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Corrosion Inhibition of Medium Carbon Steel in Sea Water by Water Hyacinth *(eichhornia crassipes)* Leaves Extract

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Abstract

Corrosion is the engineer's greatest enemy as water hyacinths are also weeds which grow on the surfaces of water bodies posing dangerous threats to aquatic lives and water transportation. Since both corrosion and water hyacinth are threat to the environment this paper sought to use one environmental menace (water hyacinth leaves extract) as an inhibitor to curb corrosion; another environmental menace. Samples of carbon steel were subjected to sea – water environment with the inhibitor at varied concentrations for an exposure period of forty – five days. Corrosion was examined using weight loss and electrode potentials techniques. The result showed that as the concentration of the inhibitor increased, the severity of corrosion reduced on the carbon steel. The pH of the sea – water which initially was neutral was observed to slowly progress to alkaline after five days, contributing to the reduced corrosion rates of the samples as the exposure period increased. It was observed that the steel sample inhibited with 20ml of 20g of the inhibitor gave the highest inhibition efficiency of 98.68 % in during the exposure period. It was concluded that water hyacinth leaves extract effectively inhibit corrosion of medium carbon steel in marine environment.

Key words: corrosion inhibition, medium carbon steel, electrode potential, water hyacinth, sea water

Introduction

Corrosion is one of the major problems that pose a great danger to engineering materials especially steel. Steel is one of the engineering materials that find application in with salt water environment. The presence of chloride ions in salt water attacks the metal. It is a general consensus that the best method to protect the metal deployed in these corrosive environments is to insert corrosion inhibitors. To this end, the use of organic and inorganic substances to inhibit corrosion of metals is well established Lebrini et al., [1]. Development of new corrosion inhibitors which effectively inhibit corrosion under a variety of conditions while being environmentally safe and acceptable is a challenging task Saratha and Vasudha [2]. Plant extracts have become important because they are environmentally acceptable, inexpensive, readily available and renewable sources of materials, and ecologically acceptable Abde-Gaber et al., [3].

Several researchers have successfully studied the inhibitive effect of natural products as corrosion inhibitors in different media Umoru et al., [4]; Aboia and James [5]; Rmila et al., [6]; Okafor et al., [7]; Sivarajua and Arulananthan [8]; Anca et al., [9]; Potgieler et al., [10]; El-Dahan [11]; Emranuzzaman et al., [12]; Loto [13]; Reha [14]; Subhashini et al., [15]; Da-Rocha et al., [16]; Rajalakshmi et al., [17] to mention but a few.

Water Hyacinth is free-floating or rooted in mud. Leaves are large and broadly lance-like extending from an inflated stalk. Roots are dark and fibrous. Leaf blades may be up to 8 inches (20 cm) long and 2 to 6 inches (5 to15 cm) wide. Plant height is variable from a few inches up to 3 feet tall. It is reproduced by fragmentation or by seeds Applied Biochemists [18]. This plant, found its uses as fertilisers; compost, mulch and ash. The technique of growing vegetables on a raft of water hyacinth and as substrate for growing mushrooms. As animal feed; as green fodder, hay, silage and leaf protein concentrate for farm animals and fish. Crafts and furniture; for making ropes, baskets, mats. Fuel; burning in the hearth, making briquettes, producing biogas – since the plant has abundant nitrogen content, paper and boards, pharmaceuticals, chemicals Keith and Hirt [19].

Seawater is used by industries such as shipping, offshore oil and gas production, power plants and coastal industrial plants. The main use of seawater is for cooling purpose but it is also used for fire-fighting, oil fuel water injection and desalination plants (Marine corrosion). The present study therefore seeks to investigate water hyacinth *(eichhornia crassipes)* leaves extract as corrosion inhibitor for medium carbon steel in sea water.

Experimental

Materials

The Medium carbon steel rod of 10mm diameter was obtained from Universal steels, Ogba Industrial Estate Ikeja, Lagos State, Nigeria. The elemental composition in Wt% is as follows:- C – 0.3377, Si – 0.1629, S – 0.0464, P – 0.0532, Mn – 0.8134, Ni – 0.1026, Cr – 0.1782, Mo – 0.0185, V – 0.0046, Cu – 0.3605, W – 0.0021, As – 0.0054, Sn – 0.0383, Co - 0.0099, Al – 0.0017, Pb – 0.0001, Ca – 0.0001, Zn – 0.0054, Fe – 97.8591

Preparation of Water Hyacinth Leaves (*Eichhornia Crassipes*) Extract

The water hyacinth plant was collected from Igbokoda, Ondo State, Nigeria. The leaves were plucked and dried in a laboratory oven at a temprature of 70^{o} C for 5 hours. The dried leaves were then pulverized to very fine particles using a mechanical grinding machine. 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. The beakers 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 this followed the method of Ambrish et al.,[20]. This extract was used to study the corrosion inhibition properties of water hyacinth on medium carbon steel in sea water. The sea water was collected from Bar-beach at Victoria Island, Lagos State Nigeria. Corrosion tests were performed on a medium carbon steel rod of 10 mm diameter. The elemental composition in Wt% of the extract of water hyacinth leaves was determined with Flame Photometer at the laboratory of School of Agricultural and Agricultural Technology, Federal University of Technology, Akure, Ondo State, Nigeria. The result was presented in Table 1.

Gravimetric Method

Weight loss measurements were performed on the medium carbon steel coupons which are dipped in 400 ml of sea water with and without addition of different concentrations of *eichhornia crassipes* leaves after being weighed. The weight loss was determined every five days for the immersion period of 45 days. Prior to measurement, each coupon was washed in water and cleaned. Corrosion rate (CR) and the inhibition efficiency (IE%) were calculated from the difference in weight loss using the equations below.

$$\mathrm{CR} \quad = \mathrm{W/AT}$$

$$IE\ \% = (1 - W2/W1)100$$

Where CR is corrosion rate in (mg/mm^2/yr),W_1 and W_2 are weight loss (mg) of medium carbon steel in the absence and presence of the inhibitor respectively. A is the total surface area (mm^2) of the coupon, T is the exposure time in days and W is the change in weight (mg).

Electrode Potential Measurement

The electrode potentials of the test specimen were read daily for forty five days using a digital multimeter (DT 830D) with zinc rod as reference electrode. The reference electrode was immersed in the media when readings were to be taken and removed afterwards. These electrode potential values were converted into standard calomel electrode (SCE) using the relation:

Electrode potential mV(SCE) = Ezn – 1030 mV Hibbert and Jones [21]

Where Ezn is Electrode potential reading obtained using the zinc rod. The values obtained displayed the electrochemical response of the medium carbon steel in sea water with different concentration of inhibitor.

Results and Discussion

Table 1: The Elemental constituents of the water hyacinth leaves extract

Elements	**Amount (parts per million)**
Nitrogen	5.068 mg/L
Chloride	124.25 mg/L
Potassium	787.428 mg/L
Sodium	364.57 mg/L
Calcium	180 mg/L
Total	**1461.316 mg/L**

$$(\%\ metal) = \frac{(787.428 + 362.57 + 180)100}{1461.316}$$

JCSE The Journal of Corrosion Science and Engineering
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$(\%\ \mathrm{metal}) = 91.2\ \%$

$$(\%\ non\ metal) \quad = \frac{(5.068 + 124.25)100}{1461.316}$$

$(\%\ \mathrm{non\ metal}) = 8.8\ \%$

Table 1 shows the elemental composition of the inhibitor (in ppm), which contains metals and non – metals. The main constituents which are metals (sodium, potassium and calcium) in 91.2% of the total amount and the non – metals (chloride and nitrogen) in 8.8% of the total amount. The inhibitive action of water Hyacinth (*Eichhornia crassipes*) leaves extract toward the corrosion of medium carbon steel can be attributed to the complete neutralization of chloride and nitrogen by the metals by a direct chemical reaction of the metals and non – metals to form hygroscopic salt which is then prevents further corrosion.

Effect of Inhibitor Concentration on Corrosion Behaviour of Medium Carbon Steel

Figs.1, 3, 5, and 7 presented the effect of inhibitor concentration on corrosion rates (CR) while Figs. 2, 4, 6 and 8 displayed the inhibition efficiency (IE) calculated from weight loss measurement of medium carbon steel coupons immersed in sea water in the absence and presence of different concentration of water hyacinth extract. The extract showed maximum inhibition efficiency at 96.68% in sea water at a concentration of 20g water hyacinth/100ml distilled water. Further increase in extract concentration to 25g water hyacinth/100ml distilled water did not cause any significant change in the performance of the extract.

The corrosion rate in the absence of inhibitor was 1.935mg/mm^2/yr which was later reduced to 0.7149 mg/mm^2/yr on addition of 20ml of 15g water hyacinth. 10ml of 20g water hyacinth

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 15, Preprint 9 submitted 25 January 2012

as the highest percentage of 92% on the 10th day of the exposure time. It was observed that the inhibition efficiency was consistent with the exposure time.

Inhibition with 5g of Water Hyacinth/100ml

5ml of 5g of water hyacinth/100ml of distilled water has the lowest inhibition efficiency of 20% after the day 5 while 10ml, 15ml, and 20 ml has inhibition efficiency of more than 50%. Highest inhibition efficiency of 84, 79 and 84 % was noticed on the 25th day of the exposure time for the coupons inhibited with 10ml, 15ml and 20ml of 5g of water hyacinth respectively. There was a slight reduction after this day, it was probably due to the breaking of the protective films on the coupons.

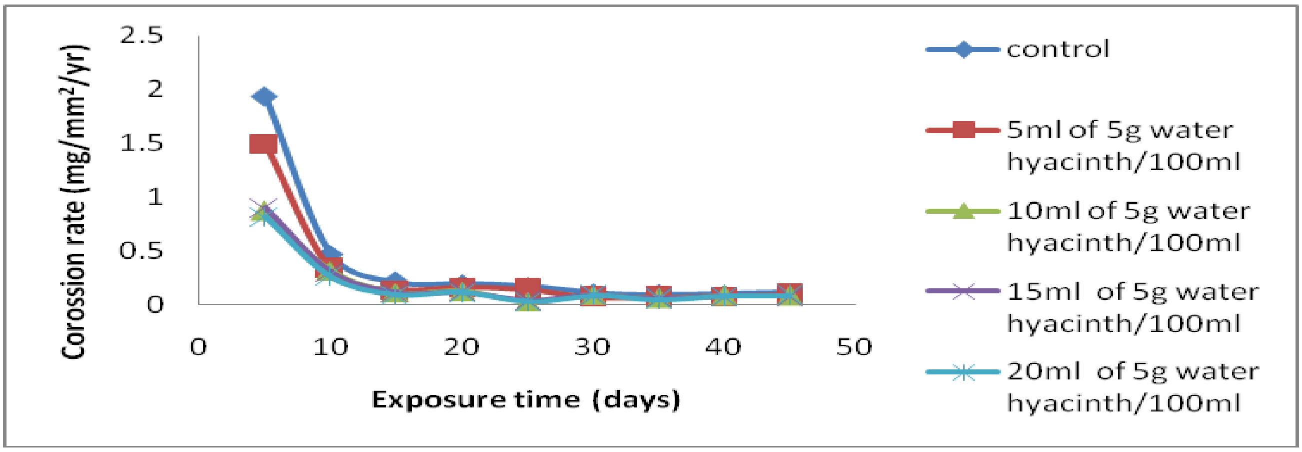

Fig.1: The plot of corrosion rate against exposure time of medium carbon steel immersed in sea water environment with different volume of 5g water hyacinth

ISSN 1466-8858 Volume 15, Preprint 9 submitted 25 January 2012

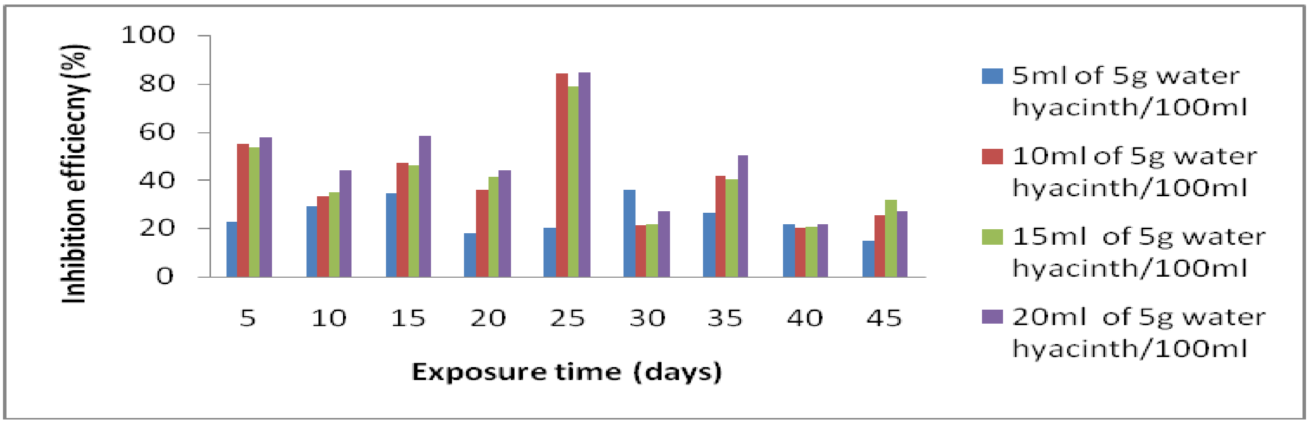

Fig.2: The plot of inhibition efficiency against exposure time of medium carbon steel immersed in sea water environment with different volume of 5g water hyacinth

Inhibition with 10g of Water Hyacinth/100ml

The corrosion rate and inhibition efficiency versus exposure time were shown in fig 2 and fig 6 respectively. The decrease in the corrosion rate of the coupons in the presence of 10g water hyacinth/ 100ml, of different concentration, indicated the effectiveness of the inhibition. The inhibition efficiency of the coupons inhibited with 10ml and 15ml of 10g water hyacinth/ 100ml gave value of 85% each which was quiet better than those inhibited with 5g of water hyacinth/ 100ml. From this result, it can be deduced that the active ingredient responsible for the inhibition increases as its concentration increases.

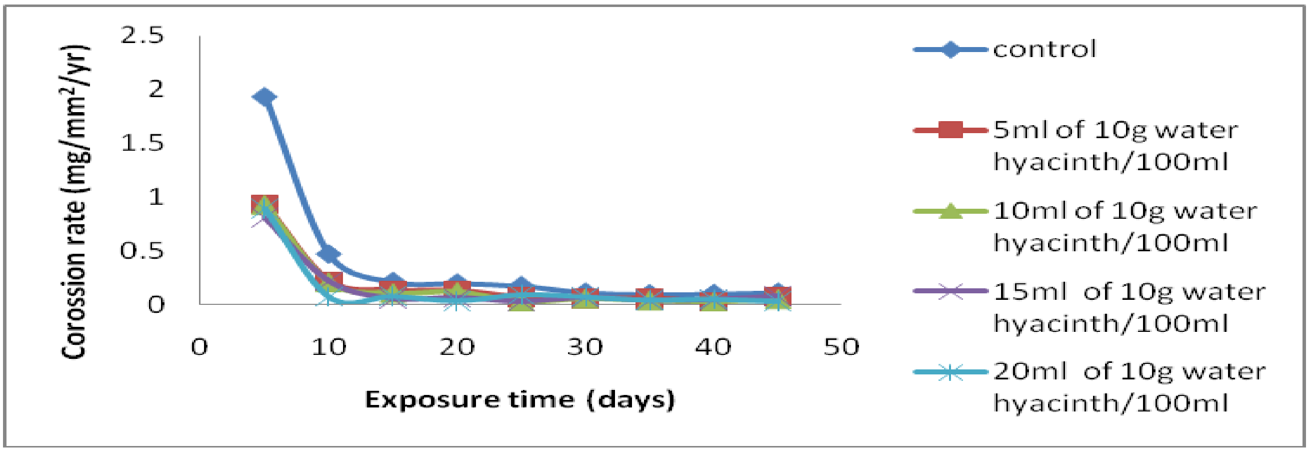

Fig.3: The plot of corrosion rate against exposure time of medium carbon steel immersed in sea water environment with different volume of 10g water hyacinth

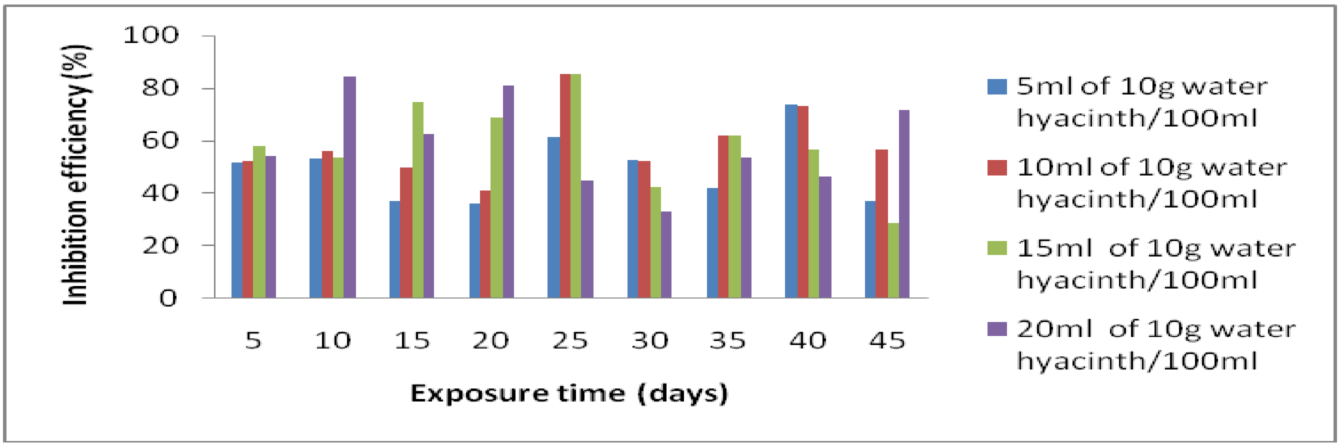

Fig.4: The plot of inhibition efficiency against exposure time of medium carbon steel immersed in sea water environment with different volume of 10g water hyacinth

Inhibition with 15g of Water Hyacinth/100ml

The reduction in the corrosion rate which led to high percentage of inhibition efficiency was due the fact that more protective films were formed as a result of more concentration of water hyacinth added. In this study, inhibitor volume of 15ml of 15g water hyacinth/ 100ml

JCSE The Journal of Corrosion Science and Engineering
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has efficiency values of 88 and 89% at the 10th and 20th day of exposure time respectively as shown in Figure 6.

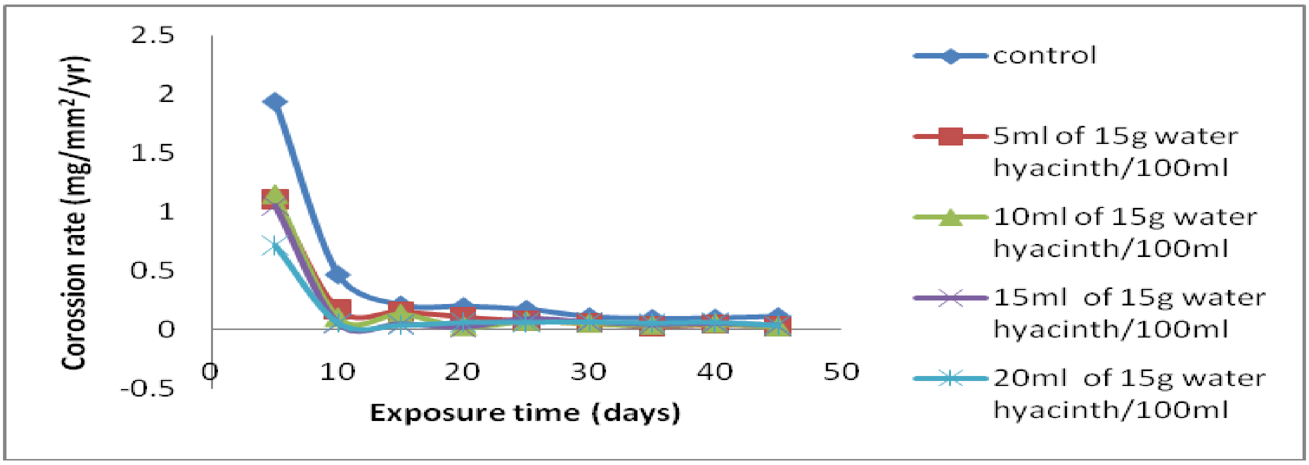

Fig.5: The plot of corrosion rate against exposure time of medium carbon steel immersed in sea water environment with different volume of 15g water hyacinth extract

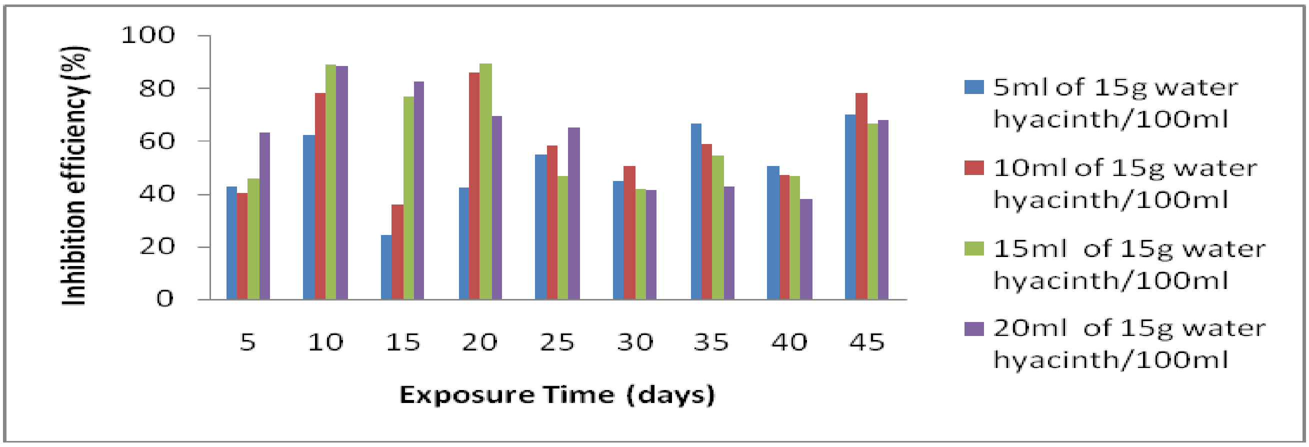

Fig.6: The plot of inhibition efficiency against exposure time of medium carbon steel immersed in sea water environment with different volume of 15g water hyacinth

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 15, Preprint 9 submitted 25 January 2012

Inhibition with 20g of Water Hyacinth/100ml

Wider spread of passive film that formed a protective layer on the surface of the coupons was responsible for the highest percentage of inhibition efficiency of 92% on the 10th day of the exposure time, on the addition of 10ml of 20g water hyacinth. This showed that a better result could be obtained by increasing the concentration of the inhibition. The inhibition of the extract may be due to the presence of higher percentage of the cathodic ions (K^{+1}, Na^{+1} and Ca^{+2}) as shown in Table 1 above. The cations may likely reacts with the chloride content of the sea water thereby reducing its aggressiveness.

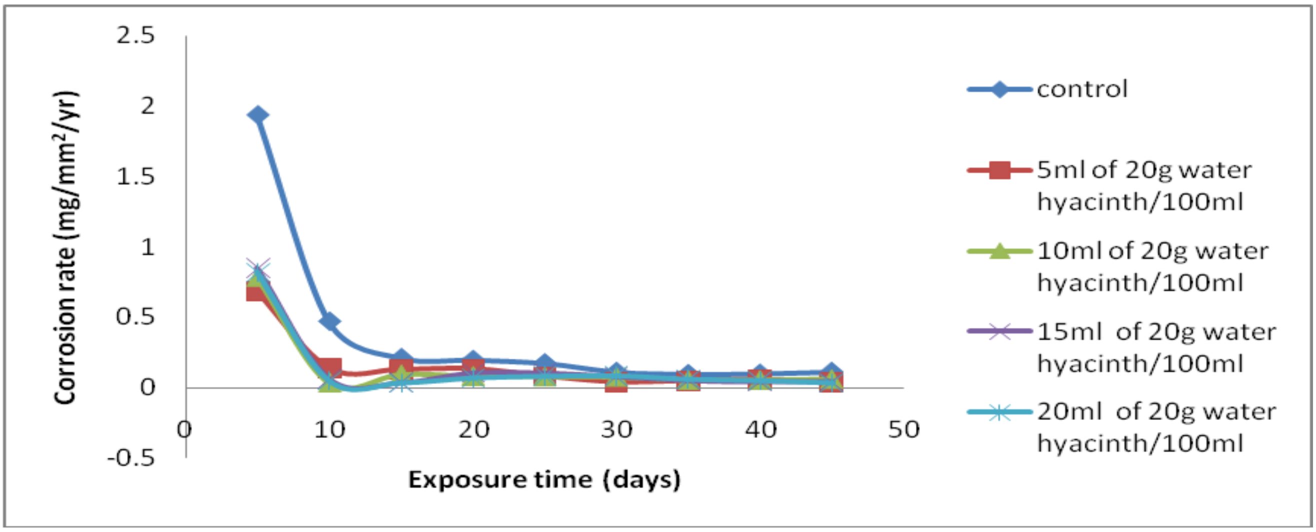

Fig.7: The plot of corrosion rate against exposure time of medium carbon steel immssersed in sea water environment with different volume of 20g water hyacinth

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 15, Preprint 9 submitted 25 January 2012

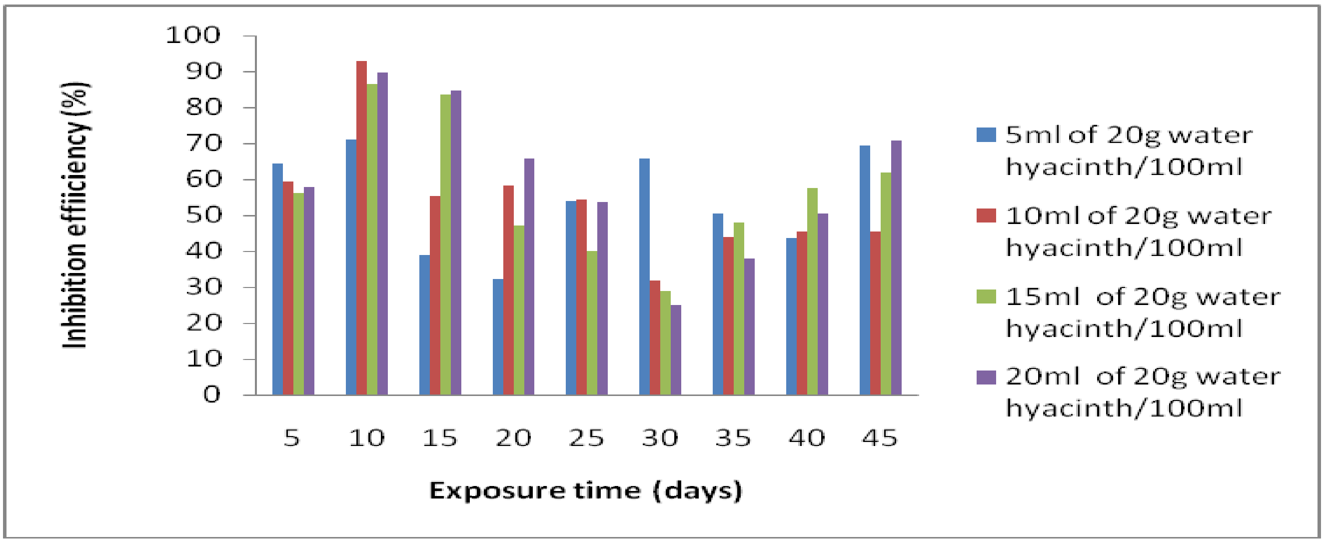

Fig.8: The plot of inhibition efficiency against exposure time of medium carbon steel immersed in sea water environment with different volume of 20g water hyacinth

Electrochemical Corrosion Behaviour of Medium Carbon Steel in Sea Water with Various Concentration of Inhibitor of Water Hyacinth Extract

Figs. 9 -12 present the trend of electrode potential with exposure time for the medium carbon steel in sea water with various concentrations of water hyacinth extract. The plot shows corrosion potentials higher in the 20g water hyacinth/100 ml distilled water compared with corrosion potential in the other concentrations.

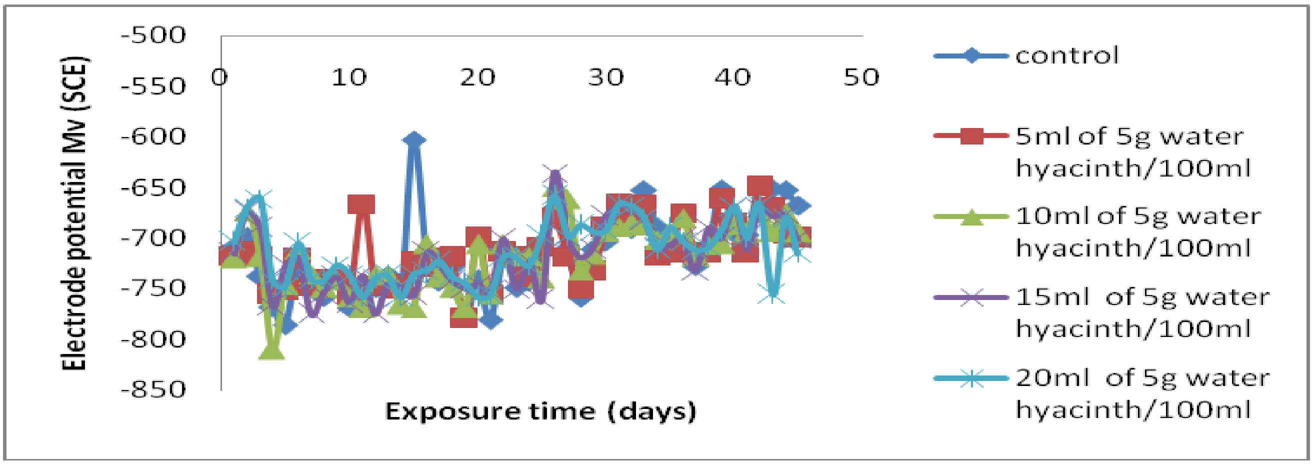

Fig.9: The plot of electrode potential against exposure time of medium carbon steel immersed in sea water environment with different volume of 5g water hyacinth/100 ml distilled water

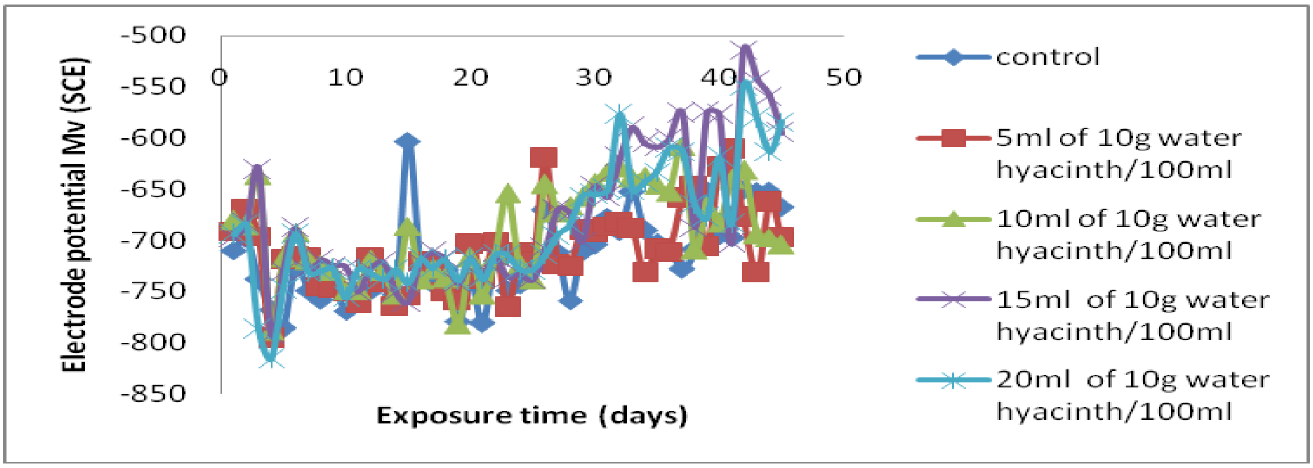

Fig.10: The plot of electrode potential against exposure time of medium carbon steel immersed in sea water environment with different volume of 10g water hyacinth/100 ml distilled water

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ISSN 1466-8858 Volume 15, Preprint 9 submitted 25 January 2012

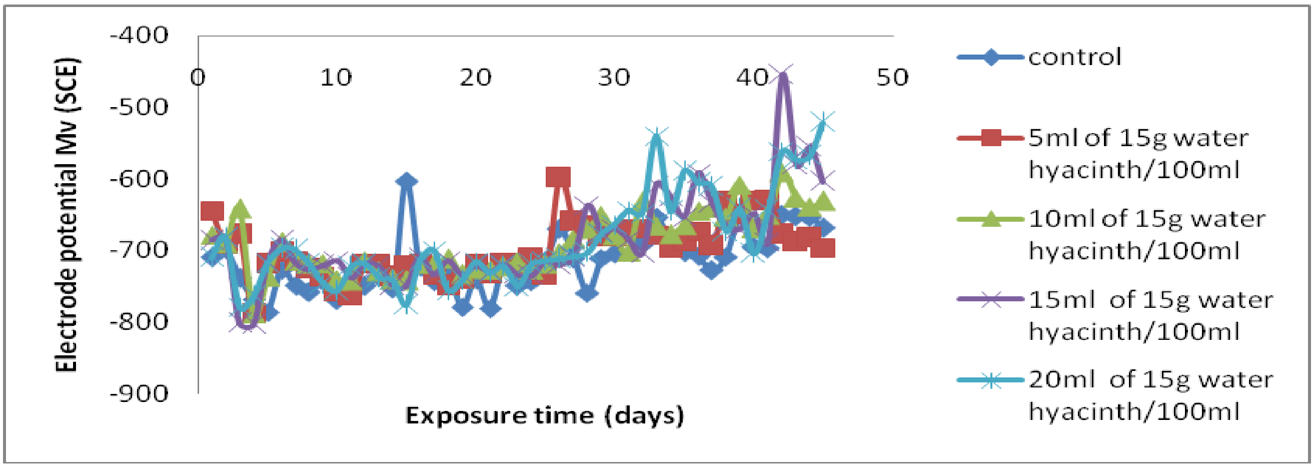

Fig.11: The plot of electrode potential against exposure time of medium carbon steel immersed in sea water environment with different volume of 15g water hyacinth/100 ml distilled water

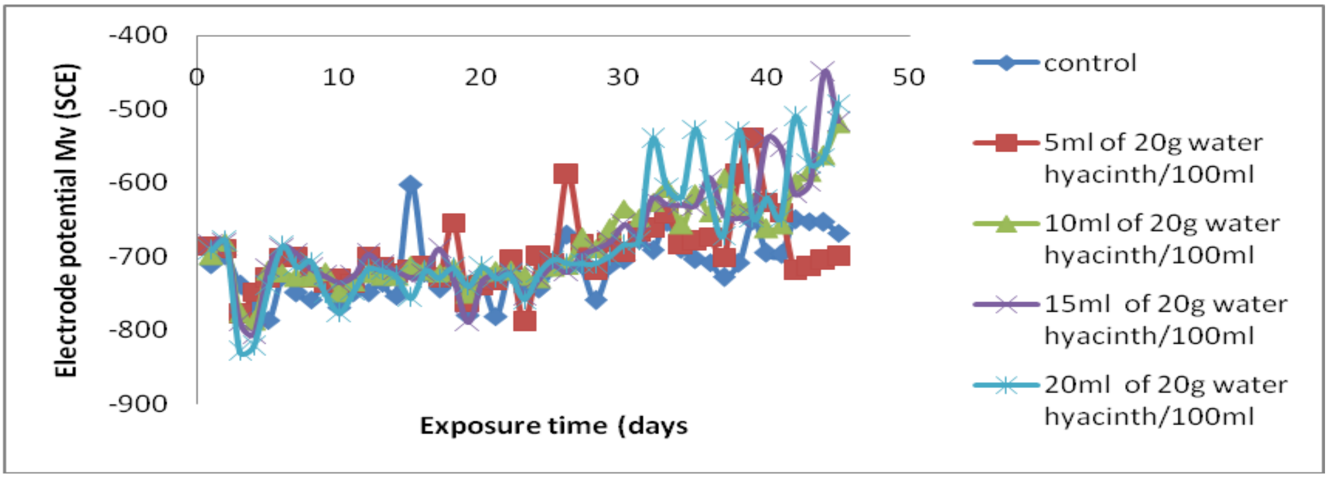

Fig.12: The plot of electrode potential against exposure time of medium carbon steel immersed in sea water environment with different volume of 20g water hyacinth/100 ml distilled water

The trend observed in the variation of electrode potential with exposure time for the medium carbon steel in sea water with various concentration of inhibitor (Figs. 9-12) wherein the sample in 20ml of 20g water hyacinth/100ml distilled water had the highest corrosion

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 15, Preprint 9 submitted 25 January 2012

potential followed by the sample in 15ml of 20g water hyacinth/100ml distilled water with the least being the sample in the 5ml of 20g water hyacinth/100ml of distilled water, this translated into the sample immersed in sea water without inhibitor (control sample) having the highest weight loss, hence corrosion rate (Fig. 1). The electrode potential variation in the 20g concentrations was very minimal tending towards positive values showing less corrosion activity. This behaviour translated into what obtained in Figs. 7 and 8; highest corrosion rate in control sample and the highest corrosion inhibition efficiency in solution with 20ml of 20g water hyacinth/100ml distilled water at the end of 45 days exposure period.

Conlusion:

The results obtained showed that water hyacinth can effectively inhibit medium carbon steel in sea water environment. More so, the inhibition efficiency of the extract increases as its concentration increased. 5ml of 5g water hyacinth/100ml offered the lowest protection, while 10ml of 20g water hyacinth/100ml gave the highest inhibition efficiency at 10th day exposure period whereas 20ml of 20g water hyacinth/100ml of distilled water gave the least corrosion rate at the end of the exposure period. The inhibition of the extract may be due to the presence of higher percentage of the cat ions (K^{+1}, Na^{+1} and Ca^{+2}) which may likely react with the chloride content of the sea water reducing it to solute. Water hyacinth *(eichhornia crassipes)* leaves extract can be used as corrosion inhibitor in sea water used by industries such as shipping, offshore oil and gas production, power plants and coastal industrial plants for cooling purposes, fire-fighting, oil fuel water injection and desalination plants and combating marine corrosion.

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