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CORROSION PROTECTION (PRE SCREENING) OF MILD STEEL USING AQUEOUS EXTRACT OF HONGE

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Abstract: Corrosion is a deterioration process for metals and an important aspect in industrial development as it causes enormous damage to infrastructure. All metals like Iron, aluminium, copper, steel etc. will eventually corrode. Corrosion is a natural and a spontaneous, thermodynamic process, hence it cannot be stopped. The rate of corrosion can be controlled, even though. Along with the conventional methods of corrosion prevention, certain chemicals are added to controlled environments to reduce the corrosivity of these environments. But with the advent of green chemistry more focus is being laid on the use of easily biodegradable and environmentally friendly alternative are being explored. In this aspect the plant extracts are being developed as green corrosion inhibitors. In the present study plant extracts of Honge leaves (A) has been investigated for corrosion protection of mild steel for prescreening only.

Index Terms **- Corrosion, inhibitors, mild steel, plant extracts**

I. INTRODUCTION

Corrosion is deterioration process undergone by various substances due to reaction with the environment/ atmosphere. Metals, polymers (plastics, glass, ceramics, concrete, brick, and composites all get corroded over a period of time on exposure to atmosphere. Corrosion of metals is an important aspect as it impacts the society and industry alike. Industries affected are air craft industry, air force, navy, automobile, oil and natural gas pipelines, construction industry, roads, sidewalks, bridges, nuclear reactors, power generation, water Infrastructure, statues, chemical industry, boilers, packaging, process industries, reinforced concrete etc. [1, 2] Corrosion is an electrochemical process, by which metals are oxidized by air or oxygen in the presence of moisture to form undesirable products, usually oxides. There are different types of corrosions such as Pitting corrosion, galvanic corrosion, crevice corrosion etc. Several countries have imposed stringent laws for corrosion inhibitors, such as Paris commission.

1.1 Paris commission

North Sea (U.K., Norway, Denmark, The Netherlands) countries came together in order to protect the marine environment, the regulations and guidelines set up for evaluation and testing of offshore chemicals, as well as harmonizing of procedures for these were set up under Paris commission (PARCOM) in 1990. According to (PARCOM) an ideal green inhibitor is non-toxic, readily biodegradable and shows no bioaccumulation [3, 4]

The focus was on two aspects first one being; the standardization of environment testing and the second is, to create a model to use the data in practical way.

Environmental testing consisted of testing the biodegradability, toxicity and bioaccumulation. In the study presented, Biodegradability was carried out using a modified procedure based on OECD 301D-for 28 days; this gives information about the persistence of the inhibitor in environment. Toxicity was evaluated using the organism at primary, secondary and tertiary level and is measured as LC50 and EC50. LC50 is the concentration of chemicals or the inhibitor required to kill of the 50% of the population of the species of organism used for the test. EC 50 is the concentration of chemicals or the inhibitor required to adversely affect (for example, loss of mobility) the 50% of the population of the species used for the test. Bioaccumulation gives the measure of the distribution of the product between octanol and water mixture, expressed as the log of octanol /water- partition co-efficient, log P_0/W.

Thus, PARCOM guidelines for a good inhibitor are summarized as:

Biodegradability – > 60% in 28 days

Marine toxicity – LC 50, EC 50 10mg/L
Bioaccumulation – log $P_0/W < 3$

In 2002, Harmonized Mandatory control system (HMCS) was implemented for the use, reduction and discharge of chemicals offshore. It requires a pre-screening process of the inhibitor used and the inhibitor must be greater than 20% biodegradable and also meet the following two criteria **[5].**

i) Biodegradation: >70% in 28 days (OECD 301A, 301E)
>60% in 28 days (OECD 301B, 301C, 301 F)
ii) Toxicity: > 10 mg/L (LC50 /EC50)
iii) Bioaccumulation: log P0/W < 3
[OECD- Organization for Economic Co-operation and Development]

Further, chemicals are ranked on calculated Hazard Quotient (HQ) in accordance with CHARM model **[6].** Generally lower the ranking the more Green the product is. A corrosion inhibitor under HMCS is considered green if all its components, HMCS-Pre-screening stage and the HQ value are <1.

In India specific guidelines have been imposed by the Petroleum and natural gas regulatory board Schedule-1E Corrosion Control. Indian Oil and Gas industries (ONGC / OIL etc) follow the environmental policy rules and regulations proposed by the ministry of Petroleum and natural gas, Government of India and UNEP guidelines. There are no specific guidelines to develop the green inhibitors. Hence with the green chemistry background, research has been carried out on water-soluble, zero toxic and easily biodegradable plant based materials or natural products and develop them into Green inhibitors for various metals in different environments like acidic medium, sea water, saline medium etc.

India is very rich in its biodiversity and home for Unani and Ayurvedic medicinal practices. There are several spices or herbs being used as home remedies. They are inexpensive, easily available and definitely possess no threat to the environment. Since most of the medicinal plants are grown and are better option over the synthetic chemicals focus is now on using these medicinal plants for corrosion protection. They are non-toxic to marine life and humans as they are being used in our day-to-day life as Unani and Ayurvedic medicines to cure ailments.

The development of Green corrosion inhibitor involves two aspects:

1. Experimental aspect: It is the inhibition efficiency of the inhibitor for the metal selected in a given medium. For this various tests are performed **[7]** which include Wheel test, Bubble test (Kettle), Static, Rotating Disc Electrode (RDE), Rotating Cylinder electrode (RCE) Jet impingement (JI), Rotating cage (RC), High temperature High pressure static (HTHPS), High temperature High pressure-Rotating disc electrode, High temperature High pressure-Jet impingement etc were evaluated for Oil and Gas applications. Field monitoring is also carried out at fields, to support the laboratory evaluation using weight loss, linear polarization resistance (LPR), Electrochemical impedance spectroscopy (EIS), Electrochemical Noise (EN) etc.

2. Environmental impact of the inhibitor: It is the second aspect as per the guidelines imposed by various countries with respective guidelines.

There has been considerable progress in corrosion science in recent days, especially to develop the Green corrosion inhibitors. Several of the plants and other natural products have been investigated as corrosion inhibitors for metals like aluminium, carbon steel etc. in various media. The environment friendly corrosion inhibitors from natural sources are being developed to minimize the use of chemical inhibitors. Gupta *et al* [8] have reported green inhibitors for mild steel in various corrosive media. Corrosion inhibition has been reported by azadirachta indica (neem) leaves and tubers of some of the plants, and Carica papaya [9-11]. An aqueous extract of betel leaves has been used as corrosion inhibitors in controlling corrosion of carbon steel in chloride environment [12, 13]. Caffeine has been used as a corrosion inhibitor for mild steel in an aqueous solution containing chloride ions [14]. Hence a study was taken up for the corrosion protection of mild steel using plant extract of Honge leaves (A) by weight loss studies in the presence and absence of hydrogen sulphide,H_2S in the more drastic conditions of 5% sodium chloride. Further studies were carried out for bioaccumulation, which was determined by the partition co-efficient of octanol-water.

II. Experimental

2.1 Pre-screening of the corrosion inhibitor:

Determination of weight loss of the coupons (Mild steel bits) is one of the common methods to calculate the corrosion rates. Weight loss measurements were carried using coupons in the present study. The coupons were cleaned and weighed before and after the experiments to remove the surface and corrosion products. Initially Synthetic seawater was used to simulate the conditions of the field for the weight loss studies. Change in the medium from synthetic seawater to 5% Sodium chloride was employed so as to maintain more stringent conditions later.

2.1.1. Pre-treatment of the coupons: Commercial grade mild steel sheets (IS 513 CRCA DD of composition-0.1% C, 0.45% Mn, 0.035% S, 0.035% P) cut into $1cm^2$ (0.05 cm thickness). These coupons were degreased with acetone. Dipped in pickling solution (2g zinc dust and 20g of NaOH in 100ml of water) [15] as per ASTM G1-90 [**16**], to clean the surface at 90^oC for 30 minutes. The coupons were removed, washed thoroughly with distilled water, and dried. These were polished with emery paper (grade 600) till the products are removed to get a shiny surface. Then the coupons were dipped in ethyl alcohol to remove the dust and stored in dessicator till they were used.

Synthetic Sea water was prepared by dissolving the salts as per the quantities given as per ASTM standard [**17**]. Plant extracts were prepared by refluxing 4 g of the plant material was with 100 cm^3 of distilled water for 45 minutes. The extract was filtered to remove the particles and the filtrate was made up to 100 cm^3 in standard flask to make for the loss of water during distillation. A stock solution was prepared by diluting 1 cm^3 of this extract to 100 cm^3. A series of solutions ranging from 10ppm to 500-ppm concentration were obtained by adding suitable aliquots to the corrosion medium. Details of the plant used for the preparation of aqueous extract to be used as corrosion Inhibitors is given in Table 1 along with its medicinal values and family.

Table 1 : Details of the Plants used for preparation of plant extracts

Code	Plant name	Family	Active ingredients	Medicinal uses
A	Indian Honge (Pongemia pinnata)	Caesalpinaceae	Alkaloids and terpenoids like demethoxy-kanugin, gamatay, glabrin, glabrosaponin, kaempferol, kanjone, kanugin, karangin, neoglabrin, pinnatin, pongamol, pongapin, quercitin, saponin, sitosterol, and tannin etc [**18]**	Used as bio diesel, Environmental Friendly

2.2. Weight loss measurements:

The MS coupons were immersed in 40 cm^3 of Synthetic sea water / 5% NaCl at room temperature (25±2 °C) for 24 hrs with and without plant extract at different concentration in ppm level, exposing an area of 2 cm^2. Weights were measured using the balance Acculab (Sartorius) model –ALC 210.4. Corrosion inhibition efficiency (IE) was calculated from

$$IE = [(Wo - W)x\ 100]/\ Wo$$

Where, Wo corrosion rates for coupon in absence of inhibitor, in mpy.

W corrosion rates for coupon in presence of inhibitor, in mpy.

All experiments were carried out in duplicates in the presence and absence of Hydrogen sulphide (H_2S). The generation of Hydrogen sulphide was carried insitu by adding 1700g/L of Acetic acid and 3530mg/L of fresh sodium sulphide ($Na_2S\ x.H_2O$) to the 5% NaCl [19].

2.2.1. Cleaning of coupons after exposure:

In the absence of Hydrogen sulphide, the coupons were removed from medium washed in distilled water thoroughly cleaned with tissue paper. Then dipped in alcohol and dried, the weight was taken.

In the presence of Hydrogen sulphide, the coupons were removed from medium washed in distilled water thoroughly, cleaned with paper. Then dipped in alcohol and dried. To remove the corrosion products, the coupons were dipped in 0.01 N HCl. Then again the coupons were dipped in distilled water, thoroughly washed, dried, and weights taken. Corrosion rate (CR) was expressed in 'mills per year' (mpy), was determined by [20]

$$CR=(K\ x\ W)\ /\ (A\ x\ T\ x\ D)$$

Where, K=a constant, depends on the unit desired. = (3.45 x106)
T=time of exposure in hours= (24)
A=area in cm^2= (2)
D=density in g/cm^3 = (7.86)
W=weight loss in g

3. ENVIRONMENTAL IMPACT

3.1. Bioaccumulation: All chemicals used were Merck AR grade. Absorbance values were recorded on ELICO SL-159, UV-Visible spectrophotometer to evaluate the bioaccumulation, Vortex mixer. Bioaccumulation [21] was determined as follows.

3.1.1. Preparation of Phosphate buffer: 50 cm^3 of 0.02M Potassium dihydrogen phosphate is taken in a 200 cm^3 volumetric flask and 32.1 cm^3 of 0.2M Sodium hydroxide was added. It was made up to the mark using distilled water.

3.1.2. Pre-saturation /equilibration of n-Octanol:

100 cm^3 of n-Octanol and 50 cm^3 phosphate buffer (in the ratio of 2:1) are taken in a 250 cm^3 separatory funnel. This mixture was shaken for half an hour vigorously and allowed to stand overnight (nearly for 24 hrs). n-Octanol was separated and used for studies; buffer was discarded.

3.1.3. Pre-saturation of Buffer:

100 cm^3 of phosphate buffer and 50 cm^3 of n-Octanol (in the ration of 2:1) are taken in a 250 cm^3 separatory funnel. This mixture is shook for half an hour vigorously and allowed to stand overnight (nearly for 24 hrs). n-Octanol was separated and discarded. Phosphate buffer was used for bioaccumulation studies.

3.1.4. Determination of Bioaccumulation:

λ max for the inhibitor in n-Octanol was determined and the absorbance at that wavelength was noted. Different volumes of the extract and n-Octanol were pipetted out into long test tubes as per the Table 2 (keeping the total volume constant at 12 cm^3; volume of n-Octanol increased with increasing volume of inhibitor). The mixtures were shaken vigorously using a vortex mixer and allowed to separate. The octanol layer was taken in the cuvette and the absorbance was determined (BE). This was poured back again into the test tube and phosphate buffer was added as per the table. This was again shaken vigorously for half an hour using vortex mixer and allowed to stand overnight. Absorbance of the octanol layer was measured (AE). Partition co-efficient 'Po/w' of plant extracts A to H was determined by measuring absorbance in two steps-

BE of octanol layer separated from (Plant extract + octanol) mixture, after shaking for 15 minutes vigorously. To the (plant extract + octanol) mixture from 1, aqueous phosphate buffer was added, shaken for 30 minutes again vigorously, and allowed to stand overnight. Octanol layer separated and absorbance **AE** measured.

Partition co-efficient 'Po/w' is defined as the ratio of the concentration of the plant extract present in the octanol layer '$C_{octanol}$' to concentration present in aqueous phase 'C_{aq}'

Table 2. Different volumes of n-Octanol, inhibitor and the phosphate buffer for the determination of AE and BE

Conc. no.	Volume of n-Octanol (cm^3)	Volume of inhibitor (cm^3)	Volume of Buffer (cm^3)
1	5	2	5
2	5.8	2.2	4
3	6.6	2.4	3
4	7.2	2.6	2
5	8.4	2.8	1

3.2. Determination of Toxicity of corrosion inhibitor:

Toxicity [**22]** test can be conducted at different levels of the food chain, like primary producers like algae etc, consumers like fishes, crustaseans which form the part of biodiversity of that particular region.

Toxicity of the Plant Extracts (PE) used as inhibitors was determined using seawater, sodium chloride. Species used was Brine shrimp also known as sea monkey whose scientific classification is given in the **Table 3**. Brine shrimp have been used as 'benchtop' for the toxicity study of corrosion inhibitor as they are excellent choice for the elementary toxicity investigations of several consumer products.

Table 3: Scientific classification of Brine shrimp

Kingdom	Animalia
Phylum	Arthropoda
Sub phylum	Crustacea
Class	Branchiopoda
Order	Anostraca
Family	Artemidae
Genus	Artemia , leach

Figure 1: Life cycle of Brine shrimp.

EC 50 is the effective concentration of a chemical substance necessary to affect the 50 % of the aquatic organism population. LC 50 is the effective concentration of a chemical substance required to kill 50 % of the population [**23]**.

Brine shrimp are marine invertebrates of about 1mm size. Freeze dried cysts are readily available in aquarium stores (obtained from Cubbon park aquarium, Bangalore). Cysts can be hatched without special equipment. Seawater was used as the medium to hatch the Brine shrimp; dosage used is 4g/1 litre of seawater. The water was kept in constant aeration with the help of pump and air bubbler. The eggs hatch after 24-36 hrs at lab temperature (about 26-28 ºC). The life cycle of the brine shrimp is given in **Figure 1**.

3.2.1. Experimental –Toxicity : Small test tubes or boiling tubes of 25 cm^3 capacity, borosil make are used 5 cm^3 of seawater was put into each test tube and the level was marked (lower meniscus) for 5 cm^3 with marker. Water was poured out. 2 cm^3 of seawater was taken in a test tube, then 10 brine shrimp in about 0.5-1 cm^3 of seawater are added carefully into each test tube using 1 ml pipette. The corrosion inhibitor was added as per the **Table 5** given at different ppm concentrations (serial dilutions given in **Table 4**). The volume is made up to 5 cm^3 (marked level) with seawater. The time of addition of the shrimp was noted. One sample was taken as control with seawater only and 10 brine shrimp are added to this also. LD-50 results were determined between 27 and 33 minutes after a tube was dosed with the corrosion inhibitor. The tubes were kept in the same condition for few days till the 50 % of the shrimp died to record the number of days, that the shrimp lived. The concentration level and the behavior of the shrimp behaving differently from the control tube, was recorded regularly.

A graph of the concentration as *x*-axis, was plotted for the data of percentage of survival. It gives the time graph of percent of survival from this the 50% survival point is taken which corresponds to a value of concentration. Corrosion inhibitor is serially diluted with seawater from 8000 ppm to 0.2 ppm as shown in Table 4 for toxicity studies.

Table 4: Serial Dilutions to get different concentrations of Plant extracts in sea water (SW)

Stock Solution	4% extract (40, 000 ppm)
5 cm^3 Stock +15 cm^3 with SW to 20 cm^3	10, 000 ppm
5 cm^3 of 10, 000 ppm made to 50 cm^3 with SW	1000 ppm
5 cm^3 of 1000 ppm made to 50 cm^3 with SW	100 ppm
5 cm^3 of 100 ppm made to 50 cm^3 with SW	10 ppm
5 cm^3 of 10 ppm made to 50 cm^3 with SW	1 ppm
0.5 cm^3 of 40,000 ppm made to 5 cm^3 with SW	4000 ppm
1 cm^3 of 40,000ppm made to 5 cm^3 with SW	8000 ppm

Table 5: Dosage of inhibitor added for Toxicity studies

Sl. no.	**DOSAGE**	**Concentration (ppm)**
1	1 cm^3 of sea water (control)	0.0
2	1 cm^3 of 1 ppm	0.2
3	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	0.5
4	1 cm^3 of 10 ppm	2
5	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	5
6	1 cm^3 of 100 ppm	20
7	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	50
8	1 cm^3 of 1000 ppm	200
9	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	500
10	1 cm^3 of 10000 ppm	2000
11	0.5 cm^3 of 40,000 ppm + 0.75 cm^3 of SW	4000
12	1 cm^3 of 40,000 ppm + 0.75 cm^3 of SW	8000

(SW-Sea water)

3.3. Biodegradation

As per OECD 306 test guidelines, biodegradation [24] is measured by determining the time for which the substance stays in the environment. The OECD 3O6 test guideline is used for the biodegradation of marine environment. Chemical compounds are subjected to a 28-day Biological Oxygen Demand (BOD) test. The compound to be rapidly biodegradable the substance must be

degradable by 60 % or more in these 28 days from the day of start of test. COD and BOD were determined as per the standard procedures [25-27]. COD is a measure of both biodegradable and non-biodegradable substances in the water sample. It is always higher than the values of BOD. Large Difference in the COD and BOD of a water sample indicates the presence of non-biodegradable substances.

Biodegradation (BD) = (BOD/ COD) *x* 100

Biodegradation should be >60% to be for a sample to be a good biodegradable corrosion inhibitor.

4. Results and discussion-

4.1. Corrosion inhibition

Effect of Inhibitor concentration on percentage inhibition efficiency (% IE) was studied by varying the concentration of the Plant Extract (PE) in the range of 10-500 ppm at room temperature for 24 Hrs period.

From the weight loss measurements for Blank (medium only) with and without H_2S, it is found that in the absence of plant extracts the corrosion rate is more (13.49 and 11.20 mpy) as shown in **Tables 6 and 7**.

Table 6: Calculation of Corrosion Rate For Blank/ Medium-Without H_2S (mpy-mills per year)

Trial no.	Weight of coupon before immersion (g)	Weight of coupon after immersion(g)	Weight loss (g)	CR (mpy)	Average CR (mpy)
1	0.4758	0.4743	0.0015	13.72	13.49
2	0.5091	0.5077	0.0014	12.80	
3	0.4938	0.4931	0.0017	15.55	
4	0.4695	0.4682	0.0013	11.89	

Table 7: Calculation of Corrosion Rate for Blank / Medium- With H_2S (mpy-mills per year)

Trial no.	Weight of coupon before immersion (g)	Weight of coupon after immersion(g)	Weight loss (g)	CR (mpy)	Average CR (mpy)
1	0.4696	0.4685	0.0012	10.97	11.20
2	0.5051	0.5041	0.0010	9.14	
3	0.4631	0.4617	0.0014	12.80	
4	0.4278	0.4265	0.0013	11.89	

Table 8: Corrosion Inhibition Efficiency of 50 ppm and 100 ppm of Plant Extracts Honge leaves in 40 cm^3 of synthetic seawater to MS-in the absence of H_2S-Immersion period of 24hrs (mpy-mills per year)

PE	Trial no.	Concentration of PE (ppm)	Weight of coupons before immersion (g)	Weight of coupons before immersion (g)	Weight loss (g)	CR (mpy)	% IE
A	1	50	0.4560	0.4551	0.0009	8.23	38.99
	2	50	0.4554	0.4545	0.0009	8.23	38.99
	1	100	0.4797	0.4789	0.0008	7.32	45.77
	2	100	0.4609	0.4602	0.0007	6.40	52.55

Table 9: Corrosion Inhibition Efficiency of 50 ppm and 100ppm of Plant Extract of Honge leaves in 40 cm^3 of synthetic seawater to MS-in the presence of H_2S-Immersion period of 24hrs

PE	Trial no	Concentration of PE(ppm)	Weight of Coupons before immersion (g)	Weight of Coupons after Immersion (g)	Weight loss (W)	CR mpy	IE %
A	1	50	0.4696	0.4690	0.0006	5.49	51.01
	2	50	0.5178	0.5172	0.0006	5.49	51.01
	1	100	0.4711	0.4706	0.0005	4.57	59.18
	2	100	0.4653	0.4649	0.0004	3.66	67.34

mpy-mills per year

As seen in **Table 8 and 9**, % IE of the plant extract of Honge leaves (A) is good corrosion protection at 100 ppm in the medium with and without H_2S.

4.2. Environmental impact

The experimental data with respect to Green properties for plant extract of Honge leaves (A) with respect to bioaccumulation, biodegradation and toxicity are given in **Tables 10, 13,** and **14**. Chemical oxygen demand (COD) and biological oxygen demand (BOD) data and results are given in **Tables 11** and **12** respectively.

Table 10: Bioaccumulation Results of Plant Extract of Honge leaves (A)

Conc.	BE	AE	P= BE / (BE- AE)	Log P	
C-1	0.398	0.222	2.26	0.354	<3
C-2	0.301	0.222	4.82	0.581	<3
C-3	0.222	0.222	0.00	0.00	<3
C-4	0.301	0.222	4.82	0.581	<3
C-5	0.222	0.222	0.0	0.00	<3

Wavelength taken in the range 230-240nm for BE and 230-238 for AE

Table 11: Data and results for Chemical Oxygen Demand (COD) of the Plant Extract Honge leaves (A)

Sample code	COD1 mg/ml	COD2 mg/ml	COD before (Sample Day 1)	COD after (Sample After 28 days)	Difference COD= (COD_{before} - COD_{after}) mg /ml
Blank DW	--	--	--	--	--
Blank SW	395.2	--	--	--	--
Honge (A)	484.16	414.96	(484.16-395.2) =88.96	(414.96-395.2) =19.76	(88.96-19.76)=69.2

Where, SW-Sea water, DW-Distilled water

Table 12: Data and results for Biological Oxygen Demand of the Plant Extract Honge leaves (A)

Sl. no	Sample	BOD Before mg/ml	BOD After mg/ml	BOD Diff mg/ml	BOD Sample =BODs-BODsw-BODb mg/ml
1	Blank DW	1.168	0.973	0.195	--
2	Blank SW	2.003	1.401	0.601	-
3	Honge (A)	53.126	7.006	46.12	(46.12-.601-.195)=45.32

Where, BODs-Biological oxygen demand sample, SW-Sea water, DW-Distilled water
BODsw-biological oxygen demand sea water, BODb- Biological oxygen demand blank (distilled water),

4.1. Biodegradation:

Table 13: Data and results of biodegradation for Plant Extract Honge leaves (A)

Sl. no	Sample	BOD Sample Avg mg/ml	Difference COD mg/ml	BD = (BOD/ COD) *x* 100 (%)	B.D %
1	Blank -DW	0.195	--	--	--
2	Blank-SW	0.601	--	--	--
3	A	45.32	69.2	(45.32/69.2*100) =65.5	65.5

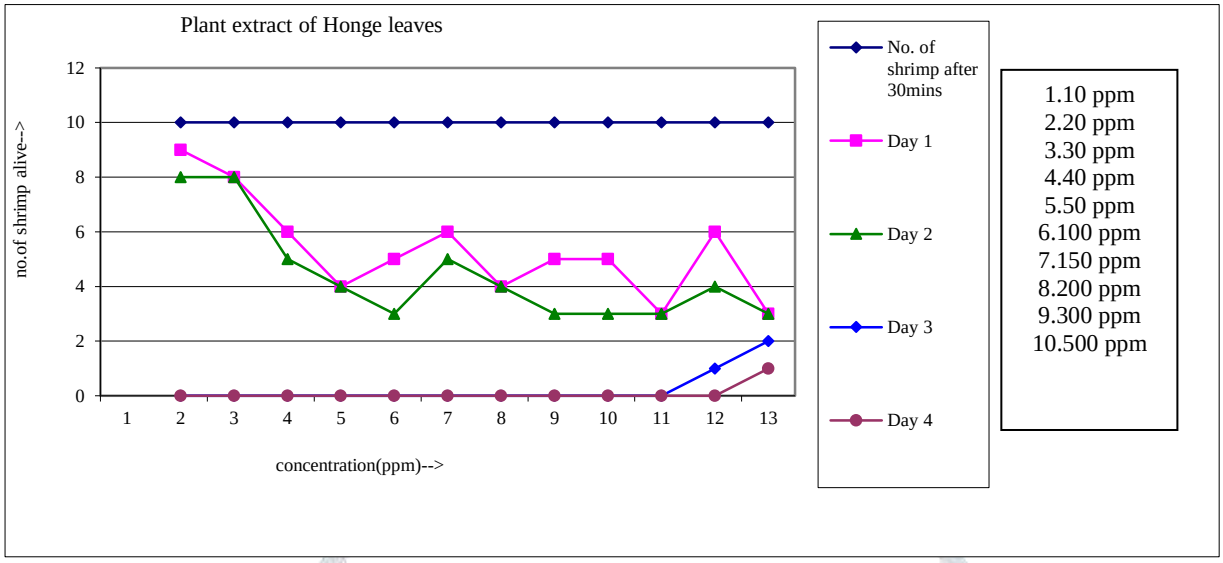
Where, SW-Sea water, DW-Distilled water

4.3. Toxicity: Data for toxicity study of the plant extract is given in Table 13 and the plot of effect of concentration on the number of shrimps is given in **Figure 2.**

Table 14: Data for the toxicity studies of the Plant Extract- Honge leaves (A)

Sl. No.	DOSAGE	Conc. of Honge PE ppm	No. of shrimp before	No. of shrimp after 30 mins	Day 1	Day 2	Day 3	Day 4
1	1cm^3 of sea water (control)	0.0	10	10	9	5	3	0
2	1 cm^3 of 1 ppm	0.2	″	″	8	8	0	0
3	0.25 cm^3 of 10 ppm +0.75 cm^3 of SW	0.5	″	″	6	5	0	0
4	1 cm^3 of 10 ppm	2	″	″	4	4	0	0
5	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	5	″	″	5	3	0	0
6	1 cm^3 of 100 ppm	20	″	″	6	5	0	0
7	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	50	″	″	4	4	0	0
8	1 cm^3 of 1000 ppm	200	″	″	5	3	0	0
9	0.25 cm^3 of 10 ppm + 0.75 cm^3 of SW	500	″	″	5	3	0	0
10	1 cm^3 of 10000 ppm	2000	″	″	3	3	0	0
11	0.5 cm^3 of 40,000 ppm + 0.75 cm^3 of SW	4000	″	″	6	4	1	0
12	1 cm^3 of 40,000ppm +0.75 cm^3 of SW	8000	″	″	3	3	2	0

FIGURE 2: Plot of effect of concentration of the Plant Extract of Honge leaves (A) on the number of shrimp



CONCLUSIONS

The Aqueous boiled plant extracts were found to exhibit good corrosion protection in the laboratory conditions. The plant selected was a local medicinal plant with low toxicity, water soluble, readily biodegradable and exhibit low bioaccumulation. Hence, they can be considered as good inhibitors for mild steel. The plant extract of leaves of Honge (A) was found to be of low toxicity, biodegradable and show good corrosion inhibition. It is concluded from the data gathered that the corrosion inhibition can be done using plant extracts where environment pollution is reduced without affecting the marine life.

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