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Evaluation of dwarf ixora coccinea extract in corrosion inhibition of mild steel in an acidic medium

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Abstract

The efficacy of the dwarf ixora coccinea extract in corrosion inhibition of mild steel in an acid medium was evaluated using a mild steel specimen of dimensions 10cm x 1cm x 1cm obtained locally and analysed for its constituent composition using spectrometer. The mild steel bar was cut into 61 pieces and notched into appropriate shape suitable for impact test. The samples were degrease using ethanol and immersed for two minutes in 10% HNO_3 to activate the surface. The bars were dried to prevent the formation of a passivation layers that may interfere with the results. The leaves of coccinea plant were dried and ground to fine powder and the extraction was done using soxhlet extractor. Twelve (12) glass jars of the extracts were used for the experiment. Six of which contain 500ml of the corrosive media (0.5, 1.0M, 1.5M, 2M of HCL, sea water and distilled water without Ixora coccinea extract while the other six contain the mixture of the corrosive media and the extract. Five specimens were completely immersed in each jar and allowed to stand for 35 days (840hrs); after 7 days interval (168hrs), the specimens were removed, washed, dried and evaluated for corrosion. Results obtained showed that strength of mild steel in various media (0.5M, 1M, 1.5M, 2.0M HCL, sea water and distilled water) without the extract after 35 days exposure period were 53, 52, 47, 43, 58 and 59j respectively; and the corresponding impact strength for the mild steel in the ixora coccinea extract were 57,55, 52, 51,59 and 61j respectively. It was also observed that the impact strength is dependent on the thickness of the mild steel. Generally, ixora coccinea extract inhibited the corrosion of mild steel in HCL acid and failed to inhibit corrosion in sea and distilled water media.

Keywords: Corrosion, mild steel, ixon coccinea, extracts, acid

1. Introduction

Corrosion can be defined as the reaction of an engineering material with its environment leading to a consequent deterioration in properties of the material. According to Eddy (2008), corrosion is the deterioration of materials by electrochemical reaction with its surrounding environment. Corrosion is costly and dangerous. Huge amounts of money are spent annually for the replacement of corroded structures, machinery, and components. Premature failure of bridges or structure due to corrosion can also result in human injury, loss of life, and other damages (Ajeel *et.al*. 2011). Taking all these factors into account, it becomes obvious why those Engineers and material scientist involved with the design and/or maintenance of structures and equipment should have a basic understanding of the steel corrosion process. Mild steel is one of the major construction materials, extensively used in chemical and allied industries for the handling of acid, alkali and salt solution. The wide industrial usage of mild steel have been driven by a number of issues, in particular its low cost and availability for the manufacturing of reaction vessels, cooling tower reservoirs and pipelines (Fayomi and popoola; 2012).

Theability of mild steel to resist corrosion attack in some environment is poor and a continuous search for method (s) for improving this limitation becomes necessary. Acid solutions are extensively used in industry; the most important applications are industrial acid cleaning, acid descaling and oil well acidizing. Hydrochloric acid is one of the most difficult environments to handle from the standpoints of corrosion and materials constructions. Another corrosion aggressive environment is seawater. Seawater systems are used by many industries such as shipping, offshore oil and gas production, power plants and coastal plants. Exposure of these structures in marine environment will cause corrosion that finally leads to total damage. Therefore, it is very important to study corrosion in these environments

Although, different techniques have been reported to address the degradation behavior of mild steel in some environments. Of all these methods, the use of inhibitors for controlling and reducing the corrosion rate of mild steel have been reported to be effective in contact with aggressive medium. The inhibitors action is due to the formation of protection film onto the metal surface blocking the metal from the corrosive agents present in solution (Abu-Dalo and Othman; 2012). Virtually, all acid inhibitors are organic compounds. And because most of them are expensive and toxic to the environment, investigation and evaluation of naturally occurring substances have continued to receive attention. Ibrahim *et al.* (2011) reported that natural corrosion inhibitors are mostly obtained from medicinal plants, aromatic spices, and herbs, but little has been done about researching the capabilities of fruits, flowers and vegetables peels' extracts as corrosion inhibitors.

Many researchers have examined various naturally occurring substances as corrosion inhibitors for different metals in various environments, and reported their metals corrosion inhibitive effectiveness. Odionenyi (2009) [8] studied the corrosion inhibition of mild steel in H_2SO_4 by ethanol extract of some vegetables.

Oladele and Okoro (2011), Badmus *et al* (2009) investigated the corrosion of mild steel in orange juice and revealed that the corrosiveness of sweet orange juice was mainly a function of its acidity. Harshida *et al.* (2012) reported aliphatic amines as corrosion inhibitors for zinc in hydrochloric acid. Faltermeier (1998) evaluated industrial copper corrosion inhibitors. Taleb and Mehad (2011) investigated the corrosion inhibition of mild steel in 2M HCl using aqueous extract of Eggplant peel. Yang-yang (2010) studied the mechanical strength and removal of a protective iron carbonate layer. Arthur *et al.* (2013) reviewed the assessment of polymeric materials used as corrosion inhibitor of metals and alloys. Thangam (2007) studied the inhibition of corrosion of carbon steel in Dam water by sodium molybdate system. Jeyasunari *et al.* (2013) investigated the electrochemical and surface corrosion inhibition of carbon steel. Sangeetha (2012) reported Banana peels as eco-friendly corrosion inhibitor for steel in sea water. Samarin *et al.* (2012) studied the extraction and utilization of phenolics in potato peels. Ajeel *et al.* (2011) studied the effects of H_2SO_4 and HCl concentration on the corrosion resistance of protected low carbon steel.

The Ixora coccinea used for this research is a species of flowering plant in the Rubiaceae family. It is a common flowering shrub native to southern India and Sri Lanka. It has become one of the most popular flowering shrubs in south Florida gardens and landscapes. Its name derives from an Indian diet.

In recent years, study of the corrosion has become significant. A lot of time and money have been spent to study corrosion behaviors of materials in different environment. All the studies were aimed at enhancing the safety of equipment's, structures, preventing leakage of gas and oil pipelines and water flow channels.

Corrosion is expensive and can pose danger to safety. It is costly to replace equipment, structures and other miscellaneous items that have been damaged as a result of corrosion. It is hazardous when corrosion has weakened a portion of a vessel, bridge or other structure causing it to fail, resulting in injury to persons and fire or explosion. Moreover, the currently used corrosion inhibitors are mostly toxic and harmful to environment and human such as chromate and nitrate which are carcinogenic. In order to understand the potential of Ixora Coccinea extract as a corrosion inhibitor, this research, will attempt to investigate its corrosion inhibition effects on mild steel in acidic, seawater and distilled water solutions.

The aim of this project is to examine the effects of ixorra coccinea (PPE) on the inhibition of corrosion and the impact strength of the mild steel after exposure. The specific objectives are: to study the corrosion rate of mild steel in acidic media; to investigate the effects of ixorra coccinea (PPE) on corrosion and mechanical properties of mild steel; to investigate the inhibition efficiency of ixorra coccinea leaf extract on mild steel corrosion in acidic media (HCl, seawater and distilled); to monitor the performance of the inhibitor at various concentrations; to offer useful recommendation on the use of ixorra coccinea (PPE) for the inhibition of the corrosion of mild steel.

2. Materials and Method

2.1 Materials

The following are the materials, equipment and reagents that were used to conduct the experiments upon which this research work is based.

2.1.1 Preparation of the Metal Specimens

A mild steel specimen of dimensions 10cm×1cm×1cm was obtained locally and was analyzed for its constituent composition using a spectrometer; the values are shown in Table 2.1. The mild steel bar was cut into 61 pieces and then notched into appropriate shape suitable for impact test. The samples were first degreased using ethanol followed by immersion for two minutes in 10%HNO_3 to activate the surface. Afterword, they were washed using distilled water followed by rinsing with ethanol. The bars were dried and stored in a desicator to prevent any reaction with the environment or the formation of a passivation layer which might interfere with the results of the experiment. The initial weight of each sample was taken using the electronic weighing machine and recorded.

Table 2.1: chemical composition of the mild steel used.

Element	C	Mn	Si	P	S	Cr	Ni	Fe
% Composition	0.18	0.65	0.10	0.04	0.13	7.20	3.50	Balance

2.2 Reagents

All reagents used were HCL (0.5M, 1.0M, 1.5M, 2.0M) Seawater and Distilled water. Corresponding inhibitor volumes were added to them to make up inhibited corrodents. Other reagents that were used are ethanol and acetone.

2.3 Equipment and Apparatus

An electronic FAJA weighing balance of model FA2004A and weighing capacity 0.0001- 200g was used for all forms of weighing involved in this study. The other apparatus that were used include: Blow drier; Soxhlet extractor, leigbig condenser, rubber pipes- for extraction setup; Conical flasks, beakers, measuring cylinders and other similar glass wares; Reaction vessels and Retort stands/ clamps. Other materials include cotton wool for cleaning metal surface, suspension threads and sticks.

2.4 Methods

2.4.1 Extraction of Ixora Coccinea

The leaves of *I. coccinea*plant were air dried and then ground to fine powder. About 45g of this was weighed and then extraction was carried out using a Soxhlet extractor with 400mls of ethanol for 3 hours. After extracting for 3 hours and cooling, the residue was poured out on a clean cloth and allowed to dry while the extract in ethanol was left in the open for the ethanol to evaporate. After evaporation, the extract was obtained in the solid form. Stock solution of the extract in the respective corrodent solutions were prepared by weighing 1.2g of the dried solid extract, dissolving in a little quantity of ethanol(less than 7mls) and then mixed with 1000mls of the corrodent.

Fig 2.1: dwarf ixora coccienea samples

2.4.2 Weight loss measurement

A total of 12 glass jars were used for this experiment. Six of them contained 500ml of the corrosive media (0.5M, 1.0M, 1.5M, 2.0M of HCl, sea water and distilled water) without the ixoracoccinea extract and the remaining six contained the mixture of the corrosive media and the extract. Five specimens were completely immersed in each jar. The setups were allowed to stand for 35 days (840 hours). At interval of 7 days (168 hours), a sample of the specimen was removed from each jar, washed with distilled water, cleaned and dried.

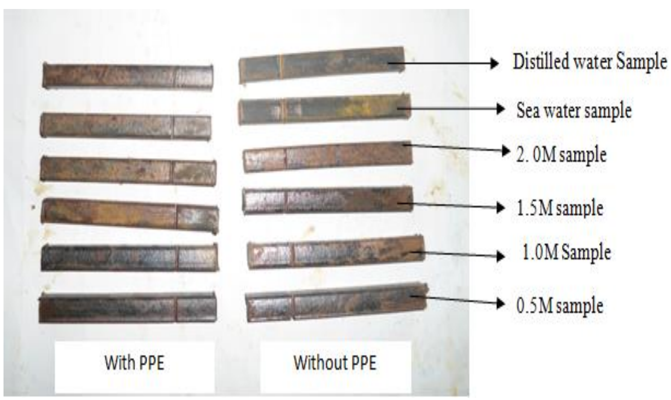

Fig 2.2: Mild steel samples after 7 days exposure in various corrosive media

The final weight W_1 of each sample was obtained using the electronic weighing balance and the weight loss W, was determined using the equation (1) suggested by Callister (1997)

$$W=W_0-W_1 \qquad \ldots (1)$$

The corrosion rate, or the rate of material removal as a consequence of the chemical action, is an important corrosion parameter. This may be expressed as the corrosion penetration rate (CPR), o.0r the thickness loss of material per unit of time. It is evaluated from the expression

$$corrosion\ penetration\ rate = \frac{KW}{\rho AT} \qquad \ldots (2)$$

Where;

W = the weight loss after exposure; T = time; ρ = represent the density; *A* = exposed specimen area; *K* is a constant, its magnitude depending on the system of units used. The CPR is conveniently expressed in terms of either mils per year (mpy) or millimeters per year (mm/yr). In the first case K = 534 to give CPR in mpy (where 1 mil = 0.001 in.), and *W*, ρ, *A*, and *t* are specified in units of milligrams, grams per cubic centimeter, square inches, and hours, respectively. In the second case, K = 87.6 for mm/yr, and units for the other parameters are the same asfor mils per year, except that *A* is given in square centimeters. For most applications a corrosion penetration rate less than about 20 mpy (0.50 mm/yr) is acceptable.

Also the inhibition efficiency (%IE) of PPE was calculated using equation (3)

$$\%I.E = \frac{CR_{Blank} - CR_{Inh}}{CR_{Blank}} \times 100 \qquad \ldots (3)$$

CR_{Blank}= corrosion rate in the absence of the inhibitor (mpy)
CR_{Inh}= corrosion rate in the presence of the inhibitor (mpy)
The specimens were then subjected to impact measurement using the izod impact testing machine.

2.4.3 Impact Strength Measurement

The Izod impact testing machine was used to determine the impact energy (J) of the specimens before and after corrosion. This machine consists of a vice which holds the test piece in an upright position, a key which holds the hammer a distance 83cm above the impact point. The specimens were prepared to standard (length=10cm, notch at 45º with a depth of 3mm). They were then fixed in the vice of the machine and then the hammer was released by turning the black knob clockwise and allowed to hit the specimen. The hammer was stopped using the brake by pushing the red knob up. The impact strength (J) was taken from the scale and recorded. From the scale, one division represents 2Joules. The test was conducted for both the inhibited and uninhibited specimens.

During this experiment, it is important to ensure that your arms and hands are not in the pendulum. It can easily break your arm.

Fig 2.3: mild steel samples after 35 days of exposure

Fig 2.4.4: impact test samples before and after fracture

3. Results and Discussions

3.1 Results

The results of this research work are presented in table 1-8 and figure 1-7

Table 1: Weight loss (g) of mild steel in different medium under varying exposure period without ixora extract

Exposure period (Days)	Hydrochloric Acid				Seawater	Distilled Water
	0.5M	1.0M	1.5M	2.0M		
7	1.66	3.07	3.35	07.99	0.33	0.26
14	1.99	3.57	4.45	08.79	0.34	0.27
21	2.48	4.29	5.81	11.31	0.37	0.29
28	2.51	4.68	6.88	11.73	0.41	0.31
35	2.52	4.99	6.92	11.77	0.47	0.33

Table 2: Weight loss (g) of mild steel in different medium under varying exposure period with ixora extract

Exposure period (Days)	Hydrochloric Acid				Seawater	Distilled Water
	0.5M	1.0M	1.5M	2.0M		
7	1.20	1.70	1.78	2.33	0.68	0.35
14	1.51	1.92	2.11	2.49	0.73	0.58
21	2.22	2.63	3.09	3.32	0.89	0.70
28	2.34	3.10	4.22	4.50	0.99	0.80
35	2.39	3.22	4.33	4.66	1.10	1.00

Table 3: Corrosion penetration rate of mild steel specimens in various media without ixora extract using weight loss method

Exposure Period (Days)	0.5M (mpy) $\times10^{-3}$	1.0M (mpy) $\times10^{-3}$	I.5M (mpy) $\times10^{-3}$	2.0M (mpy) $\times10^{-3}$	Seawater (mpy) $\times10^{-3}$	Distilled Water (mpy)$\times10^{-3}$
7	06.72	12.43	13.56	32.35	01.34	01.05
14	04.03	07.23	11.03	17.80	00.69	00.55
21	03.35	05.79	07.84	15.26	00.50	00.39
28	02.54	04.74	06.96	11.87	00.42	00.31
35	02.04	04.04	05.44	09.53	00.38	00.27

Table 4: corrosion penetration rate of mild steel specimens in various media with ixora extract using weight loss method

Exposure period (Days)	0.5M (mpy) $\times10^{-3}$	1.0M (mpy) $\times10^{-3}$	I.5M (mpy) $\times10^{-3}$	2.0M (mpy) $\times10^{-3}$	Seawater (mpy) $\times10^{-3}$	Distilled Water (mpy)$\times10^{-3}$
7	04.86	06.88	07.21	09.43	02.75	01.42
14	03.05	03.89	04.27	05.04	01.48	01.17
21	02.76	03.31	03.89	04.18	01.12	00.90
28	02.46	03.14	04.27	04.56	01.00	00.81
35	01.94	02.61	03.57	03.77	00.89	00.81

Table 5: Inhibition Efficiency (%IE) of dwarf ixora extract from weight loss measurement

Exposure period (Days)	0.5M	1.0M	I.5M	2.0M	Seawater	Distilled Water
7	28	45	47	70	-49.20	-39.09
14	24	46	61	72	-58.48	-61.97
21	18	43	50	73	-58.22	-62.00
28	03	34	39	62	-63.73	-68.04
35	05	34	36	60	-66.19	-73.17

Table 6: Impact test result of un-corroded specimen

Impact strength (J)
66

Table 7: The Impact strength (J) of mild steel in different medium under varying exposure period without ixora extract

Exposure period (Days)	Hydrochloric Acid				Seawater	Distilled Water
	0.5M	1.0M	1.5M	2.0M		
7	62	61	59	56	65	65
14	59	60	55	54	63	63
21	56	55	53	51	61	62
28	54	53	49	50	61	62
35	53	52	47	43	58	59

Table 8: Impact strength (J) of mild steel in different medium under varying exposure period with ixora extract.

Exposure period (Days)	Hydrochloric Acid				Seawater	Distilled Water
	0.5M	1.0M	1.5M	2.0M		
7	64	63	62	60	65	66
14	62	62	60	58	64	66
21	61	61	58	57	62	64
28	60	59	57	55	60	64
35	57	55	52	51	59	61

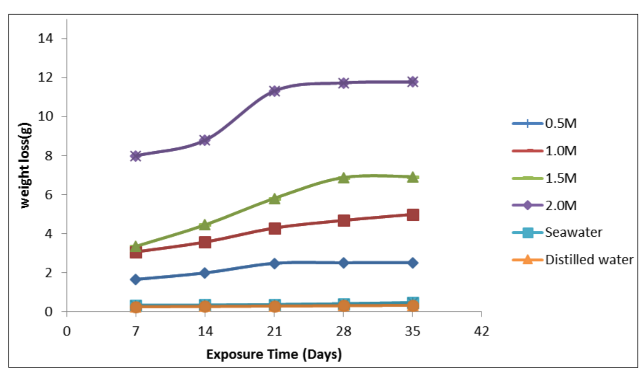

Fig 1: Graph of weight loss against exposure time in absence ixora coccinea extract

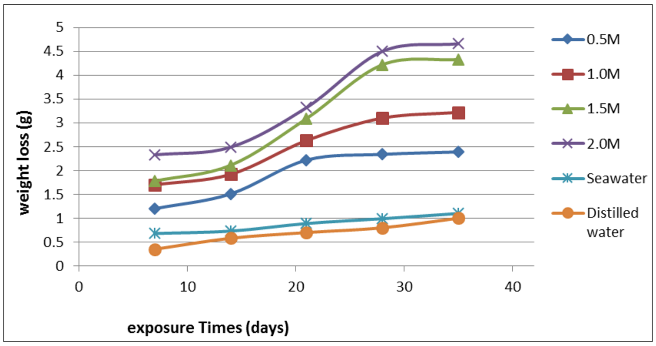

Fig 2: Graph of weight loss against exposure time of solutions containing ixoraccoccinea extract

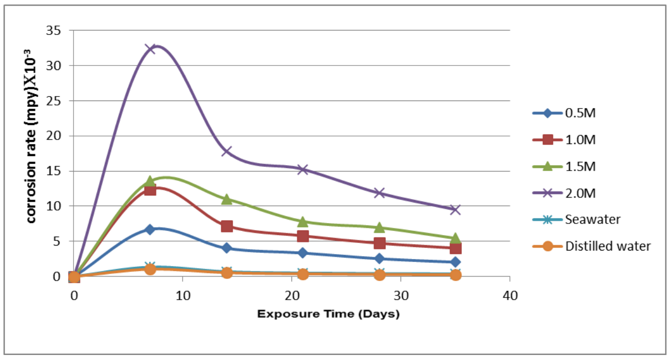

Fig 3: Corrosion Rate of mild steel specimens in various media without ixoraccoccinea extract using weight loss method.

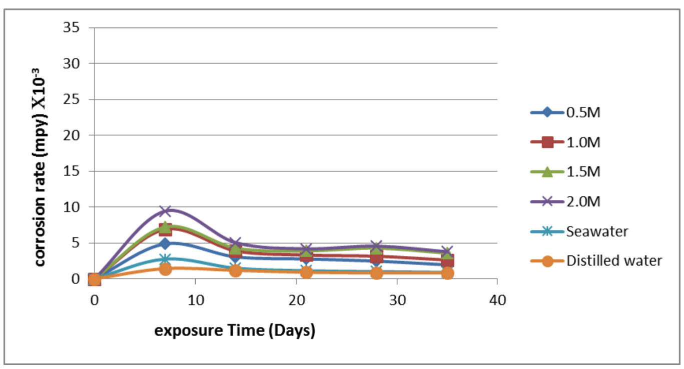

Fig 4: Corrosion Rate of mild steel specimens in various media containing ixora coccinea extract using weight loss method.

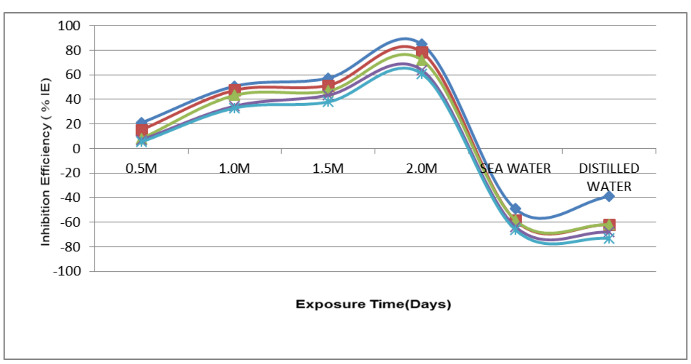

Fig 5: Graph of inhibition efficiency (%IE) against corrosive media at different time.

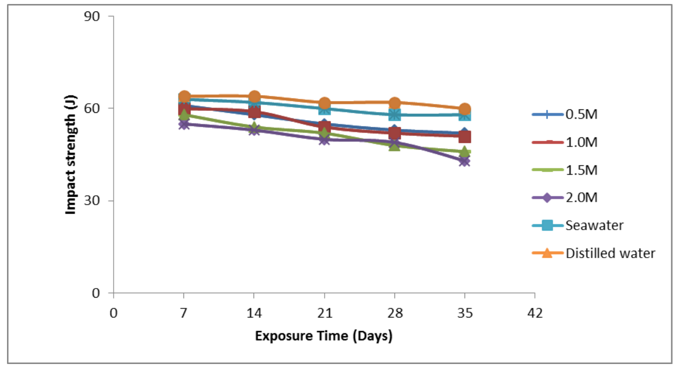

Fig 6: The impact strength (J) of mild steel in different medium without PPE under varying exposure time

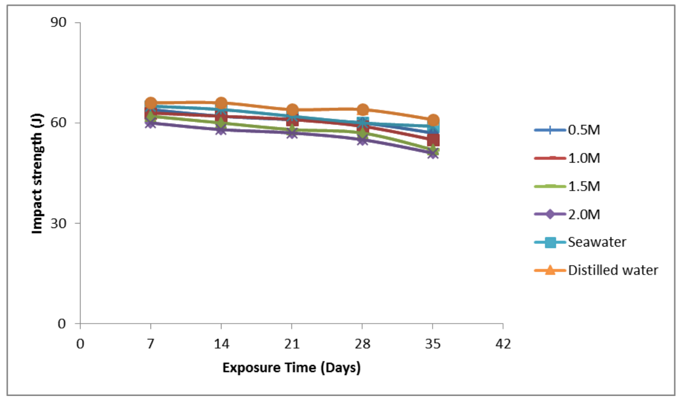

Fig 7: The impact strength (J) of mild steel in different medium containing PPE under varying exposure time

3.2 Discussions

The results showing the weight losses, corrosion rates, Inhibition efficiency and impact strengths are given in table 1- 4. Uniform corrosion was observed in almost all the mild steel bars immersed in the media.

3.2.1 Effects of corrosive media and ixora coccinea extract on weight loss of mild steel

The variation of weight loss (gram) with exposure time (hour) of each mild steel specimen removed from the various media (0.5, 1.0, 1.5, 2.0M HCl acid, sea and distilled water), without ixora coccinea extract are shown in figure 1, and the corresponding weight loss values of mild steel in different media, containing the extract are given in figure 2. In general, it was observed that the weight loss increases with increasing concentration of HCl acid and exposure time.

For the uninhibited corrosion process, the sharp increase in the weight loss of the samples in acid medium in the first 21days with marginal increase thereafter, can be attributed to the initial aggression of the acid on the surface of the metal which later decreased because of the dissolution of the iron oxide (FeO) in the acid medium and its presence will reduce the pH value of the HCl acid. For the inhibited corrosion process, the weight loss was observed to be lower compared to the uninhibited process; this may be attributed to the formation of protection film on the metal surface by the extract.

3.2.2 Corrosion rates of mild steel in the absence and presence of the extract

The corrosion penetration rate (CPR) of mild steel inserted in the various media (0.5, 1.0, 1.5, 2.0M HCl, sea and distilled water) for both processes were computed from weight loss measurement and plotted against the exposure time as presented in figure 4.3 and figure 4. The corrosion penetration rate is generally dependent on the exposure time and amount of weight loss over an exposure period. In acid media, there is a rapid rise in the rate of corrosion to a peak in the first 7 days. This is the active region during which corrosion is very fast due to the presence of oxygen. It is then followed by a sudden fall until about the 21 days. This is a transition period when the inhibitors are becoming effective (Carter, 1977). Finally, there is a gradual reduction in the rate of corrosion as exposure time increased. This is a passive period when inhibition has stabilized (West, 1986). CPR for mild steel was observed to increase with increasing concentration of HCl acid for both processes, 2.0M having the highest penetration rate and 0.5M having the least. CPR was generally observed to decrease with time.

In general, figure 4 shows that addition of ixora coccina extract has reduced the rate of corrosion in hydrochloric acid media but this rate is nearly constant for sea and distilled water over the exposure time for the two processes, which is justified by its constant weight loss given in figure 1 and figure 2.

3.2.3 Inhibition Efficiency of ixora coccinea extract on mild steel

The computed data for the inhibition efficiency (%IE) using weight loss measurements is presented in table 4.5 and clearly illustrated in figure 5. It shows that as the inhibitor concentration increases in the various corrosive media, percentage of inhibitor efficiency also increases, which means that inhibitor efficiency is directly proportional to inhibitor concentration at a particular time. Thus, %IE of ixora coccinea increases with increasing concentrations of the acid. It also revealed that at a specified concentration, percentage inhibitor efficiency is inversely proportional to time. That is, as time increases, percentage inhibitor efficiency decreases.

The negative readings obtained for sea and distilled water showed that the weight loss in the media containing the extract is higher than the corresponding weight loss in the media without the extract. And thus, ixora coccinea extract cannot serve as a corrosion inhibitor in this media.

3.2.4 Impact strength of uninhibited and inhibited mild steel samples

The impact strength of mild steel specimen in various media (0.5, 1.0, 1.5, 2.0 M HCl, sea and distilled water), without the extract, after 35days exposure period are 53, 52, 47, 43, 58 and 59J respectively. And the corresponding impact strength for mild steel specimens in various media containing the extract are 57, 55, 52, 51, 59 and 61J respectively, while the impact strength of the un-corroded specimen is 66J. It was generally observed that the impact strength is dependent on the thickness of mild steel sample. The increasing molar concentration of the acid increases the CPR (figure 3 and 4) and consequently decreased the impact strength. Also, the higher the concentration of the ixora coccinea extract, the lower the weight loss of mild steel in the acid solution and the higher the impact strength of mild steel when compared with media having no extract.

The inhibitor efficiency is encouraging and this can be used in the industries as a substitute for the imported chemical inhibitors which will save a huge amount of money use for importation of inhibitors annually. In addition, using the ixora coccinea extract will reduce the loss of impact strength due to corrosion and helps in managing waste (peel) since waste management in a problem in Nigeria. The fact that this ixora coccinea extract is a natural extract which is environmental friendly and nontoxic to human is also a reason why the industries should key into it especially in this era where there is a big environmental challenge in the world as a whole

4. Conclusion

Within the test period and the prevailing environmental conditions, this study has led to the following conclusions;

i. The rate of corrosion of mild steel in HCl acid, sea and distilled water is affected by exposure period, concentration of the acid and the presence of ixora coccinea extract. The corrosion rate increases as the exposure period and the concentration of acid increases.
ii. Ixora coccinea extract inhibited the corrosion of mild steel in HCl acid and failed to inhibit corrosion in sea and distilled water media. The results showed increase in the inhibition efficiency with increasing ixora coccinea extract concentration in various acid media. An excellent inhibition level was obtained in 2.0M HCl containing the extract in the first 21 days.

In summary, this study has shown that ixora coccinea leaf extract can be used as corrosion inhibitor. As the concentration of the inhibitor produced increases, the corrosion rate decreases and the inhibitor has an optimum efficiency of about 73% IN 2.0M HCl which proved that its usage in the process industries will reduce drastically the corrosion rate. If ixora coccinea extract is used as corrosion inhibitor, it will increase the GDP of the Nation hence the standard of living and also make our environment less prone to pollution.

5. Recommendation

- The use of ixora coccinea extract (PPE) is recommended for acid environment, especially for media containing hydrochloric acid with high concentrations due to increase in the efficiency of inhibition.
- This extract can be used to aid the weight loss, the loss of impact strength and hence the corrosion rate of mild steel in any medium containing sea and distilled water.

Therefore, the use of ixora coccinea extract as an inhibitor to the corrosion of mild steel is recommended.

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