Original Research Article

CORROSION MITIGATION OF GRAY CAST IRON AND ALUMINUM IN NaOH USING WATER HYACINTH *(Eichhornia crassipes)* PLANT EXTRACT

ABSTRACT

This research focused on the corrosion behaviour of grey cast iron and aluminium in alkaline medium (0.5M NaOH) with and without inhibitor (water hyacinth *Eichhornia crassipes* extract) of varying concentrations of 5%, 10%, 15%, 20% and 25%. The corrosion rates of the metal samples were investigated using the weight loss and electrochemical methods alongside the formulation of a dispersant using readily available chemicals to develop a colloidal solution of the extract produced by hot water digestion of the water hyacinth plant leaves. The metallography tests of the As-received samples, as well as the most and least corroded samples, were carried out using Optical Microscope (OM). The results revealed that the aluminum weight loss result in minimum corrosion rate of 0.000483 $mg/mm^2/yr$ with inhibitor efficiency of 98.93% obtained for sample A5 (25% extract) while for the grey cast iron, a minimum corrosion rate of -4.4E-05 $mg/mm^2/yr$ with inhibitor efficiency of 566.6% obtained for sample C3 (15% extract). The electrochemical result of aluminium showed an increase in corrosion potential from -1.494 VAg/AgCl to -1.482 V Ag/AgCl and that of grey cast iron from -0.5436 VAg/AgCl to -0.2839 VAg/AgCl upon the increase in inhibitor concentration. In conclusion, the use of water hyacinth *(Eichhornia crassipes)* extract controlled the corrosion or dissolution rate of grey cast iron and aluminium in (NaOH) sodium hydroxide medium.

Keywords: Microstructure, Corrosion inhibition, Water hyacinth *(Eichhornia crassipes),* Gray cast iron, Aluminum and NaOH.

1. INTRODUCTION

A material's integrity in relation to the prevailing service condition over time is questionable if its interaction with the environment cannot be controlled. Most materials exercise some type of interaction with a large number of diverse environments. Often, due to such interactions, the material's usefulness is impaired as a result of the deterioration of its mechanical properties (such as ductility and strength), other physical properties, or appearance. In metals, this loss in material's usefulness is either by dissolution or by the formation of non-metallic scale or film (Callister, 2007). As part of our everyday encounter with this form of material degradation, corrosion can cause plant shutdown, contamination of the product, reduction in components efficiency, costly maintenance, waste of valuable resources and expensive overdesign (Ahmed). The corrosion of grey cast iron and aluminium is a spontaneous process, which can compromise the materials integrity and impacts assess, environment, economic, social, and people if no measure is implemented to control it(Makar et al., 2001, Ashassi-Sorkhabi et al., 2005). Due to these harmful effects, corrosion is a detrimental phenomenon that ought to be prevented (Buchweishaija, 2009).

According to Kulkarn, (2015), the use of inhibitors for corrosion control of metals and alloys which are in contact with an aggressive environment is one among the acceptable methods and practices used to reduce or prevent corrosion. Inhibitors are substances when added in moderate concentrations to an environment, effectively reduces the corrosion rate of a metal exposed to that environment(Raja and Sethuraman, 2008). However, green inhibitors or organic inhibitors are more eco-friendly and harmless plants whose extracts have the capacity to prevent the corrosion of materials when introduced into the environment where the metal in service is subjected(Abdel-Gaber et al., 2008). Chauhan and Gunasekaran (2007), established that organic substances containing polar functions with oxygen, nitrogen and/or sulphur atoms in a conjugate system reported exhibiting the good inhibiting properties.

Water hyacinth *(Eichhornia crassipes)* whose extract was used as a corrosion inhibitor is an aquatic plant that lives and reproduces by floating freely on the surface of freshwater. The possible corrosion inhibition characteristics of green inhibitors have been investigated and concluded that the plant extract settles to give a two-phase solution in which the bottom is rich in the water hyacinth extract and the top is deficient of this corrosion inhibitive extract (Oloruntoba et al., 2012, Orhorhoro et al., 2017). In previous researches, no account has been given to how to keep this plant extract in suspension. Part of this research objective is to develop an organic inhibitor as the plant extract and formulate a solution with the extract that would keep it in suspension throughout its use under the prevailing service conditions. The interaction between aluminium and sodium hydroxide solution has not been a positive result as the former dissolves in the later. The combination of uses of aluminium and cast iron is established in the car engine system. The mitigation of corrosion of aluminium and *Gray* cast iron inhibited with water hyacinth plant extract in 0.5M NaOH is under investigation in this study.

2. EXPERIMENTAL SET-UP

2.1 Materials

Grey cast iron used for the investigation was obtained from the Foundry workshop at the Federal University of Technology, Akure. The elemental composition of the substrate was carried out by spark analysis as shown in Table 1. It is reflected that the material is insufficient of alloy component necessary to resist corrosion. The carbon content is in the range 2.1 - 4.3%, therefore the iron is gray cast iron. Table 2 shows the chemical composition of the as-received aluminium sample used for the study which also shows that the alloy is sufficient of alloying elements required to resist corrosion tendencies. The principal alloying elements are Magnesium and silicon making it a 6xxx series aluminium alloy and in this case

6063. Gray cast iron without any protection is highly susceptible to corrosion in alkaline environments (Kadhim, 2018) and aluminium would suffer severe dissolution if used to transport these alkaline fluids especially caustic soda (NaOH) without any protection.

2.2 Methods & Sample Preparation

The grey cast iron samples were cut to form different coupons of dimensions of thickness ranging from 3-5mm, length ranging from 11-13mm and breadth ranging from 10-11mm. While the aluminium samples were also cut into different couples of dimensions of thickness ranging from 8-9mm, length of 10mm and breadth ranges from 8-10mm using digital vernier calliper. Each coupon was polished mechanically using SiC emery paper (60, 120, 180, 220, 320, 400, 600, 800, 1200 grits) to obtain a mirror-like surface suitable for weight loss test and the polarization test. Accurate weight of samples was taken using the chemical weighing balance.

2.3 Preparation of Water Hyacinth *(Eichhornia crassipes)* Inhibitor Extract

Freshwater hyacinth (*Eichhornia crassipes*) was harvested as the whole adult plant from Igbokoda River in Okitipupa, Nigeria. The leaves of the water hyacinth plant were plucked and placed inside an oven for drying at a temp of 70^{o}C for 5 hours. The dried leaves were then pulverized to very fine particles using a mechanical grinding machine. The physical hyacinth leaves have to be dried and ground to powder to give room for large surface area for extraction of higher concentration of active ingredients responsible for corrosion inhibition. 5g, 10g, 15g, 20g and 25g each of the pulverized *Eichhornia crassipes* leaves were measured into 5 different beakers containing 500 ml of distilled water and were placed inside a water bath at a temperature of 60^{o}C for 5 hours. The aqueous solution in each beaker was filtered, decanted and excess water allowed to evaporate to 100 ml of filtrate following the method of Singh et al. (2010). These extracts contain many ingredients as shown in Table 3. They contain several organic compounds which have polar atoms such as O, N, P and S. They are adsorbed onto the surface through these polar atoms; protective films are formed. Adsorptions of these ingredients obey various adsorption isotherms.

2.4 Preparation of dispersant for water hyacinth extract colloidal solution

Table 4shows the number of chemicals per 50 cl of distilled water for preparing dispersants. Chemicals were obtained from Pascal venture, Akure, Nigeria. These chemicals include nitrosyl, caustic soda, sulphuric acid, texapol, SLS (sodium laurel sulphate), soda ash, STPP(bleaching agent), perfume, colour. Each of these chemicals was prepared separately and tested to determine the best dispersant for the water hyacinth leave extract. Solvents such as alcohol, acid, water have been used to extract the ingredient present in the plant material (Oloruntoba el at., 2015). From the observed properties in Table 4, caustic soda shows the best properties as a dispersant. It is considered that any dispersant used should be of moderate viscosity so as to have the capacity to keep the dispersed phase in suspension and fully dispersed. In addition, the dispersant should not involve in any interaction with the containing chamber which in turn is dependent on the chamber material makeup. Therefore, caustic soda was used as a dispersant for the formulation of water hyacinth leave extract colloidal solution used in this research.

2.5 Corrosion rate calculation by weight loss method

Grey cast iron and aluminium samples were immersed into plastics containing 100 ml of 0.5M NaOH with no inhibitor added to it; these serve as the control experiment. The prepared 30 ml, 40 ml, 50 ml, 60 ml, 70ml were poured into plastic containers containing 0.5M NaOH corrosive media each and the samples were immersed. The initial weight of the samples was taken before immersion and the corresponding weights were taken at an interval of three days using the digital electronic weighing balance. The weight losses were recorded and the cumulative weight loss was calculated. The corrosion rate was determined as:

$$R = W/A(T/365) \quad (1)$$

Where R is the corrosion rate (mg/mm^2/year), W, Weight loss, A, Area of the specimens (mm^2), T/ 365 is exposure time in days extrapolated to year.

2.6 Electrochemical Measurement

The electrolyte used for this study was 0.5M NaOH solution with varying concentrations (5%, 10%, 15%, 20%, 25% v/v) of the extract and without extract. Prior to the electrochemical test, an insulated copper wire was attached to the specific surface area before cold mounting in an epoxy resin. The samples were polished with different grits of emery paper until the surface became smooth. The embedded metal sample was used as the working electrode; the reference electrode was Ag/AgCl, while the counter electrode was a platinum rod. This test was carried out using a three-electrode cell assembly at room temperature with the AUTO LAB PGSTAT 204N instrument. The open-circuit corrosion potential was carried out for 30 minutes until a stable potential was attained. The electrochemical parameters such as the corrosion potential (*Ecorr*) and corrosion current density (*Icorr*) were calculated by analyses of the Tafel region using the General Purpose Electrochemical Software (GPES). The potentiodynamic polarization study was carried out to determine the current density, corrosion rate and inhibition efficiency (IE%). The inhibition efficiencies (IE) of Water Hyacinth *(Eichhornia crassipes)* added was determined by using equation (2):

$$IE\% = \left(1 - \frac{CRinh}{CRblank}\right) \times 100 \quad (2)$$

Where: CRinh, represents corrosion rate with inhibitor while CR_{blank} represents corrosion rate without inhibitor.

2.7 Surface Analysis and Characterization

The variation in the surface of the metal was analyzed on the As-received substrates (Gray cast iron and aluminium) as well as corroded samples by optical microscopy (OM) of model number 702907. Both grey cast iron and aluminium substrates were carefully ground progressively through various grinding emery paper of degreasing coarseness; 600µm, 800µm, 1000µm, 1200µm grit sizes. Grey cast iron and aluminium specimens of size 10 mm × 10 mm × 5mm immersed in 0.5M NaOH for 30 days in normal condition in absence of inhibitor and the specimen exposed at optimum concentrations of inhibitor were considered for optical microscopic analysis using the least and most corroded samples.

3. Results and Discussion

3.1 Corrosion rate of Aluminum in sodium hydroxide environment (0.5M NaOH)

Figure 1 represents the interaction graph between the corrosion rate and exposure time in days on the corrosiveness of the aluminium (Al) sample in the caustic soda environment. Observed from Figure 1, the corrosion reactivity of sodium hydroxide on the aluminium samples tends to reduce at higher concentration (25%) of the water hyacinth inhibitor. This could be as a result of the cations present in the water hyacinth leave composition as shown in Table 3. The cations react with the hydroxide ions from the environment (NaOH) to form protective layers on the metal substrate (Oloruntoba et al., 2017). From Table 5 it could be observed that the control sample (A) could only last for 9 days due to the harsh effect of sodium hydroxide on aluminium. While sample A1 with 5% inhibitor concentration could only last for 21 days (Table 6), however as the inhibitor concentration increases as shown in Table 6 - 9, the number of days before complete dissolution increased and this depicts an increase in the efficiency of the extract on the dissolution rate of aluminium in sodium hydroxide. Sample A3 with an inhibition concentration of 15% experienced a slight increase in corrosion rates between day 6 and day 9 from 0.005955mg/mm^2/yr to 0.009479mg/mm^2/yr and also between day 12 and day 15 as well as day 21 and 24. This could be as a result of continuous formation and breakage of the protective film layers deposited on the surface of the metal on account of the inhibitor action and withdrawn of samples for measurement at three days interval. As recorded in Figure 1, the maximum corrosion rate experienced by the aluminium alloy was 0.3302mg/mm^2/yr (without inhibitor) and the minimum corrosion rate was 0.0004830mg/mm^2/yr (with 25% concentration of water hyacinth leave extract) giving a maximum inhibitor efficiency of 99.5259% after 6 days for sample A5 with an inhibitor concentration of 25%. Therefore increasing the inhibitor concentration decreases the corrosion or dissolution rate of the metal to a great extent(Oloruntoba et al., 2012).

3.2 Corrosion rate of Gray cast iron in sodium hydroxide environment (0.5M NaOH)

Figure 2 shows the corrosion rate of grey cast iron in 0.5M NaOH against exposure time in a day and in the presence of a different concentration of water hyacinth leave extract. Figure 2reveals that the corrosion rate of grey cast iron in 0.5M NaOH decreases with increase in the concentration of the extract. The observed result predicts that upon the increase in the inhibitor concentration, there is an equivalent increase in the number of adsorption of the extract constituents on the surface of the grey cast iron which prevented the rapid dissolution of Fe^{+2} into the solution. Table 10 – 14 shows the result of weight loss in 0.5M NaOH, however, samples C3 and C4 from 12 and 13 respectively experienced gain in weight which could be on account of the tenacious adherence of the caking action of the caustic soda and film formation on the metal substrate. This further validates that the increase in inhibitor concentration reduces the corrosion or dissolution rate of the metal in 0.5M NaOH environment (Kadhim, 2018).

3.3 Potentiodynamic polarization measurement for Aluminum samples

Figure 3 shows the cathodic and anodic polarization curves of aluminium immersed in 0.5M NaOH with and without the inhibitor at varying concentrations. It could be observed that the aluminium sample immersed in 0.5M NaOH with 25% concentration of extract has the maximum corrosion potential of -1.482 VAg/AgCl and current density 3.3950E-04 A/cm^2. Whereas, the aluminum sample with 10% extract inhibitor displayed a corrosion potential of -1.484 VAg/AgCl and current density of 4.2450E-04 A/cm^2. The aluminium sample in the control caustic medium displayed the least corrosion potential value of -1.494 V with the highest current density 1.2690E-03 A/cm^2. The lower the corrosion potential, the higher the corrosion rates as indicated by the current density. The electro-potential values for the aluminium samples in the 0.5M NaOH solution increase from the control (no inhibitor) -1.494 V to -1.482 V for the 25% concentration of the water hyacinth leave extract addition. The increase in the corrosion potential with the increase in the inhibitor concentration is an indication that the water hyacinth leave extract is effective to curb the corrosion or dissolution rate of aluminium in the caustic soda medium and this further supports the weight loss result. Table 15 showed that at 25% concentration of inhibitor the inhibitor efficiency reaches a percentage value of 90.7%. This also validates its effect on the corrosion reduction tendencies on aluminium immersed in 0.5M NaOH solution.

3.4 **Potentiodynamic polarization measurement for Gray cast iron samples**

Figure 4 displays the cathodic and anodic polarization curves of grey cast iron immersed in 0.5M NaOH solution with and without the inhibitor at various concentration. From observation, grey cast iron sample immersed in 0.5M NaOH with 25% concentration of water hyacinth leave extract has the maximum corrosion potential of -0.28386 V Ag/AgCl and current density of 1.1440E-08 A/cm2. Whereas the sample with 5 % extracts inhibitory concentration showed corrosion potential of -0.49992 VAg/AgCl and current density of 2.2138E-07 A/cm^2. The control (without inhibitor) in alkaline medium displayed the least corrosion potential value of -0.543643 V Ag/AgCl and the highest current density of 3.7130E-07 A/cm^2. Also, the values of the electro-potential for the grey cast iron samples in the alkaline solution increases from -0.543643 V to -0.28386 VAg/AgCl for the 25% water hyacinth leave extract inhibitor addition. Considering the increase in the corrosion potential with a proportionate increase in the inhibitor concentration, the water hyacinth leave extract is effective to resist the corrosion of grey cast iron in the alkaline medium (NaOH). Table 16 showed that at 25% concentration of inhibitor the inhibitor efficiency reaches a percentage value of 95.8%. This validates the effect of water hyacinth leaves extracts on the corrosion reduction tendencies on grey cast-iron immersed in 0.5M NaOH solution. The serrated curve observed for grey cast iron sample C5 from Figure 4 could be as a result of the continuous formation and breakage of a tenacious coating on the metal substrate leading to fluctuations in the anodic and cathodic parameters (Arockiasamy et al., 2010).

3.5 Metallography Results for Aluminum and Gray cast iron Samples

The results from the metallography test using an optical microscope (OM) indicates the microstructure of the control samples, the least and most corroded samples. Plate 1 and 2 displays the micrographs of the as-received aluminium sample at x100 and x400 magnifications. From the plates 1 and 2, the aluminium sample displays a possible microstructure of iron-rich phase (light regions) and undissolved Mg_2Si (dark regions) and some Mg_2Si re-precipitating. This is in line with the findings of Monteiro et al. (2011). Having an intermetallic phase in its microstructure could be a limiting factor in its resistance to corrosion. This is as a result of the possibility of the intermetallic phase acting cathodically to the actual aluminium base metal. Also, from Plate 4 and 5, it could be observed that the aluminium sample A2 (most corroded) with inhibitor concentration of 5% in the 0.5M NaOH solution had suffered from severe microstructural deformities on account of the corrosive environment. However, upon increasing the concentration of the water hyacinth leave extract as an inhibitor (25%), the formation of a tenacious protective film on the metal surface as shown in Plate 5 and 6 reducing the rate of attack of the metal from the alkaline medium were observed. This further supports the claim that upon the increase in inhibitor concentration, there is an equivalent decrease in the corrosion rate.

Plate 7 and 8 represent the micrographs of the As received grey cast iron. Observed from Plate 7 and 8, the grey cast iron is probably composed of a matrix of pearlite and ferrite embedded with graphite flakes. Plate 9 and 10 shows the microstructure of the most corroded sample C (no inhibitor) and this corrosion tendency is on account of the graphite flakes behaving cathodically to the matrix in the alkaline medium (Kadhim, 2018). However, upon the increase in the inhibitor concentration and exposure time, the grey cast iron experienced a reduction in corrosion rate to a great extent as shown by Plate 11 and 12. This also supports the premise that upon the increase in water hyacinth leave extract as an inhibitor, there is a proportionate decrease in the corrosion rate as a consequence of adsorption of molecules to the surface of the cast iron.

CONCLUSION

The comparative studies carried out on water hyacinth leave extract on the corrosion behaviour of inhibited and uninhibited aluminium and grey cast iron in 0.5M NaOH environment was investigated and the following conclusions were drawn from the results:

- With percentage range of inhibitor (water hyacinth leave extract) concentration used, increasing the inhibitor concentration led to an equivalent decrease in both the cathodic hydrogen evolution reactions and anodic dissolution of aluminium and grey cast iron.

- The effect of inhibitor efficiency was well pronounced for grey cast iron with a maximum inhibitor percentage efficiency of 566.6%.
- The formation of a thin tenacious layer on the metal surface prevented the rapid dissolution of the metals. This was due to the adsorption of the phytochemical constituents of the extract on the surface of the metals
- Caustic soda can be used to keep the water hyacinth leave extract in colloidal form.
- Water hyacinth leave extract could be used in manufacturing plants especially paper producing plants to depress the dissolution rate of transporting medium made of aluminium for transporting corrosive fluid, especially caustic soda.

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FIGURES

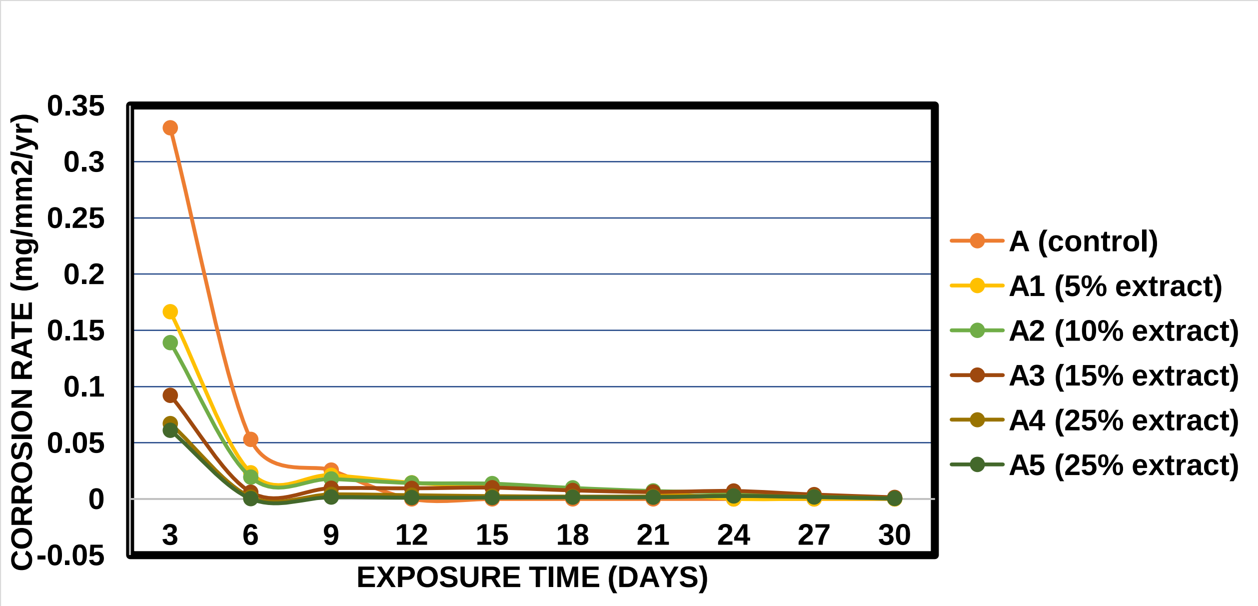


Figure 1: Plot of corrosion rate against exposure time for Aluminum samples immersed in 0.5M NaOH with or without water hyacinth extract as inhibitor.

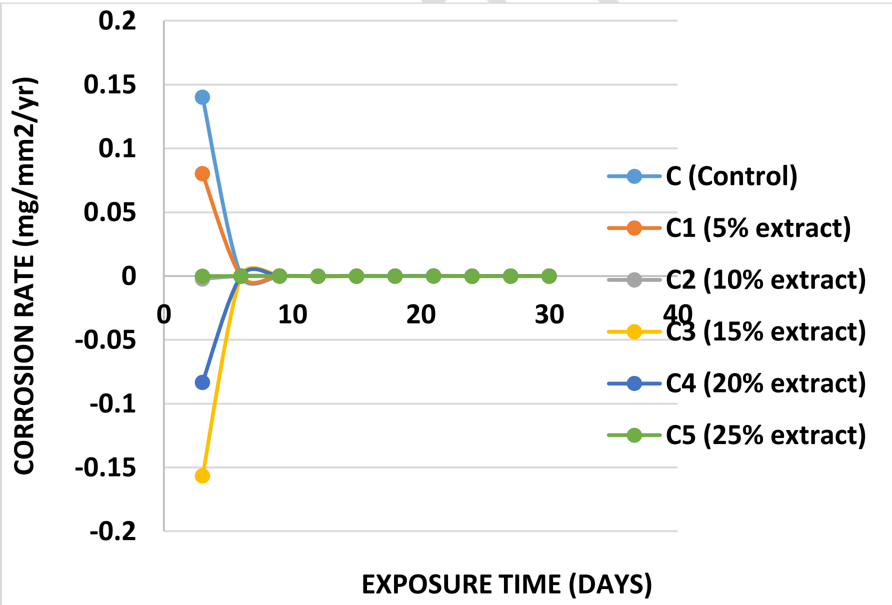


Figure 2: Plot of corrosion rate for gray cast iron samples immersed in 0.5M NaOH with or without water hyacinth extract as inhibitor

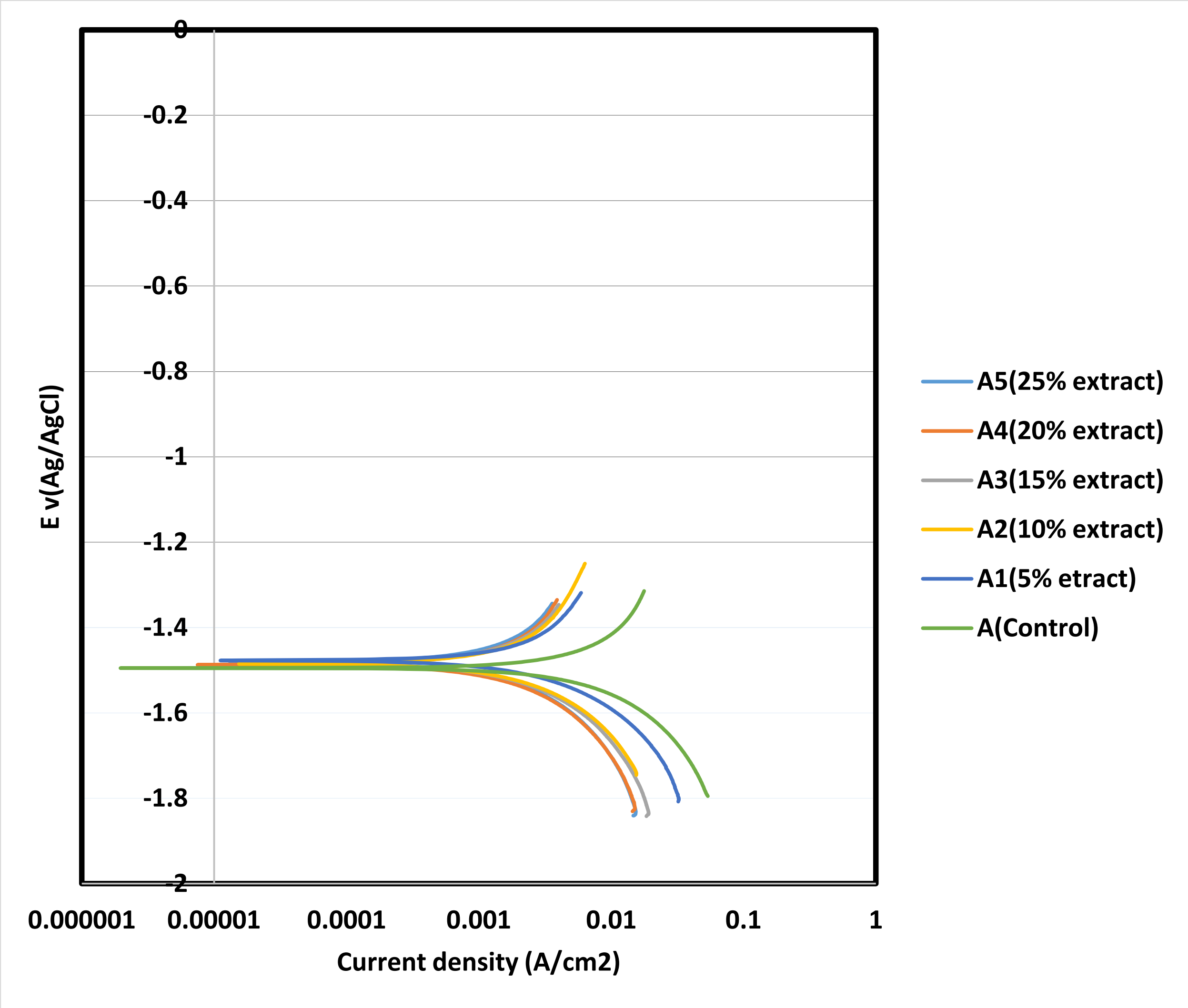


Figure 3: Potentiodynamic polarization curves for Aluminum samples immersed in 0.5M NaOH with and without water hyacinth leave extract as inihibitor

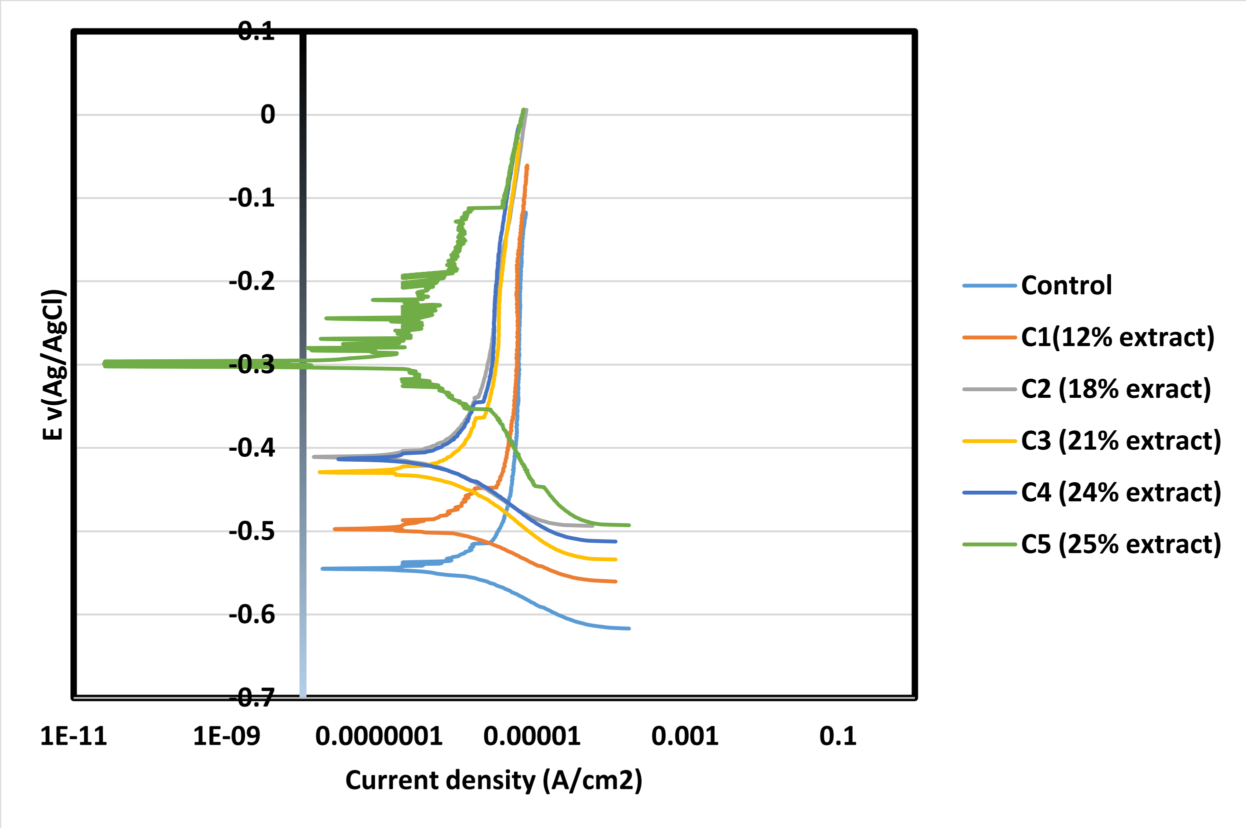
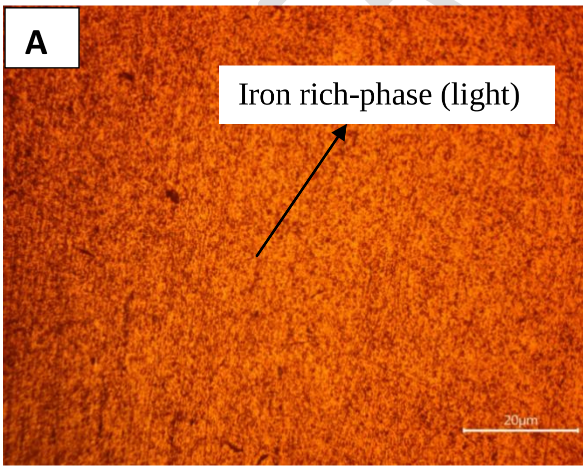


Figure 4: Potentiodynamic polarization curves for gray cast iron samples immersed in 0.5M NaOH with and without water hyacinth leave extract as inhibitor

PLATES



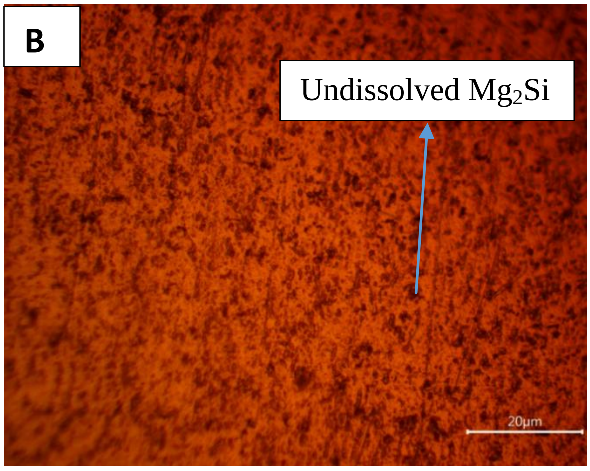


Plate 1 (A) As received Aluminum (x100) **Plate 2 (B) As received Aluminum (x400)**

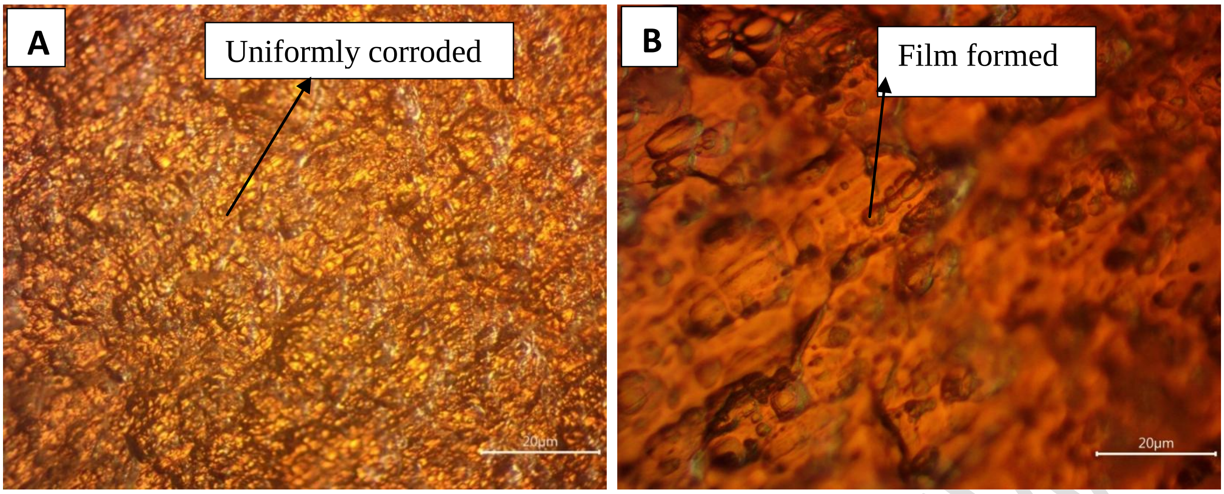


Plate 3 &4: Aluminum most corroded sample A2 at (x100) and (x400) magnifications

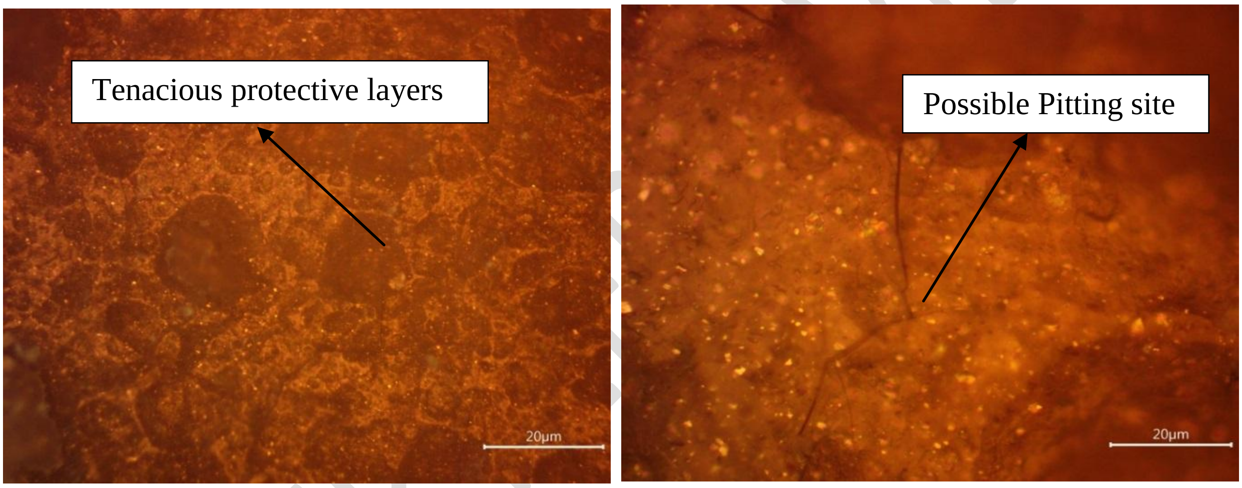


Plate 5&6: Aluminum least corroded sample A5 at (x100) and (x400) magnifications

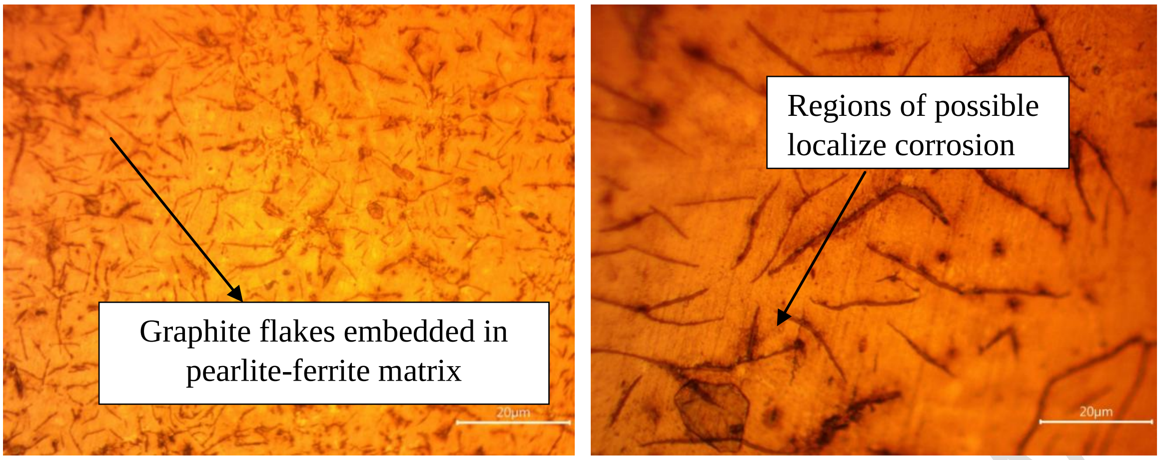


Plate 7 and 8: As received gray cast iron (x100) and (x400) magnifications

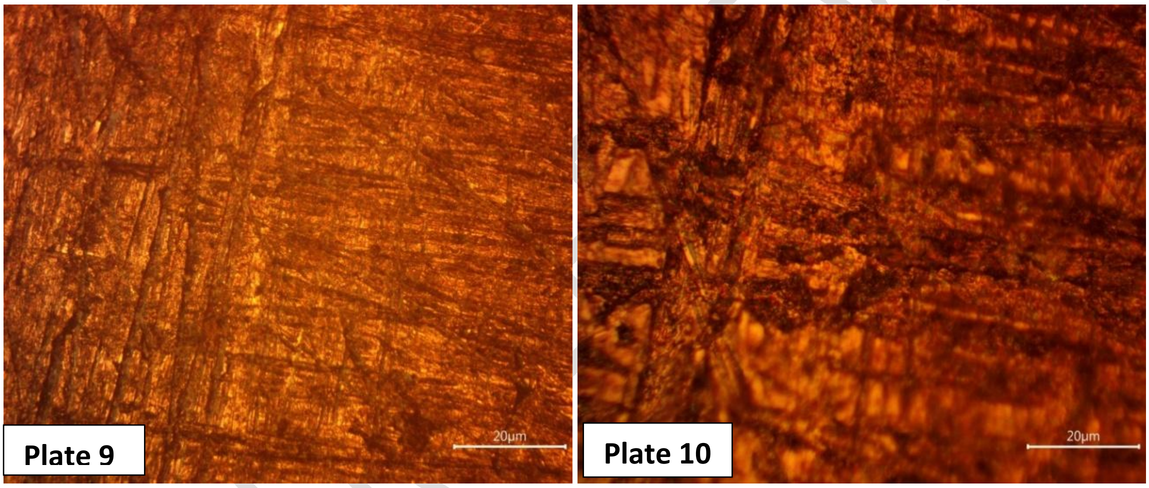


Plate 9 & 10: Gray cast iron most corroded sample Cat (x100) and (x400) magnifications

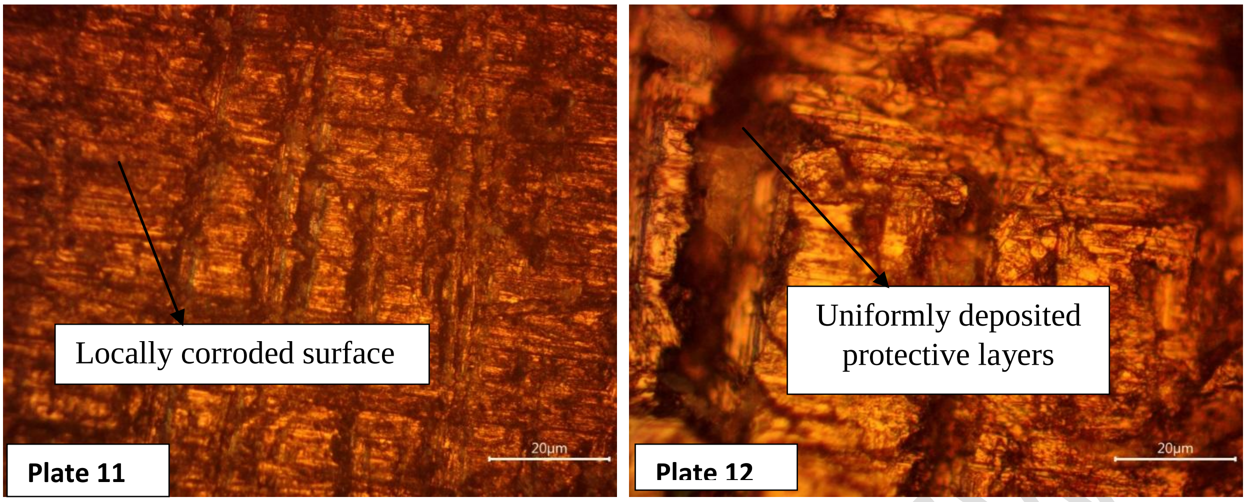


Plate 11& 12: Gray cast iron least corroded sample C3 at (x100) and (x400) magnifications

Table 1. Elemental composition (wt %) of the procured aluminum substrate

Element	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Ni**
Composition (weight %)	98.64	0.5168	0.0126	<0.0002	0.0167	0.4637	<0.0024	<0.0048
Element	**Ti**	**Be**	**Ca**	**Pb**	**V**	**Zr**	**Sn**	Zn
Composition (weight %)	0.0145	<0.0001	<0.0000	<0.0011	<0.0058	0.0033	<0.0073	<0.0085

Table 2. Elemental composition (wt %) of the procured gray cast iron substrate

Element	**C**	**Si**	**Cu**	**P**	**S**	**Cr**	**Mo**	**Ni**
Composition (weight %)	4	2.58	0.46	0.033	0.044	0.20	0.004	0.025
Element	**V**	**N**	**B**	**Al**	**Ti**	**Ca**	**Fe**	Co
Composition (weight %)	0.004	0.04	0.003	0.005	0.014	0.001	91.8	0.007

Table 3: Elemental composition of water hyacinth plant (Oloruntoba *et al*., 2012)

Elements	Nitrogen	Chloride	Potassium	Sodium	Calcium	Total
Amount	5.068 mg/L	124.25 mg/L	784.428 mg/L	364.57 mg/L	180 mg/L	1461.316

Table 4 Amount of chemicals per 50 cl of distil water for preparing dispersants

Chemicals	Nitrosol	Texapol	Caustic soda	Soda ash	STPP	Sulphuric acid	SLS	Colour	Perfume
Amount	3.47g	4.63g	3.27	15.65g	4.43g	34.47g	1.86g	0.54g	1.52g

Table 5: Weight Loss and Corrosion Rate of Aluminum sample A (Control)

SAMPLE A (Total surface area = 560mm^2)				
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)
0	2.4855	-	-	-
3	0.9658	1.5197	1.5197	0.330173
6	0.4784	0.4874	2.0071	0.052947
9	0.1235	0.3539	2.3620	0.025630
TOTAL WEIGHT LOSS		2.3620		

Table 6: Weight Loss and Corrosion Rate of Aluminum sample A1 in 0.5M NaOH

SAMPLE A1 (Total surface area = $560mm^2$)					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE ($mg/mm^2/yr$)	INHIBITOR EFFICIENCY (%)
0	2.1308	-	-	-	
3	1.4190	0.7118	0.7118	0.166543	49.55887
6	1.2206	0.1984	0.9102	0.023210	56.16371
9	0.9512	0.2694	1.1796	0.021011	18.0218
12	0.7062	0.2450	1.4246	0.014331	74.2431
15	0.4748	0.2314	1.6560	0.010828	67.2331
18	0.2413	0.2335	1.8895	0.009106	50.8214
21	0.0724	0.1689	2.0584	0.005645	30.0042
TOTAL WEIGHT LOSS		2.0584			

Table 7: Weight loss and corrosion rate of Aluminum sample A2 in 0.5M NaOH

SAMPLE A2 (Total surface area = 448mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	1.9742	-	-	-	
3	1.4622	0.5120	0.5120	0.139048	57.88632
6	1.3193	0.1429	0.6549	0.019404	63.35203
9	1.1232	0.1961	0.8510	0.017752	30.73742
12	0.9139	0.2093	1.0603	0.01421	81.3657
15	0.6628	0.2511	1.3114	0.013639	72.5243
18	0.4450	0.2178	1.5292	0.009858	67.1394
21	0.2614	0.1836	1.7128	0.007123	58.7416
24	0.0929	0.1685	1.8813	0.005720	35.5394
27	0.0246	0.0683	1.9496	0.002061	26.4801
30	0.0122	0.0124	1.9620	0.000337	49.5935
TOTAL WEIGHT LOSS		1.9620			

Table 8: Weight loss and corrosion rate of Aluminum sample A4 in 0.5M NaOH

SAMPLE A4 (Total surface area = 560mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	2.3957	-	-	-	
3	2.0873	0.3084	0.3084	0.067004	79.7064
6	2.0718	0.0155	0.3239	0.001684	96.8195
9	2.0158	0.0560	0.3799	0.004056	84.1748
12	1.9541	0.0617	0.4416	0.003351	96.9392
15	1.8952	0.0589	0.5005	0.002559	96.9858
18	1.8365	0.0587	0.5592	0.002126	96.9027
21	1.7633	0.0732	0.6324	0.002272	96.0142
24	1.6602	0.1031	0.7355	0.002800	94.1530
27	1.5730	0.0872	0.8227	0.002105	94.7476
30	1.5399	0.0331	0.8558	0.000719	97.8957
TOTAL WEIGHT LOSS		0.8558			

Table 9: Weight loss and corrosion rate of Aluminum sample A5 in 0.5M NaOH

SAMPLE A5 (Total surface area = 484mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	2.3257	-	-	-	
3	2.0829	0.2428	0.2428	0.061034	81.5145
6	2.0809	0.0020	0.2448	0.000251	99.5259
9	2.0611	0.0198	0.2646	0.001659	93.5271
12	2.0425	0.0186	0.2832	0.001169	99.0976
15	2.0188	0.0237	0.3069	0.001192	98.8397
18	1.9821	0.0367	0.3436	0.001538	98.1821
21	1.9399	0.0422	0.3858	0.001515	97.8709
24	1.8559	0.0840	0.4698	0.002639	95.6699
27	1.7948	0.0611	0.5309	0.001707	96.7077
30	1.7756	0.0192	0.5501	0.000483	98.9302
TOTAL WEIGHT LOSS					

Table 10: Weight loss and corrosion rate Gray cast iron sample C1 in 0.5M NaOH

SAMPLE C1 (Total surface area = 490mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	4.7558	-	-	-	
3	4.1912	0.5646	0.5646	0.14019	174.5828
6	4.1912	0.0000	0.5646	0.0000	100
9	4.1908	0.0004	0.5650	3.31E-05	61.0130
12	4.1917	-0.0009	0.5641	-5.6E-05	49.0909
15	4.1914	0.0004	0.5645	1.99E-05	29.6820
18	4.1907	0.0007	0.5652	2.9E-05	207.5290
21	4.1898	0.0009	0.5661	3.19E-05	62.4264
24	4.1915	-0.0017	0.5644	-5.3E-05	34.5679
27	4.1922	-0.0007	0.5637	-1.9E-05	118.7500
30	4.1926	-0.0004	0.5633	-9.9E-06	87.9268
TOTAL WEIGHT LOSS		0.5633			

Table 11: Weight loss and corrosion rate of Gray cast iron sample C2 in 0.5M NaOH

SAMPLE C2 (Total surface area = 494mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	4.7482	-	-	-	
3	4.7573	-0.0091	-0.0091	-0.00224	102.7895
6	4.7572	0.0001	-0.0090	1.23E-05	78.2686
9	4.7570	0.0002	-0.0088	1.64E-05	80.6832
12	4.7574	-0.0004	-0.0092	-2.5E-05	77.2727
15	4.7572	0.0002	0.0090	9.85E-06	65.1944
18	4.7564	0.0008	-0.0082	3.28E-05	247.8260
21	4.7554	0.0010	-0.0072	3.52E-05	58.5395
24	4.7567	-0.0013	-0.0085	-4E-05	50.6173
27	4.7577	-0.0010	-0.0095	-2.7E-05	168.7500
30	4.7572	0.0005	-0.0090	1.23E-05	115.0000
TOTAL WEIGHT LOSS		-.0090			

Table 12: Weight loss and corrosion rate of Gray cast iron sample C3 immersed in 0.5M NaOH

SAMPLE C3 (Total surface area = 460mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	4.1580	-	-	-	
3	4.7498	-0.5918	-0.5918	-0.15653	294.9315
6	4.7509	-0.0011	-0.5929	-0.00015	365.0177
9	4.7496	0.0013	-0.5916	0.000115	135.4535
12	4.7505	-0.0009	-0.5925	-6E-05	45.4546
15	4.7487	0.0018	-0.5907	9.52E-05	236.3960
18	4.7497	-0.0010	-0.5917	-4.4E-05	566.5960
21	4.7482	0.0015	-0.5902	5.67E-05	33.2156
24	4.7498	-0.0016	-0.5918	-5.3E-05	34.5679
27	4.7501	-0.0003	-0.5921	-8.8E-06	45.0000
30	4.7494	0.0007	-0.5914	1.85E-05	122.5610
TOTAL WEIGHT LOSS		-0.5914			

Table 13: Weight loss and corrosion rate of Gray cast iron sample C4 in 0.5M NaOH

SAMPLE C4 (Total surface area = 372mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	3.9041	-	-	-	
3	4.1587	-0.2546	-0.2546	-0.08327	203.6986
6	4.1586	0.0004	-0.2542	6.54E-05	115.5477
9	4.1580	0.0006	-0.2536	6.54E-05	22.9682
12	4.1592	-0.0012	-0.2548	-9.8E-05	10.9091
15	4.1597	-0.0005	-0.2553	-3.3E-05	216.6078
18	4.1593	0.0004	-0.2549	2.18E-05	1131.1770
21	4.1570	0.0023	-0.2526	0.000107	126.0306
24	4.1588	-0.0018	-0.2544	-7.4E-05	8.6420
27	4.1586	0.0002	-0.2542	7.27E-06	145.4375
30	4.1583	0.0003	-0.2539	9.81E-06	111.9634
TOTAL WEIGHT LOSS		-0.2539			

Table 14: Weight loss and corrosion rate of Gray cast iron sample C5in 0.5M NaOH

SAMPLE C5 (Total surface area = 462mm^2					
DAYS	WEIGHT (g)	WEIGHT LOSS (g)	CUMMULATIVE WEIGHT LOSS (g)	CORROSION RATE (mg/mm^2/yr)	INHIBITOR EFFICIENCY (%)
0	4.9891	-	-	-	
3	4.9893	-0.0002	-0.0002	-5.3E-05	1.00E+00
6	4.9896	-0.0003	-0.0005	-4E-05	1.71E+00
9	4.9891	0.0005	0.0000	4.39E-05	4.83E-01
12	4.9897	-0.0006	-0.0006	-4E-05	6.36E-01
15	4.9905	-0.0008	-0.0014	-4.2E-05	2.48E+00
18	4.9893	0.0012	-0.0002	5.27E-05	4.59E+00
21	4.9878	0.0015	0.0013	5.64E-05	3.36E-01
24	4.9890	-0.0012	0.0001	-4E-05	5.06E-01
27	4.9889	0.0001	0.0002	2.93E-06	1.18E+00
30	4.9904	-0.0015	-0.0013	-4E-05	5.12E-01
TOTAL WEIGHT LOSS		-0.0013			

Table 15: Electrochemical polarization parameters for aluminum immersed in 0.5M NaOH solution at different concentrations of corrosion inhibitors of water hyacinth leave extract.

SAMPLES	CORROSION POTENTIAL (V)	ANODIC CONSTANT (V)	CATHODIC CONSTANT (mV)	CORROSION CURRENT (A)	CURRENT DENSITY (A/cm^2)	CORROSION RATE (mmpy)	INHIBITOR EFFICIENCY %
Control	-1.494	2.224	0.708498	33.042E-03	1.2690E-03	359.65	-
A1(5%extract)	-1.477	20.676	0.378967	8.866E-03	7.0990E-04	96.512	73.2
A2(10%extract)	-1.484	3.230	0.463874	7.406E-03	4.2450E-04	80.619	77.6
A3(15%extract)	-1.484	1.141	0.565412	6.946E-03	4.07090E-04	75.610	79.0
A4(20%extract)	-1.486	0.939135	0.358144	4.329E-03	3.9040E-04	47.127	86.9
A5(25%extract)	-1.482	7011	751.902	3.082E-03	3.3950E-04	33.556	90.7

Table 16: Electrochemical polarization parameters for gray cast iron immersed in 0.5M NaOH solution at different concentrations of corrosion inhibitors of water hyacinth leave extract.

SAMPLES	CORROSION POTENTIAL (V)	ANODIC CONSTANT (V)	CATHODIC CONSTANT (V)	CORROSION CURRENT (A)	CURRENT DENSITY (A/cm^2)	CORROSION RATE (mmpy)	INHIBITOR EFFICIENCY %

Control	-0.543643	9.153	-6.971	4.364E-05	3.7130E-07	0.5064	-
C1(5%exract)	-0.49992	1.624E-06	0.095892	4.701E-06	2.2138E-07	0.05456	89.2
C2(10%exract)	-0.428252	3.97E+28	0.045057	2.304E-06	1.80E-07	0.02674	94.7
C3(15%exract)	-0.413627	0.908	0.10085	2.045E-06	1.8045E-07	0.02373	95.3
C4(20%exract)	-0.413515	0.573022	0.099122	1.951E-06	1.7220E-07	0.02264	95.5
C5(25%exract)	-0.28386	1.90E+28	0.076763	1.835E-06	1.1440E-08	0.02130	95.8