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Green Approach to Corrosion Inhibition of Carbon Steel in Well Water by the Extract of *Polyalthia Longifolia*

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ABSTRACT

Water extract of Polyalthia Longifolia (PL) is tested as corrosion inhibitor of carbon steel in well water in the presence of Zn^{2+} has been evaluated by mass – loss method. The formulation consisting of 10 mL of Polyalthia Longifolia extract and 5ppm Zn^{2+} offers 98% inhibition efficiency in controlling corrosion of carbon steel immersed in well water. The polarization studies showed that Polyalthia Longifolia extract acts as anodic inhibitor. The Nyquist plot showed that increases charge transfer resistance (Rt) and decreases double layer capacitance (Cdl).Finally, The protective film formed on the metal surface has been analyzed by FT-IR, SEM and EDAX Spectra.

Keywords: Corrosion inhibitor, *Polyalthia Longifolia*, Nyquist plot, FT-IR, SEM, EDAX.

INTRODUCTION

Carbon steel finds a lot of application in industries like metal finishing, boiler scale removal, pickling baths etc. It gets rusted when it comes in contact with any aqueous medium. The use of inhibitors is one of the best methods for protecting metals against corrosion. Corrosion is a chemical or electrochemical process in nature with four components are: an anode, a cathode, an electrolyte and some direct electrical connection between the anode and cathode, the adsorbed inhibitor then acts to slow corrosion process by increasing the anodic or cathodic polarization behaviour or reducing the movement or diffusion of ions to the metallic surface. Corrosion inhibitors are used to prevent the effect of corrosion in such cases. Use of hazardous chemical inhibitors is totally reduced because of environmental regulations. It is better to look for environmentally safe inhibitors. Plant extracts are mostly preferred because they are cheap, easily available, non-toxic, renewable, biodegradable and completely soluble in aqueous media. They are also eco friendly. Several leaf extracts have been studied as corrosion inhibitors. Extracts of natural products like *Murraya koenigii*[1], *Nypa fruticans wurmb*[2], *Emblica officinali*[3], *Phyllanthus amarus*[4], *Michelia champaca*[5], *khillah seeds*[6], *Ficus carica*[7], *piper guinensis*[8], *fenugreek seeds and leaves*[9], *Nyctanthes arbortristis*[10], *Caffeic acid*[11], etc. have been reported to act as good corrosion inhibitors for various metal. The environmental friendly *Polyalthia longifolia* extract is chosen as the corrosion inhibitor for this present work. The aim of this research is to investigate the inhibition effect of *Polyalthia longifolia* extract on the corrosion of carbon steel in well water. For this purpose the

electrochemical studies such as potentiodynamic polarization and AC-impedance spectroscopy. Surface film studies such as UV-visible, FT-IR, SEM and EDAX have been used in this present work.

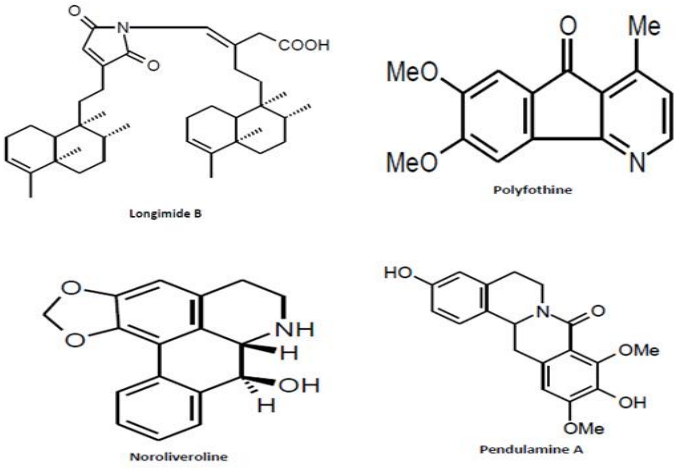


Figure.1. Active Principle of *Polyalthia Longifolia*

MATERIALS AND METHODS

Preparation of the carbon steel specimens: The carbon steel specimens were chosen from the same sheet of the following composition. Carbon – 0.1 %, Sulphur-0.026 %, phosphate- 0.06 %, Manganese- 0.4 % and the balance iron. Carbon steel specimen of the dimension 1.0× 4.0×0.2cm were polished to mirror finish, degreased with trichloroethylene and used for weight-loss and surface examination studies. Carbon steel rod encapsulated in Teflon with an exposed cross section of 1 cm^2 area was used as the working electrode in potentiodynamic polarization studies. The surface of the electrode was polished to mirror finish and degreased with trichloroethylene.

Weight-Loss method

Determination of surface area of the specimens: The length, breadth and the thickness of carbon steel specimens and the radius of the holes were determine with the help of Vernier calliper of high precision and the surface areas of the specimens were calculated.

Weighing the specimens before and after Corrosion: All the weight of the carbon steel specimens before and after corrosion was carried out using Shimadzu Balance – AY62.

Determination of corrosion rate: The weight specimen in triplicate were suspended by means of glass hooks in 100 ml various test solutions and after 24 hour of immersion, the specimens were taken out, Washed in running water, dried and weighed. From the change in weight of the specimen, corrosion rates were calculated using the following relationship.

- Corrosion Rate (mm/y) $= \dfrac{\text{Loss in weight (mg)} \quad X \quad 1000}{\text{Surface area of the Specimen } (dm^2) \text{ X Period of immersion (days)}} \times \dfrac{0.0365}{\rho}$

- Corrosion inhibition efficiency (IE) was then calculated using the equation

$$IE = 100\ [1- (W_2 / W_1)]\ \%$$

Surface Examination Study: The carbon steel specimens were immersed in various test solution for a period of one day. After one day, the specimens were taken out and dried. The nature of the film formed on the surface of metal specimen was analyzed.

Potentiodynamic Polarization Study: Potentiodynamic polarization studies were carried out using CHI electro chemical impedance analyzer, model 660A. Three electrode cell assemblies were used. The working electrode was a rectangular specimen of carbon steel with one face of the electrode exposed. A saturated calomel electrode (SCE) was used as a reference electrode and a rectangular platinum foil was used as the counter electrode. The working electrode and platinum electrode were immersed in well water in the absence and presence of inhibitor, saturated calomel electrode was connected with the test solution through a salt bridge. Potential (E) vs log current (I) plots were then recorded. Corrosion potential (E_{corr}) and Tafel slopes b_a and b_c were determined from E vs log I plots.

AC impedance measurements: A CHI electrochemical impedance analyzer (Model 660A) was used for AC impedance measurements. A time interval of 5 to 10 minutes was given for the system. The R_t (charge transfer resistance) and C_{dl} (double layer capacitance) values were calculated.

Synergism parameters: Synergism parameters are indication of synergistic effect existing between two inhibitors (1&2)

Synergism Parameters were calculated using the relation

$S_I = [1-\theta_{1+2}/1-\theta'_{1+2}]$

Where, $\theta_{1+2} = (\theta_1+ \theta_2) – (\theta_1 \times \theta_2)$

θ_1 = inhibition efficiency of substance 1

θ_2 = inhibition efficiency of substance 2

θ'_{1+2} = combined inhibition efficiency of substance 1&2

θ = surface coverage = IE% / 100

Analysis of Variance (F-test): F-test was carried out to investigate whether the synergistic effect existing between *Polyalthia longifolia* and Zn^{2+} system statistically significant or not.

UV-Visible Spectra: UV- visible absorption spectra of solutions were recorded in a UV spectra S-100 Analytic Jena spectrophotometer.

FT-IR Spectra: FT-IR spectra were recorded with the Perkin-Elmer 1600 spectrophotometer. The FTIR spectrum of the protective film was recorded by carefully removing the film mixed it with KBr and making the pellet.

SEM Study: The Surface morphology measurements of the carbon steel were examined by using JEOL JSM 6390 model. All SEM micrographs of carbon steel are taken at a magnification of X=1000.

RESULTS AND DISCUSSION

Analysis of the weight loss method: Corrosion rates (CR) of carbon steel immersed in well water in the absence and presence of inhibitor (*Polyalthia longifolia*) are given in tables 1and 2. The inhibition efficiencies (IE) are also given these tables. It is observed from table 1, that *Polyalthia longifolia* shows some inhibition efficiencies. 2ml of *Polyalthia longifolia* has 47% percent IE, as the concentration of *Polyalthia longifolia* increases, IE increases.

Table 1: Corrosion rates (CR) of carbon steel immersed in well water in the presence and absence of inhibitor system at various concentrations and the inhibition efficiencies (IE) obtained by weight loss method.

PL (ppm)	Zn^{2+} ppm	Corrosion Rate	Inhibition Efficiency (IE %)
0	0	0.1529	----
2	0	0.0810	47
4	0	0.0733	52
6	0	0.0642	58
8	0	0.0473	69
10	0	0.0382	75

Inhibition System: *Polyalthia longifolia* extract - Zn^{2+} (0 ppm), Immersion period: 1 day, pH = 7.25

Influence of Zn^{2+} on the inhibition efficiencies of *Polyalthia longifolia* Extract: The influence of Zn^{2+} on the inhibition efficiencies of *Polyalthia longifolia* extract is given in table 2. It is observed that as the concentration of *Polyalthia longifolia* extract increases the IE increases. Similarly for a given concentration of *Polyalthia longifolia* extract the IE increases as the concentration of Zn^{2+} increases. It is also observed that a synergistic effect exists between *Polyalthia longifolia* extract and Zn^{2+}. For example, 5 ppm of Zn^{2+} has 12% percent IE; 10ml of *Polyalthia longifolia* has 75% percent IE. Interestingly their combination has a high IE, namely, 98% percent. In presence of Zn^{2+} more amount of *Polyalthia longifolia* is transported towards the metal surface. On the metal surface Fe^{2+}- *Polyalthia longifolia* complex is formed on the anodic sites of the metal surface. Thus the anodic reaction is controlled. The cathodic reaction is the generation of OH^-, which is controlled by the formation of $Zn(OH)_2$ on the cathodic sites of the metal surface. Thus the anodic reaction and cathodic reaction are controlled effectively. This accounts for the synergistic effect existing between Zn^{2+} and *Polyalthia longifolia*.

$$Fe \text{------} > Fe^{2+} + 2e^- \text{ (Anodic reaction)}$$

$$Fe^{2+} + Zn^{2+} \text{ - } \textit{Polyalthia longifolia} \text{ complex------} > Fe^{2+} \text{- } \textit{Polyalthia longifolia} \text{ complex} + Zn^{2+}$$

$$O_2 + 2H_2O + 4e^- \text{ -----} > 4OH^- \text{ (Cathodic reaction)}$$

$$Zn^{2+} + 2OH \text{--------} > Zn(OH)_2 \downarrow$$

Table 2: Corrosion rates (CR) of carbon steel immersed in well water in the presence and absence of inhibitor system at various concentrations and the inhibition efficiencies (IE) obtained by weight loss method.

PL (ppm)	Zn^{2+} ppm	Corrosion Rate	Inhibition Efficiency (IE %)
0	0	0.1529	----
0	5	0.1345	12
2	5	0.0275	82
4	5	0.0122	92
6	5	0.0061	96
8	5	0.0045	97
10	5	0.0030	98

Inhibition System: *Polyalthia longifolia* extract - Zn^{2+} (5ppm), Immersion period: 1 day, pH = 7.25

Synergism Parameter (S_I): Synergism parameter(S_I) have been used to know the synergistic effect existing between two inhibition [12-15]. Synergism parameter (S_I)**.**Can be calculated using the following relationship.

$$\text{Synergism parameter } (S_I) = 1 - (1-\Theta_{1-2}/1-\Theta'_{1+2}).$$

The Synergism parameters of *Polyalthia longifolia* –Zn^{2+} system are given in table 3. For different concentration of inhibitor compounds exists. When $S_I>1$, it points to synergistic effects. In the case of $S_I<1$, it is an indication that the synergistic effect is not significant. From table 3 it is observed that value of synergism parameters (S_I) calculated from surface coverage were found to be one and above. This

indicates that the synergistic effect exist between *Polyalthia longifolia* and Zn^{2+}. Thus the enhancement of the inhibition efficiency caused by the addition of Zn^{2+} ions to *Polyalthia longifolia* is due to the synergistic effect.

Table 3: inhibition efficiencies synergism parameters for various concentrations of *Polyalthia longifolia* extracts - Zn^{2+} (5 ppm) system. When carbon steel is immersed in well water.

PL (ml)	Inhibition efficiency IE%	Inhibition efficiency IE%	Zn^{2+} ppm	Inhibition efficiency IE%	Surface coverage (Θ_2)	Combined IE% I' (1+2)	combined Surface coverage Θ_{1+2}	Synergism parameters (S_I)
2	47	0.47	5	12	0.12	82	0.82	2.59
4	52	0.52	5	12	0.12	92	0.92	5.28
6	58	0.58	5	12	0.12	96	0.96	9.24
8	69	0.69	5	12	0.12	97	0.97	9.09
10	75	0.75	5	12	0.12	98	0.98	11.0

Immersion period: 1 day, pH= 7.25

"F" test: To know whether the synergistic effect existing between *Polyalthia longifolia* extract and Zn^{2+} is statistically significant or not, F-test was used [12,13]. The results are given in table 4.It is observed that the calculated F-value 30.46 is greater than the table 4 value for 8 degrees of freedom at 0.05 level of significance. Hence it is concluded that the synergistic effect existing between *Polyalthia longifolia* extract and Zn^{2+} (5 ppm) is statistically significant.

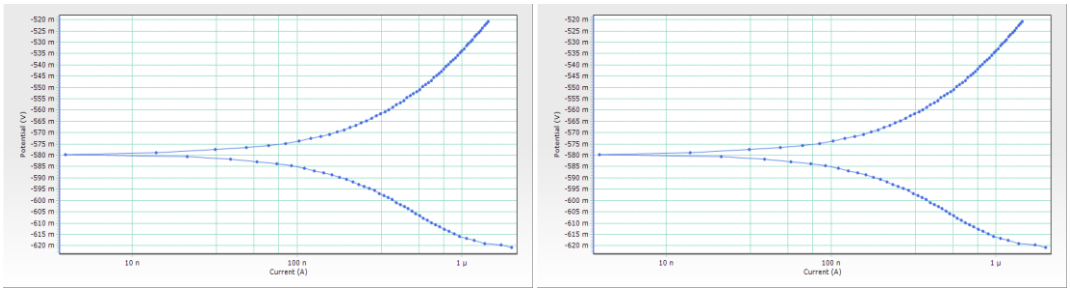
Table 4: Distribution of F value Between the Inhibition Efficiencies of *Polyalthia longifolia* extract and Zn^{2+} System

Source of variance	Sum of squares	Degrees of freedom	Mean Square	F	Level of significance
Between the sample	544.5	1	544.5	30.46	p>0.05
Within the sample	143	8	17.87		

Analysis of Potentiodynamic Polarization study: Polarization study has been used to confirm the formation of protective film formed on the metal surface during corrosion inhibition process. If a protective film is formed on the metal surface, the corrosion current value (I_{corr}) decreases [12-15]. The potentiodynamic polarization curves of carbon steel immersed in well water in the absence and presence of inhibitors are shown in fig 2(a, b), the corrosion parameters are given table 5. When carbon steel was immersed in well water the corrosion potential was -579 mV vs SCE. When 10ml *Polyalthia longifolia* extract and Zn^{2+} (5 ppm) are added to the above system the corrosion potential shifted to the noble side -548 mV vs SCE. This indicates that a film is formed on the anodic sites of the metal surface. This film controls the anodic reaction of metal dissolution by forming Fe^{2+}- *PL* complex on the anodic sites of the metal surface. The corrosion current decreases from 2.417×10^{-7}A/$cm^2$to 1.95×10^{-7}A/cm^2.Thus polarization study confirms the formation of a protective film on the metal surface.

Table 5: Corrosion parameters of carbon steel immersed in well water in the absence and presence of inhibitor system obtained from potentiodynamic polarization study.

System	E_{corr} mV vs SCE	B_c mV/ decade	B_c mV/ decade	I_{corr} A/cm^2
Well water	-579	58.101	72.226	2.417×10^{-7}
Well water + *PL* (10ml) +Zn^{2+} (5ppm)	-548	26.079	128.3	1.95×10^{-7}



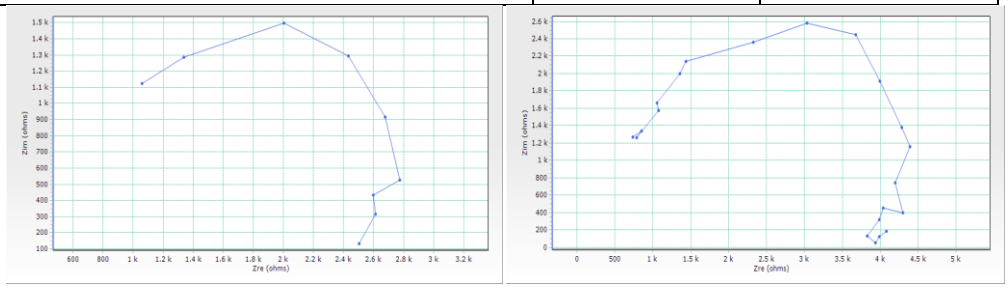
(a) **(b)**

Figure.2 Polarization curves of Carbon steel immersed in test solution
a) Well water(Blank), b) Well water +*Polyalthia longifolia* extract(10ml) + Zn^{2+} (5 ppm)

Analysis of AC Impedance spectra: AC impedance spectra (electrochemical impedance spectra) have been used to confirm the formation of protective film on the metal surface. If a protective film is formed on the metal surface, charge transfer resistance (R_t) increases; double layer capacitance value (C_{dl}) decreases[12-15]. The AC impedance spectra of carbon steel immersed in well water in the absence and presence of inhibitors (*Polyalthia longifolia* extract-Zn^{2+}) are shown in (Nyquist plot) fig.3(a,b). The AC impedance parameters namely charge transfer resistance (Rt) and double layer capacitance (C_{dl}) derived from Nyquist plots are given in table.6. It is observed that when the inhibitors (*Polyalthia longifolia* extract +Zn^{2+} (5 ppm)) are added the charge transfer resistance (R_t) increases from 1450 Ω cm2 to 4000 Ω cm2. The C_{dl} value decreases from 3.2063×10^{-9} F cm$^{2\,-1}$ to 1.1623×10^{-9} F cm$^{2\,-1}$.

Table 6: Corrosion parameters of carbon steel immersed in well water in the absence and presence of inhibitor system obtained from AC impedance spectra

System	Nyquist plot	
	R_t ohm cm^2	C_{dl} F/cm^2
Well water	1450	3.2063×10^{-9}
Well water + *Polyalthia longifolia* extract (10 ml) +Zn^{2+} (5 ppm)	4000	1.1623×10^{-9}



(a) **(b)**

Figure.3 AC impedance spectra of carbon steel immersed in test solution
(a) Well water (Blank), (b) Well water + *Polyalthia longifolia* extract (10ml) + Zn^{2+}(5ppm)

Analysis of UV Visible spectra: The UV-Visible absorption spectrum of an aqueous solution of *Polyalthia longifolia* extract and Fe^{2+} (Freshly prepared $FeSO_4$ solution) is shown in fig.4(a) a peak appears at 210nm. This is due to Fe^{2+} - *Polyalthia longifolia* complex formed in solution. The UV-Visible absorption spectrum of the film formed on the metal surface after immersion in the solution containing well water 10ml of *Polyalthia longifolia* extract and 5ppm of $Zn^{2+}$is shown in fig.4(b) Peak appears at 214nm. This matches the Fe^{2+}- *Polyalthia longifolia* extract complex in solution. Hence it is confirmed that the protective film consist of Fe^{2+}- *Polyalthia longifolia* extract complex[12,13].

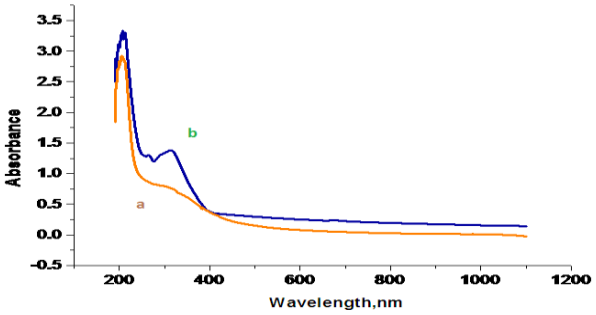
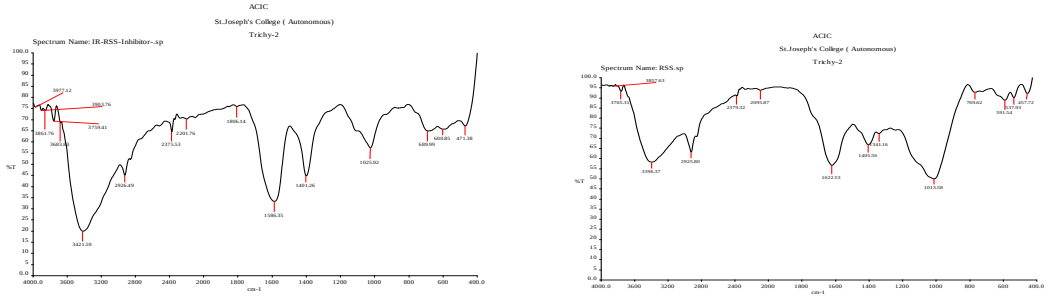


Figure.4 UV-absorption spectra of solution containing

a) *Polyalthia longifolia* extract + Fe^{2+} complex in solution, (b)Protective film formed on the surface of Carbon steel immersion in the solution containing 10ml of *Polyalthia longifolia* extract + 5 ppm of Zn^{2+}

FTIR spectra: The active principle in an aqueous extract of *Polyalthia longifolia* is shown in fig.1. A few drops of an aqueous extract were placed in on a glass plate and evaporated to dryness. A solid was obtained. Its FTIR spectrum is shown in fig.5 (a). The C=C stretching frequency appear at 600 cm^{-1}. The C=O stretching frequency appears at 1586 cm^{-1}. The CN stretching frequency appears at 1025 cm^{-1}. The stretching frequency for O-C appear at 2926 cm^{-1} The NH stretching frequency appears at 3421 cm^{-1}. The FTIR spectrum of the the solution containing well water, 10ml *Polyalthia longifolia* extract and 5ppm Zn^{2+}. is shown in fig.5 (b). The C=O stretching frequency has shifted from 1586 to 1622 cm^{-1}. The C=C stretching frequency has shifted from 600 to 591 cm^{-1}. The O-C stretching frequency has shifted from 2925 to 2924 cm^{-1}. The O-H stretching frequency has shifted from 3421 to 3396 cm^{-1} .The peak at 769 cm^{-1} is due to Zn-O and the peak at 1405 cm^{-1}corresponds to $Zn(OH)_2$. This confirms $Zn(OH)_2$ is formed on the metal surface. Thus the FTIR spectrum leads to the conclusion that the protective film consists of Fe^{2+}- *Polyalthia longifolia* extract complex and $Zn(OH)_2$ [12,13].



(a) **(b)**

Figure.5 FTIR spectra

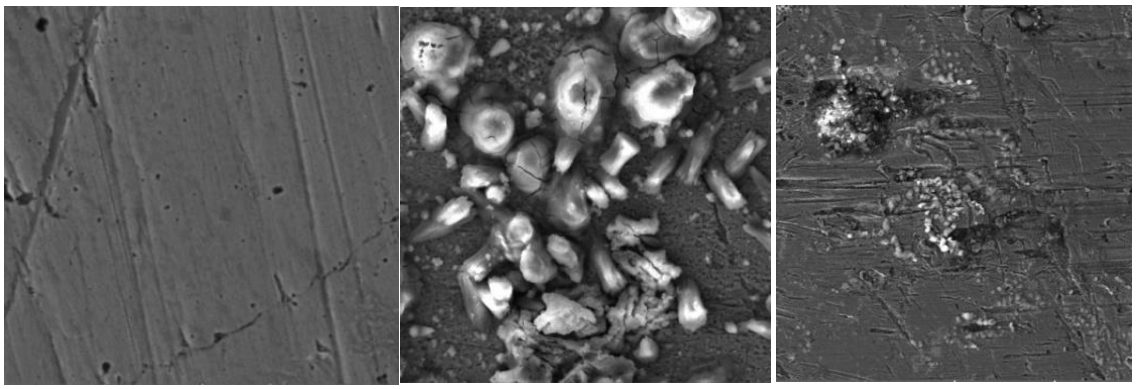
(a) Pure *Polyalthia longifolia,* (b) Film formed on metal surface after immersion in test solution containing 10 ml *Polyalthia longifolia* extract +5ppm Zn^{2+}

Influence of Sodium Dodecyl sulphate (SDS) on the corrosion inhibition efficiency of the *Polyalthia longifolia* extract -Zn^{2+} system: SDS is an anionic surfactant, it is a biocide. The corrosion inhibition efficiency and biocidal efficiency of the *Polyalthia longifolia* extract +Zn^{2+} +SDS system are given in table 7. When carbon steel was immersed in well water (in the absence of inhibitor), the number of colony forming units per ml is $9X10^3$. Various concentrations of SDS (50,100,150,200,250) ppm were added to *Polyalthia longifolia* extract(10mL)+ Zn^{2+}(5ppm) system. The corrosion inhibition efficiency and the biocidal efficiency were calculated. The formulation consisting of 10ml of *Polyalthia longifolia* extract and 5ppm Zn^{2+} has 98% of corrosion inhibition efficiency and 22% of biocidal efficiency. When 50ppm of SDS is added to *Polyalthia longifolia* extract –Zn^{2+} system, the inhibition efficiency increases from 98 to 99%, the biocidal efficiency increased from 22% to 52%. Its observed that the formulation consisting of 10mL *Polyalthia longifolia* extract + $Zn^{2+}$and 150ppm of SDS has 99% corrosion inhibition efficiency and 100% biocidal efficiency.

Table 7: Influence of SDS on the corrosion inhibition efficiency of the *Polyalthia longifolia* extract (10mL)+ Zn^{2+} (5ppm) system

Polyalthia longifolia extract (ml)	Zn^{2+} (ppm)	SDS (ppm)	CR mm/y	IE %	Colony forming units/mL	Biocidal Efficiency (BE)%
0	0	0	0.1529	-	$9x10^3$	-
10	5	0	0.0030	98	$7x10^3$	22
10	5	50	0.0015	99	$4.3x10^3$	52
10	5	100	0.0015	99	$1.5\ 10^3$	83
10	5	150	0.0015	99	Nil	100
10	5	200	0.0015	99	Nil	100

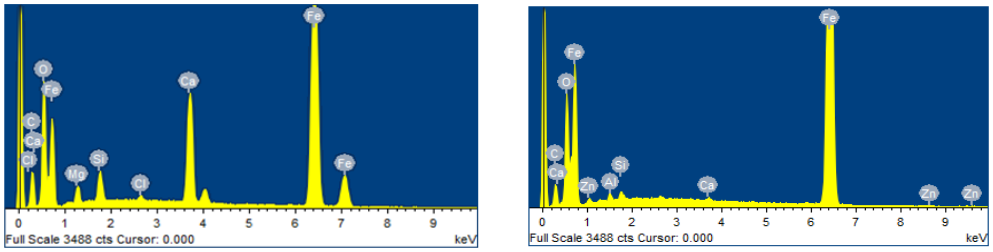
SEM Analysis of Metal Surface: SEM provides a pictorial representation of the surface. To understand the nature of the surface film in the absence and presence of inhibitors and the extent of corrosion of carbon steel, the SEM micrographs of the surface are examined [12,13,15].The SEM images of different magnification (X1000) of carbon steel specimen immersed in well water for 1day in the absence and presence of inhibitor system are shown in fig 6 (a, b , c) respectively. The SEM micrographs of polished carbon steel surface in fig 6 (a). Shows the smooth surface of the metal. This shows the absence of any corrosion products (or) inhibitor complex formed on the metal surface. The SEM micrographs of carbon steel surface immersed in well water. Fig.6 (b) shows the roughness of the metal surface which indicates the highly corroded area of carbon steel in well water. However fig.6(c) indicates that in the presence of inhibitor (10mL *Polyalthia longifolia* extract and 5ppm Zn^{2+}) the rate of corrosion is suppressed, as can be seen from the decrease of corroded areas. The metal surface almost free from corrosion due to the formation of insoluble complex on the surface of the metal. In the presence of *Polyalthia longifolia* extract and Zn^{2+}, the surface is covered by a thin layer of inhibitors which effectively controls the dissolution of carbon steel



(a) **(b)** **(c)**

Figure.6.SEM analysis of
(a) Polished Carbon steel,(b) Carbon steel immersed in well water, (c) Carbon steel immersed in well water +*Polyalthia longifolia* extract (10ml) + Zn^{2+} (5 ppm)

Energy Dispersive Analysis of X-Rays (EDAX): The EDAX survey spectra were used to determine the elements present on the metal surface before and after exposure to the inhibitors solution [12,13,15]. The goal of this section was to confirm the results obtained from chemical and electrochemical measurements that a protective surface film of inhibitor is formed on the metal surface. To achieve this goal EDAX examination of the metal surface were performed in the absence and presence of inhibitors system. The EDAX spectrum of carbon steel immersed in well water is shown in fig 7(a). It shows the characteristic peaks of some of the elements constituting the carbon steel sample. The EDAX spectrum of carbon steel immersed in well water containing 10ml of *Polyalthia longifolia* extract and 5 ppm of Zn^{2+} is shown in fig7(b). In addition, the intensity of C and O signals are enhanced. The enhancement in C and O signal is due to the presence of inhibitor. These data show that metal surface is covered the N, O, C atoms. This layer is undoubtedly due to the inhibitor system. The high contribution of O and C is not present on the metal surface exposed in well water. Fig 7(b) shows that the Fe peaks observed in the presence of inhibitor are considerably suppressed relative to these observed in well water (blank solution). The suppression of the Fe peaks occurs because of the overlying inhibitor film. This observation indicates the existence of an adsorbed layer of inhibitor that protects steel against corrosion. These results suggest that N, O and C atoms of *Polyalthia longifolia* extract has coordinated with Fe^{2+}, resulting in the formation of Fe^{2+}-*Polyalthia longifolia* extract complex on the anodic sites of metal surface.



(a) **(b)**

Figure.7: EDAX spectra of
(a) Carbon steel sample after immersion in well water (blank), (b) Carbon steel sample after immersion in solution containing well water +10ml of *Polyalthia longifolia* extract + 5 ppm of Zn^{2+}

APPLICATIONS

Mechanism of Corrosion Inhibition : Results of the weight-loss study show that the formulation consisting of 10mL L-*Polyalthia longifolia* extract and 5 ppm Zn^{2+} has 98% IE controlling corrosion of carbon steel in well water. A synergistic effect exists between Zn^{2+} and *Polyalthia longifolia* extract. Polarization study reveals that this formulation function as anodic inhibitor.AC impedance spectra reveals that protective film is formed on the metal surface. In order to explain these facts the following mechanism of corrosion inhibition is proposed.

- When the solution containing well water 10ml *Polyalthia longifolia* extract and 5 ppm Zn^{2+} is prepared, there is formulation of Zn^{2+}-*Polyalthia longifolia* extract complex in solution.
- When carbon steel is immersed in this solution the Zn^{2+} - *Polyalthia longifolia* extract complex diffuses from the bulk of the solution towards metal surface.
- Zn^{2+}-*Polyalthia longifolia* extract complex diffuses from the bulk solution to the surface of the metal and is converted into Fe^{2+} - *Polyalthia longifolia* extract complex, which is more stable than Zn^{2+} - *Polyalthia longifolia* extract
- On the metal surface Zn^{2+}-*Polyalthia longifolia* extrct complex is converted into Fe^{2+} - *Poyalthia longifolia* extract on the anodic sites and Zn^{2+} is released.Zn^{2+}- *Polyalthia longifolia* extract + Fe^{2+}—--> Fe^{2+}-*Polyalthia longifolia* extract + Zn^{2+}
- The released Zn^{2+} combines with OH^- to from Zn $(OH)_2$ on the cathodic sites.
  $Zn^{2+} + 2OH^-$ ------> Zn $(OH)_2$
- Thus the protective film consists of Fe^{2+} -*Polyalthia longifolia* extract complex and Zn $(OH)_2$.
- The EDAX analysis SEM micrographs image confirms the formation of protective layer in the metal surface.

CONCLUSIONS

The inhibition efficiency (IE) of the *Polyalthia longifolia* extract –Zn^{2+}system in controlling corrosion of carbon steel in well water has been evaluated by weight loss method. The present study leads to the following conclusion.

- Weight loss study reveals that the formation consisting of 10ml of *Polyalthia longifolia* extract and 5ppm of Zn^{2+} has 98% inhibition efficiency, in controlling corrosion of carbon steel in well water.
- A Synergistic effect exists between $Zn^{2+}$and *Polyalthia longifolia* extract.
- Statistical study of F-test revealed that the synergistic effect existing between *Polyalthia longifolia* extract sand Zn^{2+} is statistically significant.
- Polarization study reveals that *Polyalthia longifolia* system function as Anodic inhibitor.
- AC impedance spectra reveal that a protective film is formed on the metal surface.
- UV visible spectra reveal that a protective film consists of Fe^{2+-}-*Polyalthia longifolia* extract complex.
- The FTIR spectra reveal that a protective film consists of Fe^{2+-}-*Polyalthia longifolia* extract and $Zn(OH)_2$.
- The EDAX, SEM micrographs confirm the formation protective layer on the metal surface.

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REFERENCES

[1] Sharmila, A. Angelin Prema, P. Arockia Sahayaraj, Influence of Murraya Koenigii (Curry Leaves) Extract on The Corrosion Inhibition of Carbon Steel In HCl Solution, *Rasayan.J.Chem*, **2010**, 3(1),74-81.

[2] K. Orubite- Okorosaye, N.C. Oforka, Corrosion Inhibition of Zinc on HCl using Nypa fruticans Wurmb Extract and 1,5 Diphenyl Carbazone, *J. Appl. Sci. Environ. Mgt*, **2004**, 8 (1), 57 – 61

[3] R. Saratha , V. G. Vasudha, "Emblica Officinalis (Indian Gooseberry) Leaves Extract as Corrosion Inhibitor for Mild Steel in 1N HCl Medium," *E-Journal of Chemistry*, **2010**, 7(3), 677-684, doi:10.1155/2010/162375

[4] M. Sangeetha, S. Rajendran, J. Sathiyabama, A. Krishnaveni, P. Shanthy, N. Manimaran, B. Shyamaladevi, Corrosion Inhibition by an Aqueous Extract of Phyllanthus Amarus, *Portugaliae Electrochimica Acta*, **2011**, 29(6), 429-444

[5] R. Saratha, R. Savitha, S. Sivakamasundari, The influence of Michelia Champaca leaves extract on the Corrosion inhibition of mild steel in sulphuric acid medium, *J. Electrochem Soc.India*, 2003, 52(2), 59-63.

[6] A.Y. El-Etre, Khillah extract as inhibitor for acid corrosion of SX 316 steel, *Applied Surface Science*, **2006**, 252(24), 8521–8525

[7] A. I. Onen, J. T. Barminas , J. Jacob, Inhibitory Action of Ficus carica Extracts on Aluminium, Corrosion in Acidic Medium, *Chem Sci Trans*, **2013**, 2(4), 1326-1333.

[8] E.E Ebenso, N.O. Eddy, A.O. Odiongenyi, Corrosion inhibitive properties and adsorption behaviour of ethanol extract of Piper guinensis as a green corrosion inhibitor for mild steel in H_2SO_4, *African Journal of Pure and Applied Chemistry*, **2008**, 2 (11), 107-115.

[9] Ehteram A. Noor, Comparative Study on the Corrosion Inhibition of Mild Steel by Aqueous Extract of Fenugreek Seeds and Leaves in Acidic Solutions, *Journal of Engineering and Applied Sciences*, **2008**, 3 (1), 23-30.

[10] R.Saratha and V.G.Vasudha, Inhibition of Mild Steel Corrosion in 1N H_2SO_4 Medium by Acid Extract of Nyctanthes arbortristis Leaves, *E-Journal of Chemistry*, **2009**, 6(4), 1003-1008

[11] F.S. de Souza, A. Spinelli, Caffeic acid as a green corrosion inhibitor for mild steel, *Corrosion Science*, **2009**, 51(3), 642–649.

[12] P.Angel, A.Sahaya Raja, J.Sathiyabama, V. Prathipa, Corrosion inhibition of *Vitex negundo* extract as a green corrosion inhibitor for carbon steel in well water, *International Journal of Chemical Studies*, **2014**, 2(1), 31-37.

[13] S.Siva Kumar, A.Sahaya Raja, J.Sathiyabama, V. Prathipa., Spectroscopic methods used for analysing protective film formed by L-Histidine on carbon steel, *Int.J.Pharm Drug Anal*, **2014**, 2(7), 601-611.

[14] A.Sahaya Raja, S. Rajendran, R.Nagalakshmi, J.AngelinThangakani, M.Pandiarajan, Eco-Friendly Inhibitor Glycine-Zn^{2+} System Controlling Corrosion of Carbon Steel in well water, *Eur. Chem. Bull*, **2012**, 1(3), 130-136.

[15] A. Sahaya Raja, S.Rajendran, P.Satyabama., Inhibition of Corrosion of Carbon Steel in Well Water by DL-Phenylalanine-Zn^{2+} System, *Journal of Chemistry*, 2013, 2013, Article ID 720965, 8 pages,doi:10.1155/2013/720965.