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Hybridization of Plant Extracts for Corrosion Prevention of Mild Steel

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ABSTRACT

Corrosion control of metals is of technical, economical, environmental and aesthetical importance. The use of inhibitors from plant extract is one of the best option of protecting metals and alloys against corrosion as it is environmentally acceptable, readily available and renewable. This paper exposed the use of some of the commonly available extracts, in addition to showing how hybridization of plant extract can enhance performance in the prevention of corrosion. Neem leave, bitter leave and Moringa were tested to determine their potency in the prevention of corrosion. Moringa exhibited the best performance and was hybridized with Neem leave extract because of its abundance within the locality of this experiment with a view to enhance its use in corrosion prevention. Weight loss, corrosion rate and inhibition efficiency were tested using mild steel sheet. Neem leaf extract in combination with Moringa at a ratio of 70:30 percentage weight produced hybridized inhibition extract that gave superior corrosion inhibition performance. The corrosion inhibition performance in plant extracts is due to the presence of surface active constituents which normally enhanced the film formation over the metal surface, thus, mitigating corrosion. Abundance of Neem leave in the locality where this experiment took place has made Neem tree an economic tree instead of being a waste.

Keywords: Corrosion prevention, Inhibitor, Hybridization, Plant extract, Mild steel

INTRODUCTION

Corrosion may be defined as a destructive phenomenon, chemical or electrochemical, which can attack any metal or alloy through reaction by the surrounding environment and in extreme cases may cause structural failure [1] .Corrosion can also occur in materials other than metals, such as ceramics, wood or polymers, although in this context, the term degradation is commonly used. Corrosion degrades the useful properties of materials and structure including strength, appearance and permeability of liquids and gases. Temperature, concentration, humidity of air, effect of PH, conductance of the medium etc is known to cause corrosion in materials. Corrosion is a diffused controlled process, as it occurs on exposed surfaces. Methods such as passivation or chromate conversion helps to reduce its activity on exposed surface and increase its corrosion resistance. Corrosion is a constant and continuous problem, often difficult to eliminate completely. Its prevention would be more practical and achievable than complete elimination. In virtually all situations, metal corrosion can be managed, slowed or even stopped by using proper techniques.

Some research groups have reported the successful use of naturally occurring substances to inhibit the corrosion of metals in acidic, neutral and alkaline environment. Plant extracts commonly known as green corrosion inhibitors like Tannins and their derivatives can be used to protect steel, iron and other tools from corrosion [2]. Ebenso *et al.*, [3], showed the inhibition of corrosion with ethanolic extract called African bush pepper (*piper guinensis*) on mild steel. Zucci and Omar, [4] investigated plant extracts of *Papaia*, *Poinciana Pulcherrima*, *Cassia Occidentalis*, *Datura Stramonium* seeds and *papaya*, *Calotropisprocera B*, *AzadirachtaIndica* and *Auforpiosapturkiale* sap for their corrosion inhibition potential and found that all the extracts except those of *Auforpioturkiale* and *Azadirachtaindica* reduced the corrosion of steel with an efficiency of 88-96% in 1 M of HCl and with a slightly lower efficiency in 2 MHCl [4].Furthermore, Rosemary leaves were studied as

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corrosion inhibitor for the AL+2.5Mg alloy in a 3% NaCl solution at 25^0C [5]; The inhibitive effect of the extract of khillah (*Ammivisnaga)* seeds on the corrosion of SX 316 steel in HCl solution was determined using weight loss measurements as well as potentiostatic technique. The mechanism of action is attributed to the formation of insoluble complexes as a result of interaction between iron cations and khillah [6]; Delonixregia extract inhibited the corrosion of aluminium in Hydochloric acid solutions [7]; Umoren *et al.*, [8], studied the corrosion inhibition of mild steel in H_2SO_4in the presence of gum Arabic (naturally occurring polymer) and polyethylene glycol (synthetic polymer). It was found that polyethylene glycol was more effective than gum Arabic.

Leelavathi *et al.*, [9], focused on *Cassia alata* leaves extract (Candle Bush) as corrosion inhibitor for mild steel in HCl medium using mass loss, electrochemical measurements and surface analytical techniques. The inhibition efficiency of cassia alata leaves increases with increase in concentration of the inhibitor and time of immersion. Maximum inhibition efficiency of 88% attained at 6 hours. Other researchers focused on extracts from *carica papaya* leaves [10], Neem leaves extracts (*Azadirachtaindica*) on mild steel in H_2SO_4 [11]. Eddy *et al*., [12] studied inhibition of the corrosion of mild steel by ethanol extract of Musa species peel using hydrogen evolution, a thermometric method of monitoring corrosion. Inhibition efficiency of the extract was found to vary with concentration, temperature, period of immersion, pH and electrode potential. Literature search reveals that so far, no study has been done on the inhibitive effect of Neem extracts through hybridization with bitter leaf and Moringa Oleifera on corrosion of mild steel in acid medium.

This paper presents the result of hybridization of plant extracts for corrosion prevention in mild steel.

EXPERIMENTAL PROCEDURE

Materials and Preparation of Plant Extract

To carry out the research, the following materials/equipment were used: mild steel coupons, digital scale, thermostat, heating mantle, soxhlet extractor, beakers, measuring cylinders, sample bottles which are used for subsequent analysis, sieve, distillation apparatus, test tubes, tissue paper, funnel etc..

Preparation of the Sample

Fresh leaves of neem tree, Moringa Oleifera and bitter leaf were taken in a natural condition from the plant and were dried for 10 -15 days in natural shade under room temperature. The dried leaves were grounded to powder form, and known weights are placed in different containers.

Extraction

Extraction of the dried leave sample was done using ethanol. 300 g of dried powdered Neem leaf, 150 g each of Moringa and bitter leave were each extracted with 600 ml of ethanol respectively. The extraction method adopted was soxhlet extraction. The soxhlet extractor was fixed to condenser which collects water from a reservoir placed at an elevation above it. The condenser condenses the vaporized ethanol and it falls into the powdered plant leaves packed in the soxhlet extractor, the cycle continues as the condensed ethanol soaks the powdered leaves until it gets saturated and then begins to discharge back into the round bottom flask, Figure 1 shows the extraction process set-up.

Figure1. *Extraction Process using a Soxhlet Extraction Device*

Figure2. *Evaporation of Ethanol from the Extract*

After the extraction, the extracts were placed on a water bath (distillation equipment) as shown in Figure 2. This is to allow the aqueous solution filtered, such that ethanol present in the extract evaporate thereby leaving the crude extract which was then left open for it to cool at a room temperature.

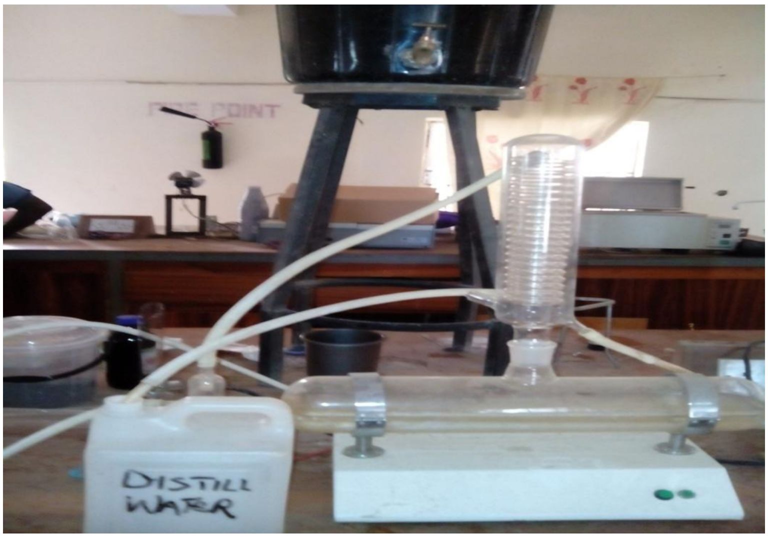

Figure3. *Distillation Equipment for Producing Bi-distilled Water*

Test Solution

The concentrated HCL acid used for this has a density of 1.18 g/cm^3, a percentage purity of 37% and molar mass of 36.5 /mol. Equation (1) was used to obtain the Molarity of the concentrated HCL acid.

$$Molarity = \frac{\text{Concentration}}{\text{molar mass}} \qquad (1)$$

Concentration = Standard volume x density x percentage purity

For 1 liter (1000 cm^3) of standard HCL acid,

$$\text{Concentration} = 1000 \times 1.18 \times 37\%$$

Hence, the Molarity is given by:

$$Molarity = \frac{1000 \times 1.18 \times 37}{36.5} = 11.96\ M$$

From the relation in equation (2),

$$C_1V_1 = C_2V_2 \qquad (2)$$

Where C = Concentration and V = Volume

Since 100 ml of 2 m HCL is required, hence, 11.96 x V_1 =2 x 100, therefore V_1 =16.72 ml. It therefore implies that 16.72 ml of HCL acid was dissolved in 100 ml of distilled water in a standard flask to obtain the desired concentration.

Weight Loss Measurements

Weight loss measurement were performed on 10 mild steel coupons in 2 M HCL solution with and without the addition of 10 ml of plant extract as the corrosion inhibitor. All the mild steel strips were rectangular in shape having dimensions 6cm x 4cm x 0.08 cm with a small hole of 2mm diameter near the upper edge of the strip for handling. Each sample was weighed using weighing balance and the beakers to which the coupons are inserted were all labeled to differentiate them. The specimens were immersed in beaker containing 100 ml of the acid solution at 32^oC and this volume was kept constant for all beakers.

One of the clean coupons was immersed in the absence of inhibitor to serve as the control same. Three of the clean coupons were again immersed completely in the inhibited acidic solution. Subsequent test were also carried out on the remaining six coupons through hybridization of extract put in acidic solution, such that the extract were varied in percentage.

The duration of the immersion was 24 hours at 32^oC (305 k), progressively for 7 days from the test solution, this is to allow for a measurable amount of the specimen to react in the solution.

For each experiment, a freshly prepared solution was used. At 24 hours interval, the samples were removed from the test solution, cleaned carefully with a tissue to remove any corroded product(s), dipped in acetone, dried and re-weighed to determine the weight loss parameters. From this observed data, the percentage inhibition efficiency (I.E), the Corrosion rate Cr (mm/y), weight loss W_L (g) and surface coverage (h) were determined.

Weight Loss

Loss in weight (W_L) as a result of corrosion can be calculated using equation (3);

$$W_L = W_i - W_f \quad (3)$$

Where W_i and W_f are the initial and final weights respectively.

Corrosion Rate

The corrosion rate of mild steel can be calculated from weight loss of coupons at a temperature of 305 K, hence at fixed concentration and varied immersion times,

$$Cr(mmy^{-1}) = \frac{K \times W_L}{AtD} \quad (4)$$

[13]

Where: K is a constant given by 87.6, W_L is the corrosion weight loss of mild steel (g) in the t, A is the surface area of the metal exposed (24 cm^2), t is the exposure time (hrs) and D is the density of mild steel (7.8 g/cm^3).

Corrosion Inhibition Efficiency

The percentage of inhibitor efficiency (I.E) was computed using equation (5);

$$I.E = \frac{Wo - Wi}{wo} \times 100 \quad (5)$$

[14]

Surface Coverage

The degree of surface coverage of mild steel by molecules of the inhibitors at varied immersion time and at room temperature was calculated using equation (6)

$$h = \frac{Wo - Wi}{Wo} \quad (6)$$

[14]

Inhibitor Preparation

Table 1 provides a summarized list of the percentage combination of the three leaf extracts of plants used for the experiment.

Table1. *Prepared Samples for Plant Extracts Used*

S/No.	Code	Description
1	A1 A2 A3	Neem leaves extract (100%) Bitter leaves extract (100%) Moringa leaf extract (100%)
2	B1 B2 B3	90% Neem leaf extract with 10% Moringa leaf extract 80% Neem leaf extract with 20% Moringa leaf extract 70% Neem leaf extract with 30% Moringa leaf extract

RESULTS AND DISCUSSION

The results were obtained from experiment carried out at room temperature.

Table2. *Corrosion for Mild Steel in 2M HCL in the Absence of Inhibitor*

Exposure time (days)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (mm/day) x 10^{-3}
1	13.9	13.80	0.10	2.51
2	13.9	13.68	0.22	1.93
3	13.9	13.55	0.35	2.57
4	13.9	13.43	0.47	2.37
5	13.9	13.30	0.60	2.24
6	13.9	13.15	0.75	1.99
7	13.9	12.70	1.20	3.31

Table 2 provides the data obtained for mild steel in 2M HCL in the absence of inhibitor over an immersion period of 7days. It reflects that for the un-smeared coupon (control), there is a gradual increase of mass loss (g) and corrosion rate (mm/day) from 0.10 – 1.20 and 1.93 x 10^{-3} – 3.31 x 10^{-3} respectively with increased immersion time. Furthermore, there is a significant increase of weight loss on the 7th day. The results of the inhibitor free solution manifested higher level in terms of weight loss and corrosion rate compared with those that have concentrations of inhibitor in the test solution. This destruction of the material is a clear evidence of corrosion taking place within the solution. The acid accelerated the process of the material’s destruction.

Table3. *Corrosion Rate for Mild Steel in 2M HCL in the Presence of 100% Neem Leaf Extract*

Inhibitor	Days (hrs)	Conc. (ml)	W_I (g)	W_F (g)	W_L (g)	H	I.E (%)	C_R(mm/day) x 10^{-3}
A1	1	20	13.35	13.31	0.04	0.60	60	0.77
	2	20	13.35	13.26	0.09	0.58	58	0.87
	3	20	13.35	13.18	0.17	0.52	52	1.09
	4	20	13.35	13.12	0.23	0.51	51	1.11
	5	20	13.35	13.04	0.31	0.48	48	1.19
	6	20	13.35	12.96	0.39	0.48	48	1.25
	7	20	13.35	12.72	0.63	0.47	47	1.74

A1=Neem leaf extract

Table 3 shows the corrosion parameters of 100% Neem leave extract (inhibitor) for mild steel in 2M HCL acid test solution, the values of which were obtained after 7 days immersion period. It was observed that the values of weight loss (g) and corrosion rate (mm/day) increases from 0.04 – 0.63 and 0.77 x 10^{-3} – 1.74 x 10^{-3} respectively. Similarly, the inhibition efficiency reduces with immersion time. Average values obtained over 7 days reveals that weight loss was 0.26g, corrosion rate 1.14 x 10^{-3} mm/day and average inhibition performance of 52% manifested. It is obvious that the inhibition property of the Neem extract decreased with time, an indication of instability of the extract with time.

Table4. *Corrosion Rate for Mild Steel in 2M HCL in the Presence of 100% Bitter Leaf Extract.*

Inhibitor	Days (hrs)	Conc (ml)	W_I (g)	W_F (g)	W_L (g)	H	I.E (%)	C_R(mm/day) x 10^{-3}
A2	1	20	13.34	13.31	0.03	0.69	69	0.58
	2	20	13.34	13.26	0.08	0.63	63	0.77
	3	20	13.34	13.21	0.13	0.63	63	0.83
	4	20	13.34	13.15	0.19	0.59	59	0.91
	5	20	13.34	13.08	0.26	0.58	58	0.97
	6	20	13.34	13.00	0.34	0.54	54	1.09
	7	20	13.34	12.77	0.57	0.52	52	1.57

A2=Bitter leaf extract

Table 4 shows the corrosion parameters of 100% bitter leaf extract (inhibitor) for mild steel in 2M HCL acid test solution, the values of which were also obtained after 7 days immersion period. It was observed that the values of weight loss (g) and corrosion rate (mm/day) increases from 0.03 – 0.57 and 0.58 x 10^{-3} – 1.57 x 10^{-3} respectively. Similarly, the inhibition efficiency reduces with immersion time. Average values obtained over 7 days reveals that weight loss was 0.22 g, corrosion rate 0.96 x 10^{-3} mm/day and average inhibition performance of 59% manifested. The result indicates Bitter leaf as a better inhibitor than Neem leaf as it concerns decrease in corrosion and weight loss values displayed by it over the studied period. The surface coverage (H) values are very useful in explaining the adsorption characteristics.

Table5. *Corrosion Rate for Mild Steel in 2M HCL in the Presence of 100% Moringa Leaf Extract*

INHIBITOR	DAYS (HRS)	CONC. (ML)	W_I (G)	W_F (G)	W_L (G)	H	I.E (%)	C_R(MM/DAY) X 10^{-3}
A3	1	20	14.33	14.30	0.02	0.84	84	0.38
	2	20	14.33	14.29	0.04	0.80	84	0.38
	3	20	14.33	14.23	0.10	0.75	75	0.64
	4	20	14.33	14.17	0.16	0.67	67	0.77
	5	20	14.33	14.10	0.23	0.60	60	0.89
	6	20	14.33	14.01	0.32	0.57	57	1.03
	7	20	14.33	13.82	0.51	0.57	57	1.40

A3=Moringa leaf extract

Table 5 shows the corrosion parameters of 100% Moringa leaf extract for mild steel in 2M HCL acid test solution, the values of which were also obtained after 7 days immersion period. It was observed that the values of weight loss (g) and corrosion rate (mm/day) increases from 0.02 – 0.51 and 0.38 x 10^{-3} – 1.40 x 10^{-3} respectively. The maximum of 84% inhibition efficiency is achieved even at 10 ml quantity of the inhibitor concentration after 48 hrs exposure time. Similarly, the inhibition efficiency reduces with immersion time. The average weight loss is 0.19g and corrosion rate is 0.78 x 10^{-3} mm/day for studied time period.

Figure 4show how the values of the weight loss (g) vary with immersion time for the un-smeared coupon (control) and the three smeared coupon.

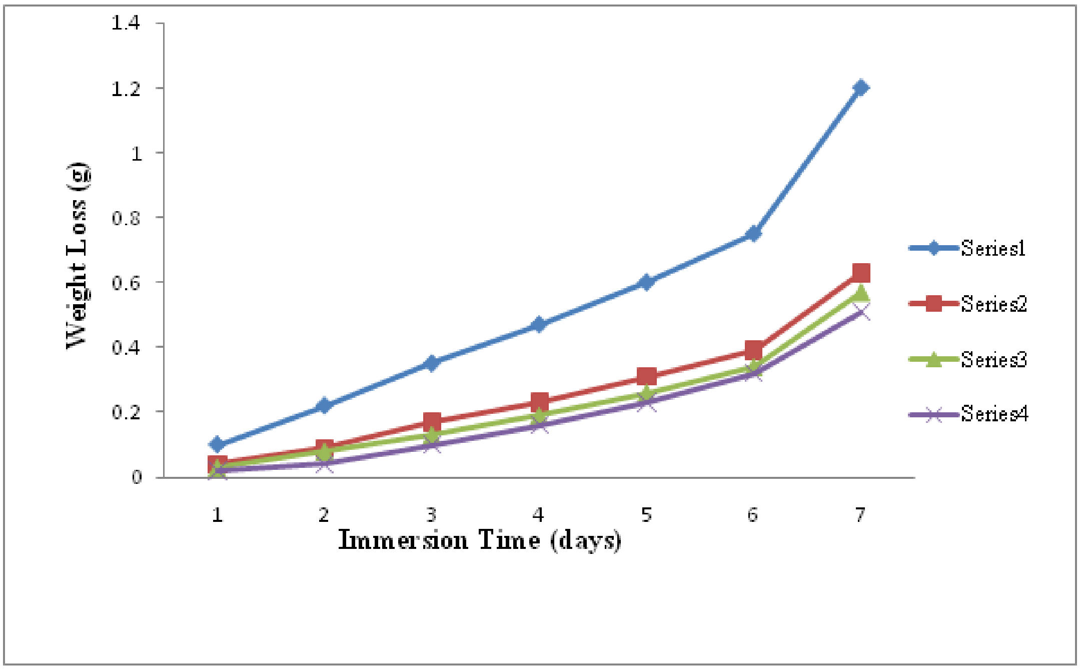

Figure4. *Variation of Mass Loss with Different Immersion Time on Mild Steel in 2M HCL.*

Series 1 = un-smeared coupon (control)

Series 2 = Azadirachhtaindica

Series 3 = Vernoniaamygdalina

Series 4 = Moringa Oleifera

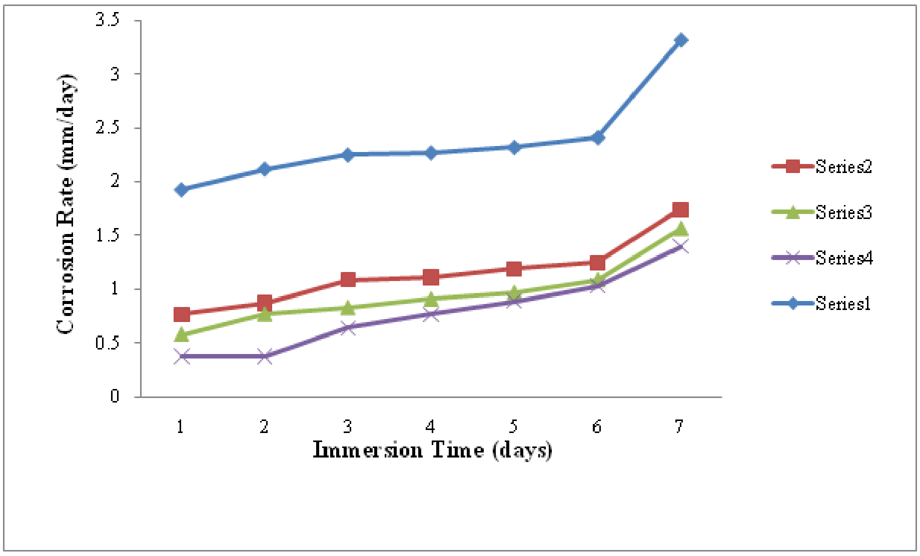

Figure5.*Variation of Corrosion Rate with Immersion Time*

From Figure 5, the three coupons were found to have a progressive corrosion rate up to 168 hrs while the un-smeared coupon (control) experienced a rapid increase in weight loss. The smeared coupons (*Azadirachhtaindica* and *Vernoniaamygdalina*) were observed to have almost the same corrosion rate and weight loss up to 168 hours but *Azadirachtaindica* had higher weight loss than the *Vernoniaamygdalina*. *Moringa Oleifera* had displayed less value of corrosion rate and weight loss compared to the others. *Moringa Oleifera* (A3) showed better inhibition performance than the other plants extract tested with an average efficiency of 67%. This is because of the lesser values of weight loss and corrosion rate displayed by it coupled with its high level of inhibition as against that of A1 and A2 with 52% and 59% respectively.

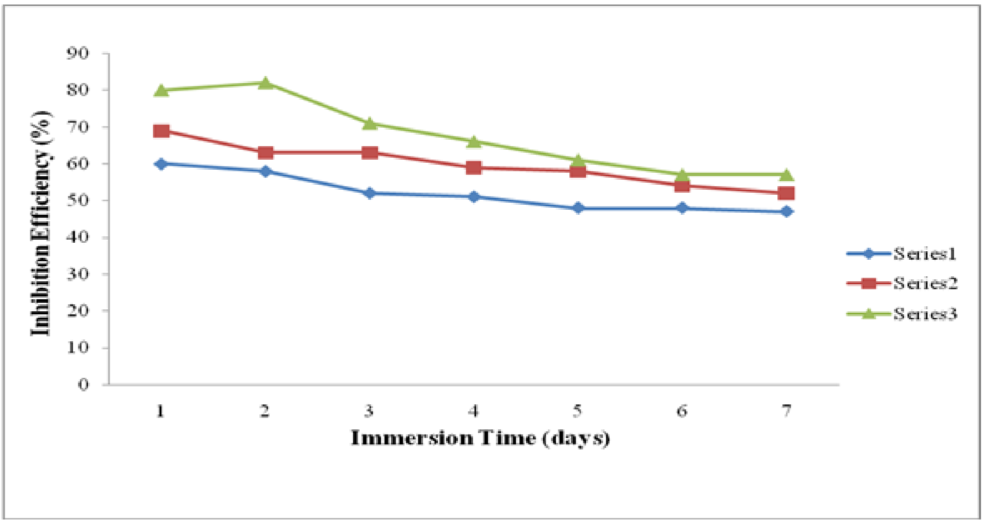

Figure6. *Inhibition efficiency with time of immersion*

Series 1 = Moringa Oleifera Series

Series 2 = Vernoniaamygdalina

Series 3 = Azadirachhtaindica

Figure 6 indicates that although the three smeared coupons were observed to have almost the same efficiency, the *Vernoniaamygdalina* was slightly higher in efficiency than the *Azadirachtaindica*. However, *Moringa Oleifera* showed better inhibition performance. Maximum inhibition efficiency was achieved at 84% after 48 hrs immersion period for *Moringa Oleifera.*

Since Moringa exhibited better inhibition efficiency than the other plant extract tested, it was used to hybridize it with Neem leaf extract to see if it will enhance the efficiency of Neem leaf extract which is in abundance locally. Table 6 provides the result obtained after varying the percentage of Moringa extract in Neem extract.

From Table 6, a combination of 90:10 percentage weight of Neem to Moringa leaf extract(B1) maintained almost the same trend with that of 100% Neem extract in terms of weight loss, corrosion rate and inhibition performance. However, there is a slight reduction in weight loss and corrosion rate on the 4th, 5th, 6th and 7th day with an increase of average inhibition efficiency from 52% to 53%. For a ratio of 80:20, (B2), the weight loss, corrosion rate and inhibition efficiency maintained the same rate after 96 hrs immersion period. Subsequently, there is a significant slowing down of weight loss and corrosion rate on the 5th and 7th day which increased its average inhibition performance to 54%. When a ratio of 70:30 percentage weights was tested, greater interaction was achieved in the solution which inhibited the destruction of the material. This combination exhibited the best hybrid performance than the other hybrid extracts. A result that showed a much reduction in weight loss and corrosion rate values while also maintaining an average inhibition performance of 60%.

Table 6. *Hybridization of Neem and Moringa Oleifera Leave Extracts in %.*

Inhibitor	Days (hrs)	W_i (g)	W_f (g)	W_L (g)	H	I.E (%)	C_R(mm/day) x 10^{-3}
B1	1	13.45	13.41	0.04	0.60	60	0.77
	2	13.45	13.36	0.09	0.58	58	0.87
	3	13.45	13.29	0.16	0.54	54	1.03
	4	13.45	13.22	0.23	0.51	51	1.11
	5	13.45	13.16	0.29	0.51	51	1.12
	6	13.45	13.08	0.37	0.50	50	1.19
	7	13.45	12.83	0.62	0.48	48	1.71
B2	1	14.25	14.21	0.04	0.63	63	0.70
	2	14.25	14.16	0.09	0.58	58	0.87
	3	14.25	14.09	0.16	0.54	54	1.03
	4	14.25	14.03	0.22	0.53	53	1.06
	5	14.25	13.96	0.29	0.51	51	1.12
	6	14.25	13.88	0.37	0.50	50	1.19
	7	14.25	13.66	0.59	0.50	50	1.63
B3	1	14.52	14.49	0.03	0.69	69	0.58
	2	14.52	14.45	0.07	0.68	68	0.67
	3	14.52	14.38	0.14	0.60	60	0.90
	4	14.52	14.33	0.19	0.59	59	0.91
	5	14.52	14.27	0.25	0.58	58	0.96
	6	14.52	14.20	0.32	0.57	57	1.03
	7	14.52	13.96	0.56	0.54	54	1.49

B1 = 90% Neem leaf extract with 10% Moringa leaf extract

B2 = 80% Neem leaf extract with 20% Moringa leaf extract

B3 = 70% Neem leaf extract with 30% Moringa leaf extract

Thus, hybridization of *Moringa Oleifera* with Neem leave extracts at a ratio of 30:70 made a positive impact in the inhibition of corrosion on mild steel. There was an average weight loss from 0.26 g – 0.25 g for B1 and B2 while the average weight loss was 0.26 g – 0.22 g for B3. Similarly, the corrosion rate was reduced from 1.14 x 10^{-3} mm/day to 1.11 x 10^{-3}, 1.08 x 10^{-3} and 0.93 x 10^{-3} mm/day for B1, B2 and B3 respectively.

CONCLUSIONS

Natural plant extract have been shown to help in the inhibition of corrosion. Some plants that exist in abundance may have low inhibition capacity to inhibit corrosion possibly because of the low amount of chemical compounds needed to stop the process of corrosion. However, a plant that has shown to be useful in the prevention of corrosion can be used to hybridize it with a low performance plant extract with a view to utilizing all plants instead of wasting the natural resources. However, as has been seen in this experiment, an appropriate ratio must be found in order to make the hybrid compounds perform well. Neem leaf extract in combination with Moringa at a ratio of 70:30 percentage weight produced hybridized inhibition extract that gave superior corrosion inhibition performance. The corrosion inhibition performance in almost all the sited plant extracts was due to the presence of surface active constituents which normally enhanced the film formation over the metal surface, thus mitigating corrosion. Inspection of the chemical structures of some of the constituents of the plants extracts reveal that all molecules are long chain hydrocarbons carrying a polar group(s) at one or either ends. Abundance of Neem leave in the locality where this experiment took place has made Neem tree an economic tree instead of being a waste.

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