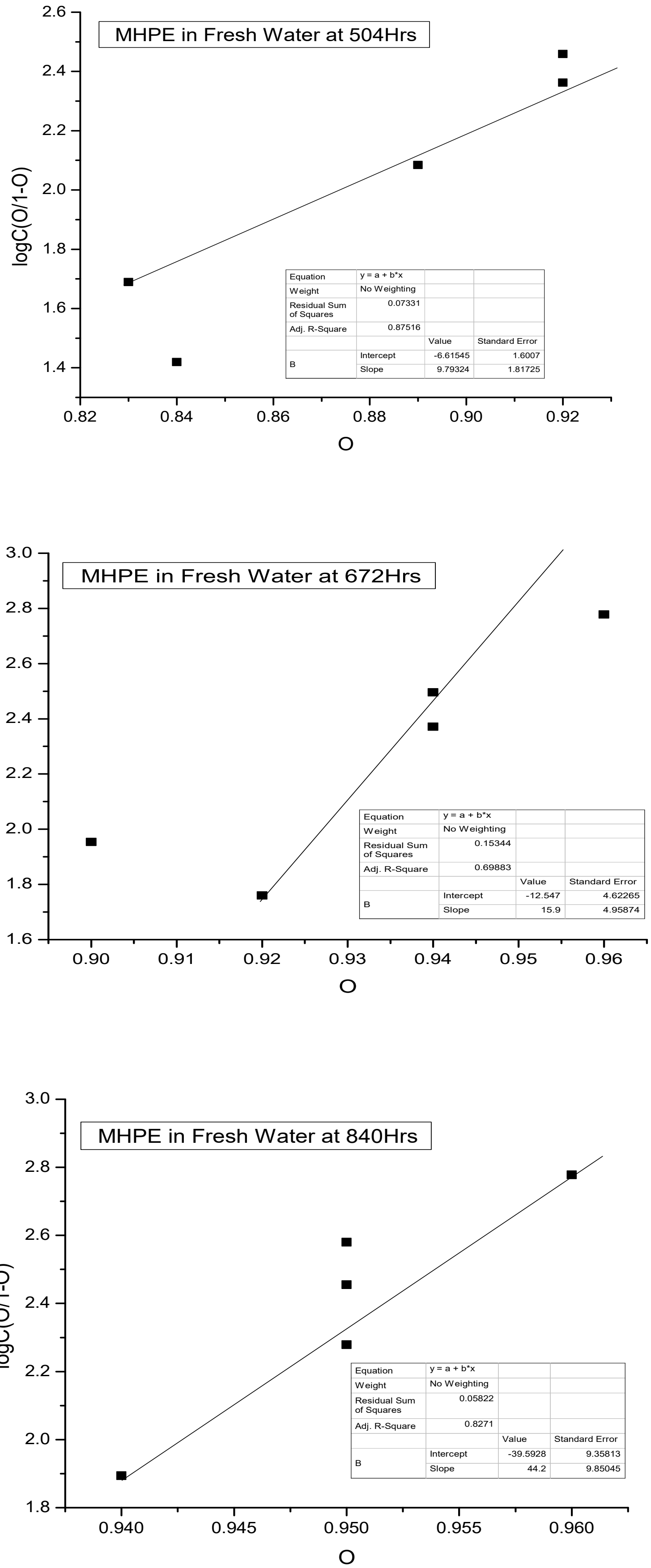
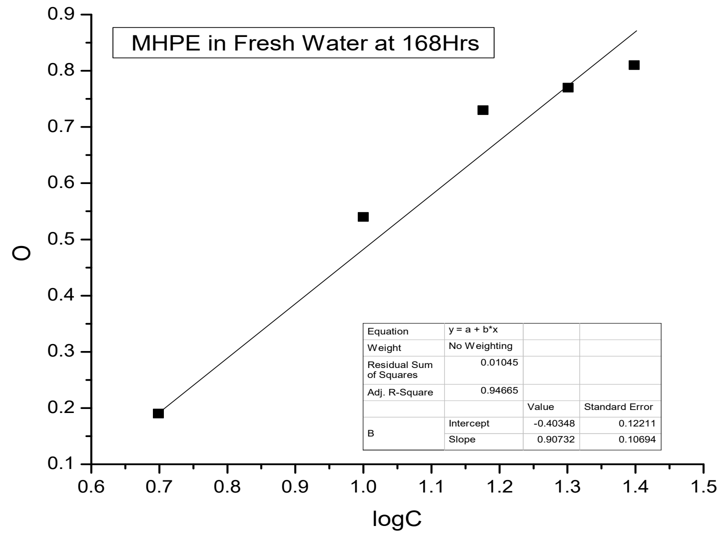
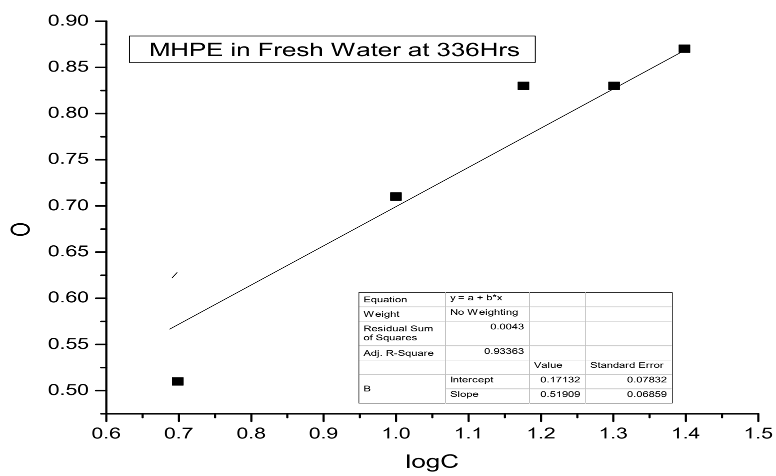
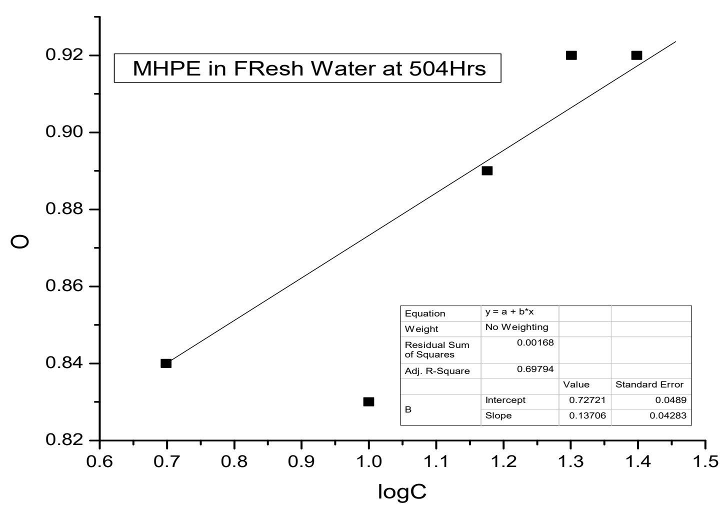
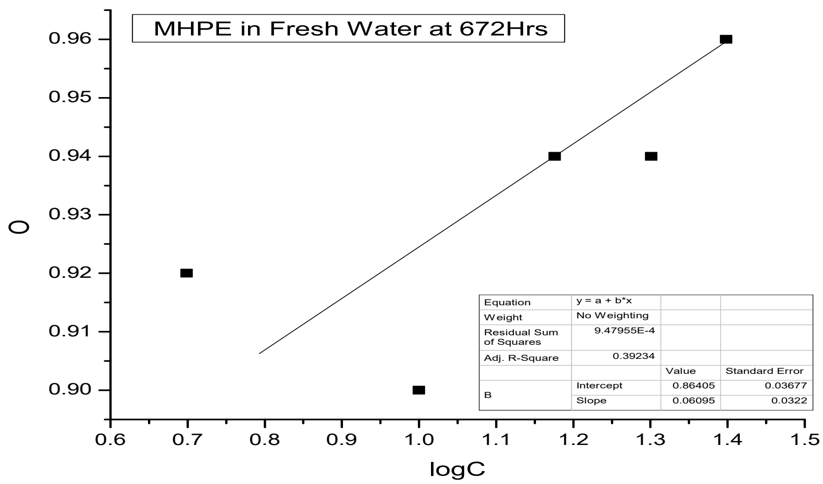


Fig. 17: Frumkin adsorption isotherm plot


MHPE in Fresh Water at 168Hrs
logC
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.01045
Adj. R-Square 0.94665
Value Standard Error
B Intercept -0.40348 0.12211
Slope 0.90732 0.10694


MHPE in Fresh Water at 336Hrs
logC
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.0043
Adj. R-Square 0.93363
Value Standard Error
B Intercept 0.17132 0.07832
Slope 0.51909 0.06859


MHPE in FResh Water at 504Hrs
logC
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.00168
Adj. R-Square 0.69794
Value Standard Error
B Intercept 0.72721 0.0489
Slope 0.13706 0.04283



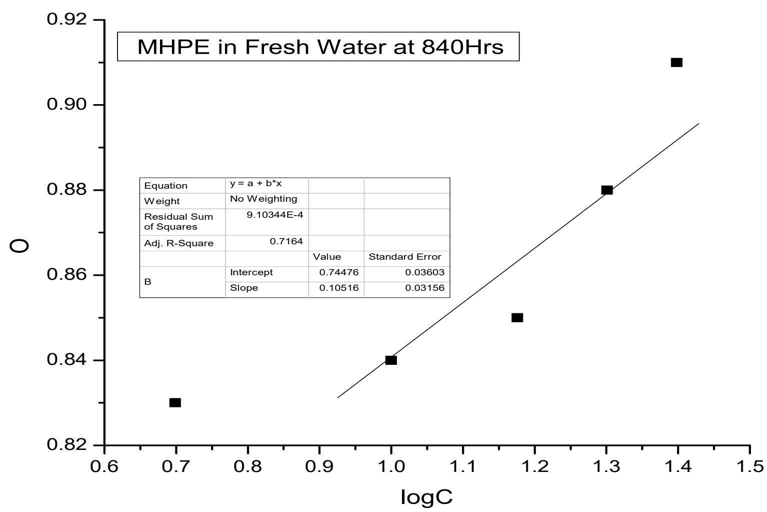
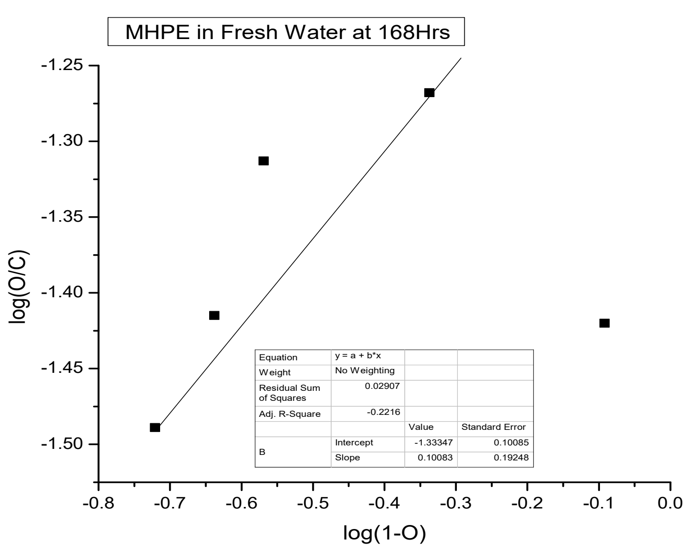
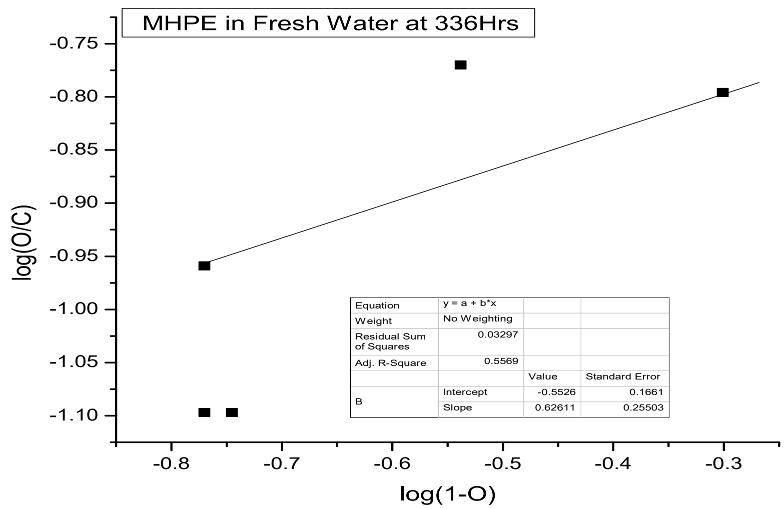
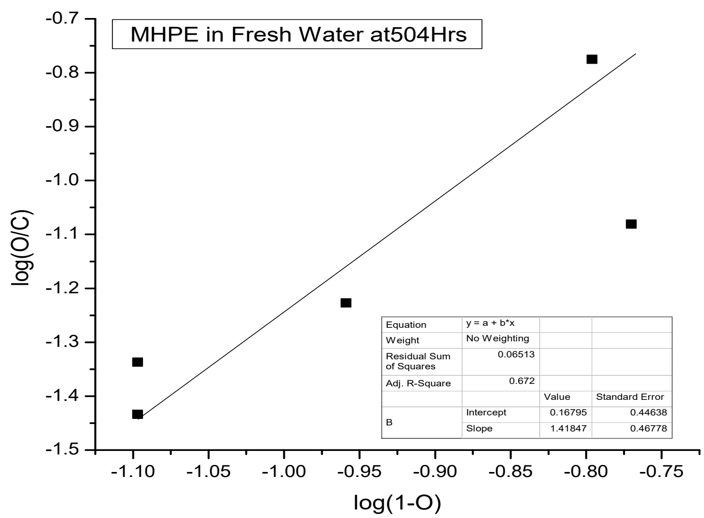


Fig.18: Temkin adsorption isotherm plot

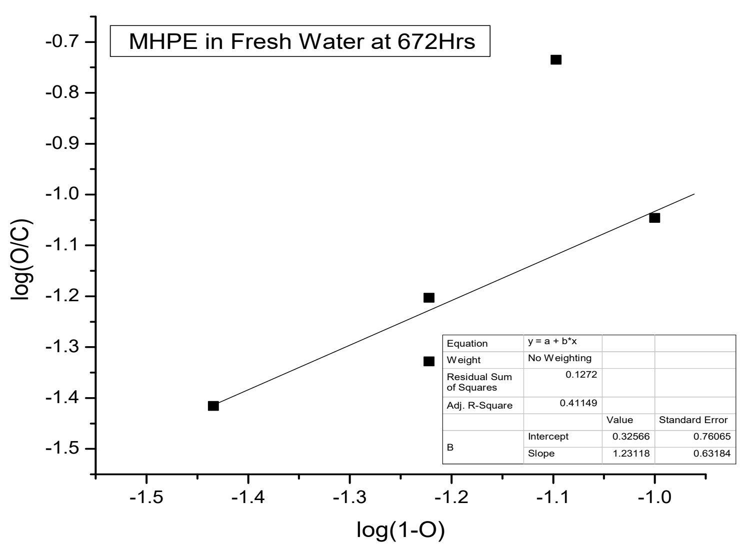




MHPE in Fresh Water at 336Hrs
log(O/C)
log(1-O)
-0.75
-0.80
-0.85
-0.90
-0.95
-1.00
-1.05
-1.10
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.03297
Adj. R-Square 0.5569
Value Standard Error
B Intercept -0.5526 0.1661
Slope 0.62611 0.25503



MHPE in Fresh Water at504Hrs
log(O/C)
log(1-O)
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
-1.10
-1.05
-1.00
-0.95
-0.90
-0.85
-0.80
-0.75
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.06513
Adj. R-Square 0.672
Value Standard Error
B Intercept 0.16795 0.44638
Slope 1.41847 0.46778



MHPE in Fresh Water at 672Hrs
log(O/C)
log(1-O)
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
-1.5
-1.4
-1.3
-1.2
-1.1
-1.0
Equation y = a + b*x
Weight No Weighting
Residual Sum of Squares 0.1272
Adj. R-Square 0.41149
Value Standard Error
B Intercept 0.32566 0.76065
Slope 1.23118 0.63184

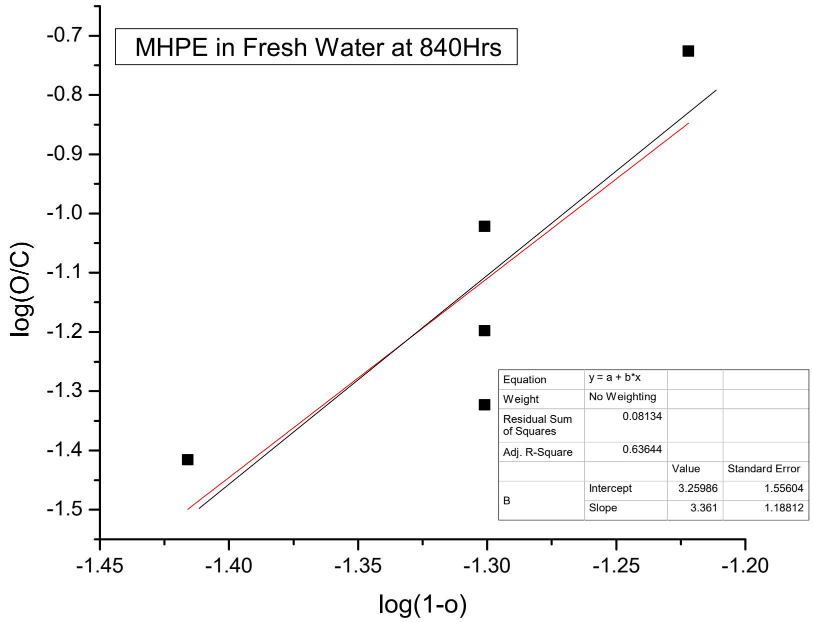


Fig.19: Flory-Huggins adsorption isotherm plot

FTIR Study of the Extract (MHPE)

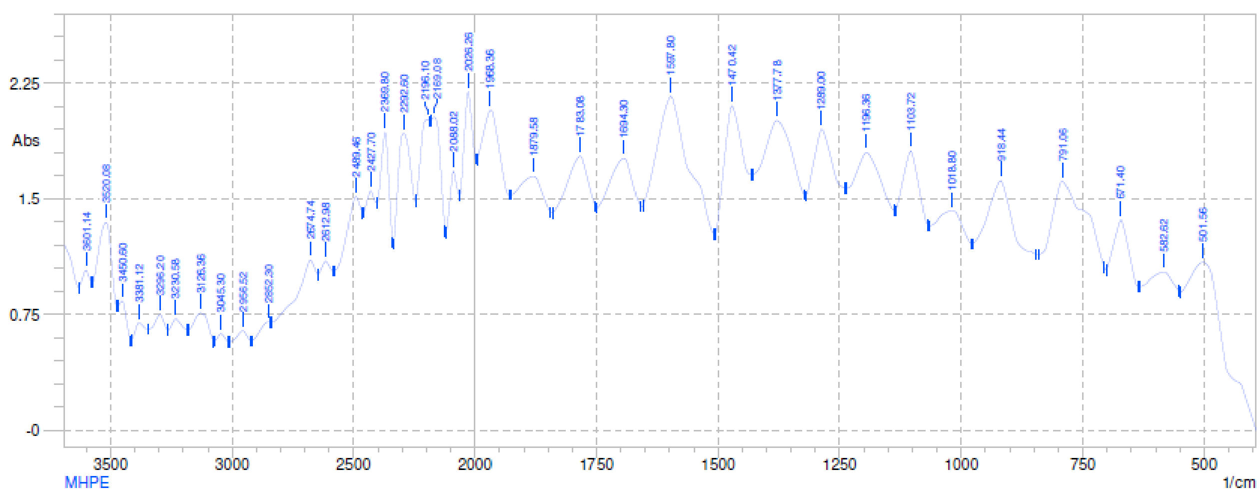


Fig.20: FTIR of MHPE

Table 4: FTIR Interpretation table of MHPE

Peak position cm-1	Peak Intensity	Assignment
3601.14 3520.08	Sharp, weak	O-H free of Alcohols, Phenols
3450.6 3381.12 3296.2 3230.58 3126.36	Medium, broad	O-H or N-H Stretch of Alcohols, Phenols, Amines, Acids, carboxylics
3045.3 2956.52	Sharp, strong	C-H of Alkenes, Arenes, Alkyl groups

2196.1 2169.08	Sharp, variable	C≡ or N≡ of Alkynes, nitriles
1783.08 1289 1196.36	Strong	C-O stretch of Acids, halides, esters, Anhydrides
1597.8	Medium, strong	N-H bond of Amines, Amides
1470.42	Variable	C=C of Arenes, Alkenes
1377.78	Medium	C-H Stretch of methyl
1103.72	Strong	C-Stretch of ethers
791.06	Strong	C-H bond of $RCH=CR_2$

FTIR Study of the corrosion product

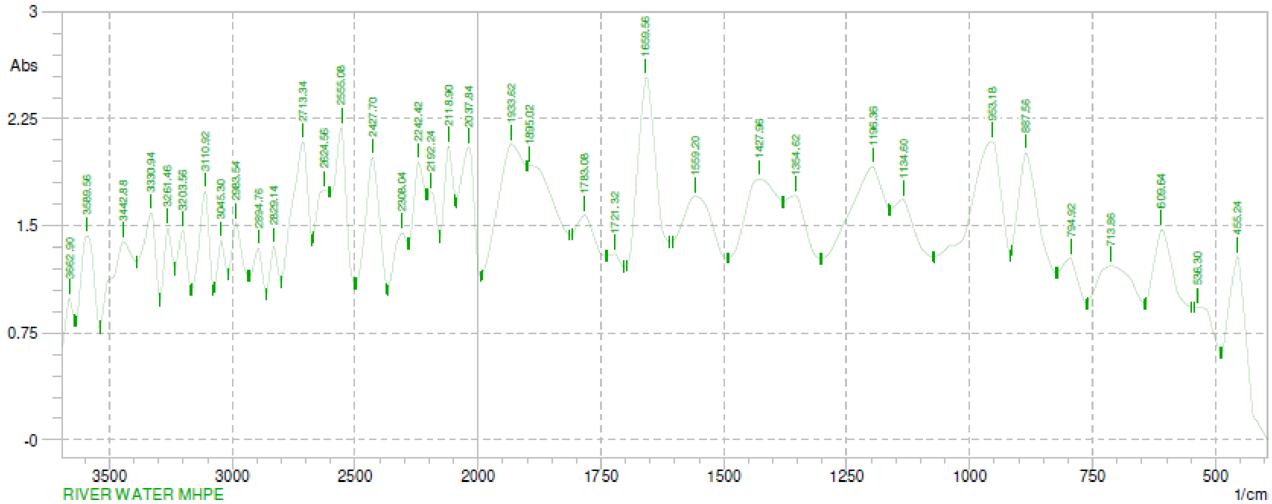


Fig.21: FTIR of Corrosion Product of River Water

Table 5: FTIR Interpretation table of MHPEin Fresh Water (River Water)

Peak position cm-1	Peak Intensity	Assignment
3662.9 3589.56	Sharp, weak	O-H free of Alcohols, Phenols
3442..88 3330.94 3261.46 3203.56 3110.92 2983.54	Medium, broad	O-H or N-H of Alcohols, Phenols, amines, acids, carboxylics
3045.3 2894..76 2829.14 2713.34	Medium, strong	C-H Stretch of Arenes, Akenes, Aldehydes, Alkyl
2242.42 2192.24	Sharp, variable	C≡ or N≡ of Alkynes, nitriles
1783.08	Very strong	C=O of Aldehydes, ketones, esters, acids
1659.56 1559.2	Quite variable	C=C of Alkenes, Arenes
1427.96	Strong	C-H bond of Alkyl groups

1196.36	Strong	C-O stretch of Acids, Esters, Anhydrides
1134.6	Strong	C-Stretch of ethers
794.92	Strong	C-H bond of $RCH=CR_2$

4. DISCUSSION

Corrosion Rate

The effectiveness of the extract is shown in fig1 to fig 10.As the concentration of the inhibitor increases; it reduces the rate of corrosion of the coupon in the corrosion environment with respect to time. The presence of compounds with complex structures in the extract is responsible for corrosion inhibition. The SEM, FTIR of the extract, corrosion product and adsorption parameters supports the fact.

Inhibitor Efficiency

Fig.11 to fig.15 shows the efficiencies of the extract in fresh water. Thus; the more the extract in the corrosion medium, the slower the corrosion rate

SEM

The SEM result shows the morphology of the surfaces of the coupon. The inhibited is less degraded as compared to the control.

Analysis of FTIR Spectra Test Result

Table 1 to table 4 above indicate the presence of the following (-OH,(Alcohols, Phenols), $-NH_2$, (Amines), -CHO, (Aldehyde) -COOH, (Carboxylics), $-NO_2$, (Nitriles), the corrosion product (River water+ MHPE). Corrosion inhibitor of organic origin in fresh water corrosive media decreases by prevents the reaction of the metal with the media.

Analysis of Adsorption Parameters

The adsorption site on the metal surface shows an evenly distributed identical and the maximum number of absorbed molecules per site is one, that means a monolayer adsorption and physisorption adsorption [1].

5. CONCLUSION

Corrosion behavior of mild steel in Fresh water with and without addition of *maize husk* polar extract (MHPE) for various exposing time at atmospheric temperature was studied. This result concludes that; the corrosion rate of mild steel decreases meaningfully with the increase of maize husk polar extract (MHPE) concentration. The inhibition efficiency (IE) of MHPE reaches to 96.5% at 840 hours in Fresh water. The prime efficiency of MHPE concentration is 25ML in fresh water at exposure of 840 hours.

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Conflict of Interest

The authors declare no conflicts of interests any matter related to this paper.

Data and materials availability

All related data have been presented in this paper.

Peer-review

External peer-review was done through double-blind method.

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