

Investigation and Evaluation of the Corrosion Inhibition Properties of Water Hyacinth Extract on Low Carbon Steel

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ABSTRACT

The use of plants extract as inhibitors has been identified by several researchers as an alternative way to prevent metal and alloys from corrosion. This research work focused on the investigation of corrosion inhibition of low carbon steel in sea water with water hyacinth extract as inhibitor. The extract from water hyacinth was obtained from river in Nigeria and analysed for chemical composition. Samples of low carbon steel were subjected to sea water with and without the inhibitor at different concentrations for an exposure period of 45 days. Corrosion rate was examined using weight loss and inhibition efficiency calculated. The result obtained show that as the concentration of inhibitor increases, the harshness of corrosion reduces on the low carbon steel. Inhibition efficiency of the extract increased with an increase in concentration of the extract with 79.63% inhibition efficiency at 20g/500mls.

Keywords: Inhibition, water hyacinth, corrosion rate, weight loss, low carbon steel

INTRODUCTION

Steel and steel-based alloys are widely employed in majority of engineering and structural applications such as acid pickling, cleaning and oil-well acidizing processes. Low carbon steel contains approximately 0.05-0.25% carbon making it malleable and ductile. Low carbon steel account for large proportion of the total output of steel. Their uses include; automobile, furniture, refrigerators, roofing, etc. Low carbon steel has a relatively low tensile strength, but it is cheap and easy to form [1].

Corrosion is the deterioration of materials by chemical interaction with their environment. Degradation implies deterioration of physical properties of the material [1, 2]. The environment could be of any type such as atmosphere, water; sea water, acids, alkaline, steam, gases, soils, liquid metals, etc. Corrosion is one of the most critical problems ravaging storage and transportation facilities among others; and in most cases, the traditional corrosion protection systems (cathodic protection and coatings) are either not efficient enough, have short service life, or cannot be applied [3,4,5]. Researchers have therefore created tremendous effort work in the field of corrosion inhibition of metals

using natural products and corrosion inhibiting ability of plant phytochemicals such as tannins, alkaloids, organic amino acids and organic dyes, etc. This has brought about sustained interest on the corrosion inhibiting property of natural products of plant origin [6,7]. The most practical method of protecting metal is the use of inhibitors especially in acid solutions to prevent unexpected metal dissolution and acid consumption [8]. A number of organic and inorganic compounds have been studied as inhibitors to prevent metals from corrosive attacks. Usually, organic compounds exert a significant influence on the extent of adsorption on the metal surface and therefore can be used as effective corrosion inhibitor. The efficiency of these organic corrosion inhibitors is associated with the presence of polar functions with Sulphur (S), Oxygen (O) or Nitrogen (N) atoms in the molecule, heterocyclic compounds and π electrons [10]. The polar function is often regarded as “the reaction centre” which establishes the adsorption process [11].

Due to the hazardous effects of most synthetic inorganic inhibitors and restrictive environmental regulations, researchers have focused on the need for the design of cheap, non-toxic and environmentally benign natural products as

corrosion inhibitors. Natural organic compounds which are either synthesized or extracted from aromatic herbs, spices and medicinal plants have played major roles in this regard. Plants extracts are seen as rich sources of naturally synthesized chemical compounds that can be produced by simple processes at low cost and are biodegradable in nature. The application of naturally extracted compounds from leaves or seeds as corrosion inhibitors have been widely reported by several authors [8, 12, 13, 14, 15].

Thus, in this research work, investigation was carried out on water hyacinth as a potential inhibitor on low carbon steel. Water hyacinth (*Eichhornia crassipes*) is an aquatic plant which can live and reproduce floating freely on the surface of fresh waters or can be anchored in mud. The plant originated in the Amazon basin and was introduced into many parts of the world as an ornamental garden pond plant due to its beauty. It has proliferated in many areas and can now be found on all continents apart from Europe.

The mature plant consists of long pendant roots, rhizomes, stolons, leaves, inflorescence and fruit clusters. Water hyacinth has recently been reported as a good substance for the production of paper, biogas, fiber board, yarn and rope, basket work and charcoal briquetting. Water hyacinth entered Nigeria waters through pot-novo creek in Benin Republic in September 1984. Since that time, it has been spreading and has gotten to the confluence of Rivers Niger and Benue, and spread to other rivers in Nigeria such as Ologbo River where the water hyacinth used in this research work was collected. This aquatic plant is problematic in Nigeria coastal waters as it blocks the navigation way, blocking irrigation channels and rivers, recreational activities, hydropower generation, restricting livestock access to water, destroying natural wetland, eliminating native aquatic plants, reducing infiltration of sunlight, changing the temperature, pH and oxygen levels of water and reducing gas exchange at the water surface. Others include, increasing water loss through transpiration (greater than evaporation from an open water body), altering the habitats of aquatic organisms, reducing aesthetic values of waterways, reducing water quality from decomposing plants, destroying fences, roads and other infrastructure when large floating rafts become mobile during flood events, and destroying pastures and crops when large floating rafts settle over paddocks after flood events.

MATERIALS AND METHOD

Materials

In this research work, the following materials were used;

- Water Hyacinth (*Eichhornia crassipes*) collected from Ologbo River, Nigeria
- Grinding Machine
- Plastic Bucket
- Water
- Vacuum Pump Filtration Apparatus
- Laboratory Water Bath Shaker
- Analytical Scale Balance
- Samples of Low Carbon Steel

Method

Fresh water hyacinth (*Eichhornia crassipes*) was harvested as whole adult plant from Ologbo River, Nigeria (Figure 1).



Figure1. *Fresh Water Hyacinth*

The collected fresh water hyacinth samples were cleaned from epiphytes by washing under running tap water, chopped into smaller sizes and properly dried under room temperature to evaporate the very high moisture content without denaturing the plant (Figure 2). The dried samples were grinded to a uniform fine powder (Figure 3) using a grinding machine. The grinded water hyacinth samples were further refined by filtering with fine sieve to provide sufficient surface area for digestion and proper extraction.



Figure2. *Dried Water Hyacinth Samples*

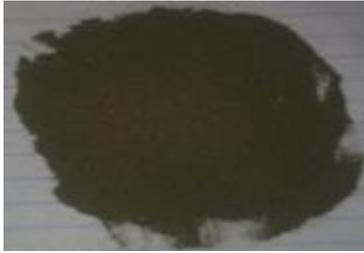


Figure3. Grinded Water Hyacinth Sample

1.5kg of the refined water hyacinth powder was measured and soaked in 4000mls of de-ionized water and warmed on heat mantle at 30°C for a period of 45minutes to allow for softening, proper digestion and extraction. This was subsequently poured into 10litres capacity plastic bucket with cover and stored under room temperature for 24hours. The container was stirred at intervals to enhance proper dissolution of the water hyacinth powder. At the end of 24hour reaction, the soaked water hyacinth powder was filtered using vacuum pump filtration apparatus (Figure 3). This process produced 3000mls of filtrate (water hyacinth extract).



Figure4. Vacuum Pump Filtration Apparatus

The 3000mls of filtrate was divided into two beakers of 2000mls (Figure 4). In order to concentrate the water hyacinth extract, the beakers were subjected to laboratory water bath shaker set at a temperature of 60°C for a period of two weeks where evaporation took place. At the end of each day, the beakers and their contents were sealed with aluminium paper foil and masking tape and stored in refrigerator so as to avoid growing mould or fermentation. This process was sustained until the entire water content of the extract gradually dried out. Thus, leaving 100% concentrated extract of water hyacinth.



Figure5. Water Hyacinth Extract Subjected to Laboratory Water Bath Shaker

A piece of low carbon steel rod was obtained and the chemical composition determined. The low carbon steel rod has density of 7.85g/cm³ and Young's Modulus 210GPa and this was properly machined to produce five (5) prototype. These sets of mild steel specimen were used as models for simulating corrosion rate. Each low carbon steel samples were measured for weight loss separately before and after corrosion test using analytical scale balance (Figure 5).



Figure6. Analytical Scale Balance

500mls of sea water was mixed separately with 4g, 8g, 12g, 16g and 20g of water hyacinth extract respectively and poured into a separate container. Another five containers of separate 500ml of sea water without addition of extract served as the control set up. The exposure periods were as follows: 9days (216hrs), 18days (432hrs), 27days (648hrs), 35.25days (846hrs), and 45days (1080hrs). The weight loss for each of the specimens was obtained by finding the difference between the initial and final weight. The standard expression for measurement of corrosion rate is given by Equation (1).

$$\text{Corrosion Rate (mm/day)} = \frac{87.6w}{DAT} \quad (1)$$

where,

w = Corrosion weight loss of low carbon steel (mg)

A= Area of the sample (cm²)

T = Exposure time (Hrs.)

D = Density of low carbon steel (g/cm³) = 7.85g/cm³

Inhibition efficiency was computed from Equation(2)

$$IE (\%) = \frac{W_0 - W}{W_0} \quad (2)$$

where,

W and W₀ are the corrosion rates with and without inhibitor respectively. The degree of surface coverage was computed from Equation (3).

$$\text{Degree of Surface Coverage } (\theta) = \frac{1}{\%IE} \quad (3)$$

RESULTS AND DISCUSSION

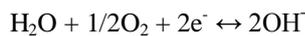
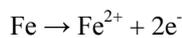
The results of the chemical composition of low carbon steel sample used in this research work is shown in Table 1.

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Table1. Chemical Composition of Low Carbon Steel Sample

Elements	C	Mn	Si	P	S	Fe
% composition	0.16	0.30	0.21	0.04	0.03	99.26

The results of phytochemical analysis of water hyacinth extract was carried out to determine the presence and degree of active plant compounds (Table 2). The elemental composition analysis of water hyacinth extract indicates reduction in the anions and cations which is a suggestion of adsorption of some of the molecules onto the alloy surface. The corrosion rates of the uninhibited sample and the inhibited samples are shown in Table 3-Table 8. Figure 6 shows the graphical representation of the corrosion rate as a function of exposure time for the inhibited and uninhibited samples. It was observed from the graph that the corrosion rate for the uninhibited low carbon steel in sea water experienced a stable increase from the start of the experiment to the end. Their weight loss also increased steadily as the exposure time increases (Figure 7). This could be attributed to the presence of dissolved air in the system.



This type of corrosion can therefore, be controlled by eliminating oxygen from the corroding medium, or retarding the diffusion to the cathodic areas. The corrosion of the inhibited low carbon steel samples shown a nominal corrosion rate as the exposure time increases. As presented in Figure 6, corrosion rate of the inhibited sample decreases with exposure time from left to right. The decreased in corrosion rate of the inhibited sample was as a result of the alteration (passivation) in the mechanism of corrosion due to the presence of inhibitor as confirmed by Rosliza [16] and also because the exposure time under investigation falls within the active region for corrosion for these materials as reported by Sanda [17]. Figure 8 shows a graphical representation of the inhibition efficiency against exposure time for low carbon steel samples.

Table2. Result of Phytochemical Analysis of Water hyacinth extract

Sample/Code	Alkaloids	Saponins	Tannins	Flavonoid	Glycosides	Total Phenol	Triterpenoid
Water Hyacinth	Present ++	Present +	Present +	Present ++	Present +	Present +	Present ++

From the graph, it was observed that the inhibition efficiency increased with increase in exposure time.

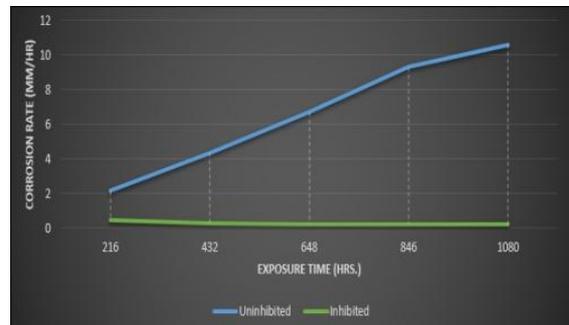


Figure7. Corrosion Rate against Exposure Time (hrs.)

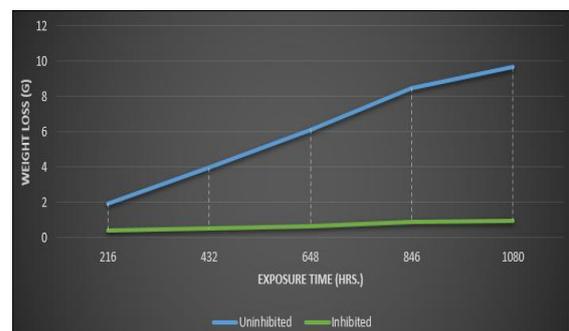


Figure8. Weight Loss against Exposure Time (hrs.)

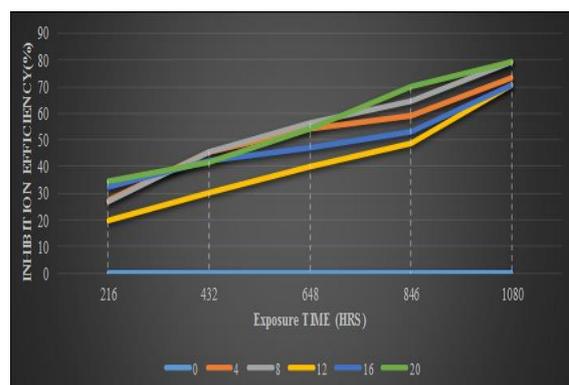


Figure9. Inhibition efficiency (%) against exposure time (hrs.)

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Table3. Weight Losses and Corrosion Rates of Uninhibited Low Carbon Steel Sample

S/N	Exposure Time (Day)	Sample Area (cm ²)	Initial Weight(g)	Final Weight (g)	Weight Loss (g)	Corrosion Rate(mm/hrs.)
1.0	216	47.13	128.58	126.62	1.96	2.15
2.0	432	47.13	126.62	124.61	3.98	4.36
3.0	648	47.13	124.61	121.63	6.12	6.71
4.0	846	47.13	121.63	117.63	8.49	9.31
5.0	1080	47.13	117.81	111.60	9.68	10.61

Table4. Corrosion Rate, Weight Loss and Efficiency of the Inhibited Low Carbon Steel Sample in 4g Water Hyacinth Concentration (Inhibitor Concentration)

S/N	Exposure Time (hrs.)	Sample Area(cm ²)	Inhibitor Concentration(g)	Initial Weight(g)	Final Weight(g)	Weight Loss(g)	Inhibition Efficiency(%)	Corrosion Rate(mm/hrs.)
1	216	47.13	3.0	128.58	128.23	0.35	27.38	0.386
2	432	47.13	3.0	128.23	127.64	0.59	45.70	0.321
3	648	47.13	3.0	127.64	126.95	0.69	54.21	0.253
4	846	47.13	3.0	126.95	126.20	0.75	59.31	0.211
5	1080	47.13	3.0	126.20	125.27	0.93	73.38	0.203

Table5. Corrosion Rate, Weight Loss and Efficiency of the Inhibited Low Carbon Steel Sample in 8g Water Hyacinth Concentration (Inhibitor Concentration)

S/N	Exposure Time (hrs.)	Sample Area (cm ²)	Inhibitor Concentration (g)	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Inhibition Efficiency (%)	Corrosion Rate (mm/hrs.)
1	216	47.13	6.0	128.47	128.12	0.35	27.09	0.381
2	432	47.13	6.0	128.12	127.54	0.58	45.50	0.320
3	648	47.13	6.0	127.54	126.82	0.72	56.69	0.264
4	846	47.13	6.0	126.82	125.10	0.82	64.82	0.230
5	1080	47.13	6.0	125.10	124.11	0.99	79.38	0.218

Table6. Corrosion Rate, Weight Loss and Efficiency of the Inhibited Low Carbon Steel Sample in 12g Water Hyacinth Concentration (Inhibitor Concentration)

S/N	Exposure Time (hrs.)	Sample Area (cm ²)	Inhibitor Concentration (g)	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Inhibition Efficiency (%)	Corrosion Rate(mm/hrs.)
1	216	47.13	9.0	128.36	128.10	0.26	19.94	0.281
2	432	47.13	9.0	128.10	127.72	0.38	29.98	0.210
3	648	47.13	9.0	127.72	127.21	0.51	40.09	0.197
4	846	47.13	9.0	127.21	126.59	0.62	48.74	0.187
5	1080	47.13	9.0	126.59	125.69	0.90	70.86	0.174

Table7. Corrosion Rate, Weight Loss and Efficiency of the Inhibited Low Carbon Steel Sample in 16g Water Hyacinth Concentration (Inhibitor Concentration)

S/N	Exposure Time (hrs.)	Sample Area (cm ²)	Inhibitor Concentration (g)	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Inhibition Efficiency (%)	Corrosion Rate(mm/hrs.)
1.0	216	47.13	12.0	127.35	126.94	0.41	32.35	0.452
2.0	432	47.13	12.0	126.94	126.41	0.54	42.15	0.293
3.0	648	47.13	12.0	126.41	125.81	0.59	47.31	0.219
4.0	846	47.13	12.0	125.81	125.14	0.67	53.41	0.188
5.0	1080	47.13	12.0	125.14	124.25	0.88	70.56	0.174

Table8. Corrosion Rate, Weight Loss and Efficiency of the Inhibited Low Carbon Steel Sample in 20g Water Hyacinth Concentration (Inhibitor Concentration)

S/N	Exposure Time (hrs.)	Sample Area (cm ²)	Inhibitor Concentration (g)	Initial Weight(g)	Final Weight (g)	Weight Loss (g)	Inhibition Efficiency(%)	Corrosion Rate(mm/hrs.)
1	216	47.13	15.0	127.35	126.91	0.44	34.63	0.483
2	432	47.13	15.0	126.91	126.38	0.53	41.37	0.288
3	648	47.13	15.0	126.38	125.70	0.68	53.96	0.249
4	846	47.13	15.0	125.70	124.82	0.88	70.09	0.247
5	1080	47.13	15.0	124.82	123.83	0.99	79.63	0.218

CONCLUSION

Having carried out a research work on the investigation and evaluation of the corrosion inhibition properties of water hyacinth extract on low carbon steel, the following deductions were drawn:

- Water Hyacinth extract possess remarkable anti-corrosion properties on low carbon steel in sea water.
- Low carbon steel was inhibited to a significant extent at ambient temperatures and under still condition
- The mechanism of action of the Water Hyacinth extract was predicted to be a formation of protective film on the surface of the low carbon steel in sea water.
- The corrosion rate of low carbon steel is a combined function of the concentration of Water Hyacinth extract and exposure time.
- Significantly high Inhibitor Efficiency (IE) (79.63%) was found at highest concentration (20g) of Water Hyacinth. Thus, low carbon steel protection efficiency increases with the increase of inhibitor concentration and exposure period.

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