Corrosion Inhibition of Mild Steel in Simulated Concrete Pore Solution Prepared in Well Water in Presence of Beetroot Extract

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Abstract

Corrosion Resistance of mild steel in simulated concrete pore solution (scps) prepared in well water in the absence and presence of beet root(BR)extract and Zn^{2+} has been evaluated by mass loss method. The formulation consisting of 10 ml of beet root extract and 10ppm Zn^{2+} offers 96% inhibition efficiency to mild steel immersed in well water. The mechanistic aspects of corrosion inhibition have been investigated by polarization study reveals that this formulation controls the cathodic reaction predominantly AC impedance spectra reveal that a protective film is formed on the metal surface.

Keywords : Mild steel, concrete corrosion, simulated concrete pore solution, plant extract, beetroot.

Introduction:

Environmental friendly inhibitors have attracted several researchers. Naturalproducts are nontoxic, biodegradable and readily available. They have been usedwidely as inhibitors. Naturalproducts such as caffeine [1, 2] have been used asinhibitors. Corrosion inhibition of steel by plant extracts in acidic media has beenreported [3, 4]. Scale inhibiting nature of plant extracts for various kinds ofmetals are summarized briefly [5]. Natural compounds as corrosion inhibitors forindustrial cooling systems have been studied [6]. Aqueous extract of Rosemaryleaves [7], Zenthoxylum - alatum [8] and Lawsonia [9] have been used to inhibitcorrosion of metals. Corrosion inhibition of iron in hydrochloric acid solutionsby naturally occurring Henna has been investigated [10]. An aqueous extract ofplant material rhizome (Curcuma Longa L) powder has been used as a corrosioninhibitor for carbon steel [11]. Aqueous extracts of Onion [12], Androgaphispanizulata [13] have been used as corrosion inhibitors. Inhibitive action of Carcia papaya extracts on the corrosion of mild steel in acidic media and their adsorption characteristics have been studied [14]. Azadirachtaindica in acid solution has good corrosion inhibitive property [15].

Corrosion inhibition ofcarbon steel in low chloride media by an aqueous extract of Hibiscus rosasinensis Linn has been evaluated by mass-loss method and electrochemicalstudies [16]. Investigation of natural inhibitors is particularly interesting becausethey are non-expensive, ecologically friendly/ acceptable and possess no threat tothe environment.

Several research papers have investigated the corrosion behavior of metals in presence of simulated concrete pore solution (scps) [17-28] usually steel rebars have been used in such studies. The present study is undertaken to investigate the corrosion of mild steel in scps prepared in well water. A saturated solution of calcium hydroxide is used as scp solution[29-33] Polarization study has been used to evaluate the corrosion resistance of mild steel.

The present work is undertaken:

(i) To evaluate the inhibition efficiency (IE) of an aqueous extract of beet root (BR) in controlling the corrosion of carbon steel in well water, in the absence and presence of Zn^{2+}

(ii) To understand the mechanistic aspects of corrosion inhibition by potentiodynamic polarization studies and AC impedance analysis

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Experimental Methods

Preparation of plant extract

An aqueous extract of beet root was prepared by grinding 10 g of beet root with double distilled water, filtering the suspending impurities, and making up to 100 mL. The extract was used as corrosion inhibitor in the present study.

Preparation of specimens

Mild steel specimens (0.0267% S, 0.06% P, 0.4% Mn, 0.1% C and the rest iron) of dimensions 1.0 cm x 4.0 cm x 0.2 cm were polished to a mirror finish and degreased with trichloroethylene

Simulated concrete pore solution (SCPS)

A saturated calcium hydroxide solution is used in the present study,as SCP solution. The electrodes made of mild steel wire were immersed in the SCP solution and AC impedance , polarization study was carried out.

Mass-loss method

Relevant data on the well water used in this study are given in Table I. Mild steel specimens in triplicate were immersed in 100 mL of the solutionscontaining various concentrations of the inhibitor in the presence and absence ofZn^{2+} for one day. The weight of the specimens before and after immersion wasdetermined using Shimadzu balance, model AY 62. The corrosion products werecleansed with Clarke's solution [34]. The inhibition efficiency (I.E.) was then
calculated using the equation

$$I.E = 100\ [1-(W2/W1)]\ \%$$

where W1 and W2 are the corrosion rates in the absence and presence of the inhibitor, respectively

Table 1. Parameters of well water.

Parameter	Value
pH	8.38
Conductivity	3110 µ mhos/cm
TDS	2013 ppm
Chloride	665 ppm
Sulphate	14 ppm
Total hardness	1100 ppm

Potentiodynamic polarization

Polarization study was carried out in Electrochemical impedence Analyser model CHI 660 A using a three electrode cell assembly was used.The working electrode was used as a rectangular specimen of mild steel with the one face of the electrode of constant 1cm^2 area exposed. A saturated calomel electrode(SCE) was the reference electrode and platinum was the counter electrode . From the polarization study,corrosion parameters such as corrosion potential(E_{corr}) correction current(I_{corr}) and tafel slopes (anodic= ba and cathodic=bc)were calculated

AC impedance measurements

The instrument used for polarization was also used for AC impedance study.The cell set up was the same as that used for polarization measurements. The real part and imaginary part of the cell impedance were measured in ohms at various frequencies. The values of charge transfer resistance, R_t, and the doublelayer capacitance, C_{dl}, were calculated.

Results and discussion

Analysis of results of mass loss method:

The corrosion rate (CR) of mild steel immersed in well water (whose composition is given in Table 1) in the absence and presence and presence of inhibitor systems are given in Table 2.

The aqueous extract of beet root (B R) is a good inhibitor to carbon steel in well water. 2ml of beet root extract and 10ppm of Zn^{2+}shows 91% IE.As the concentration (BR) extract in increases IE also increases are given in Table- 2

Table-2 Corrosion rate (CR) of mild steel immersed in SCPS prepared in well water , in the absence and presence of inhibitors , and the inhibition efficiency(IE) obtaind by mass loss method

BR Extract ml	IE %	CR mdd
2	71	13.92
4	75	12.00
6	83	8.16
8	92	3.84
10	96	1.92

Analysis of polarization curves

The potentiodynamic polarization curves of mild steel immersed in well water in the absence and presence of beet root (BR) Extract and Zn^{2+} has shown in Fig 1&2 . The corrosion parameters are given in Table 3. When mild steel is immersed in well waterthe corrosion potential is -517 mV vs. SCE (Saturated Calomel Electrode). The corrosion current is 1.544 x 10^{-6} A/cm^2. When 10 ml of BR Extract and 10 ppm of Zn^{2+} are added to the above system, the corrosion potential shifts to the cathodic site (-486 mV vs. SCE). This suggests that this formulation controls the cathodic reaction predominantly. In the presence of this inhibitor system, the corrosion current decreases from 1.544 x 10^{-6}A/cm^2 to 1.344 x 10^{-5} A/cm^2. This suggests the inhibitive nature of this inhibitor system.

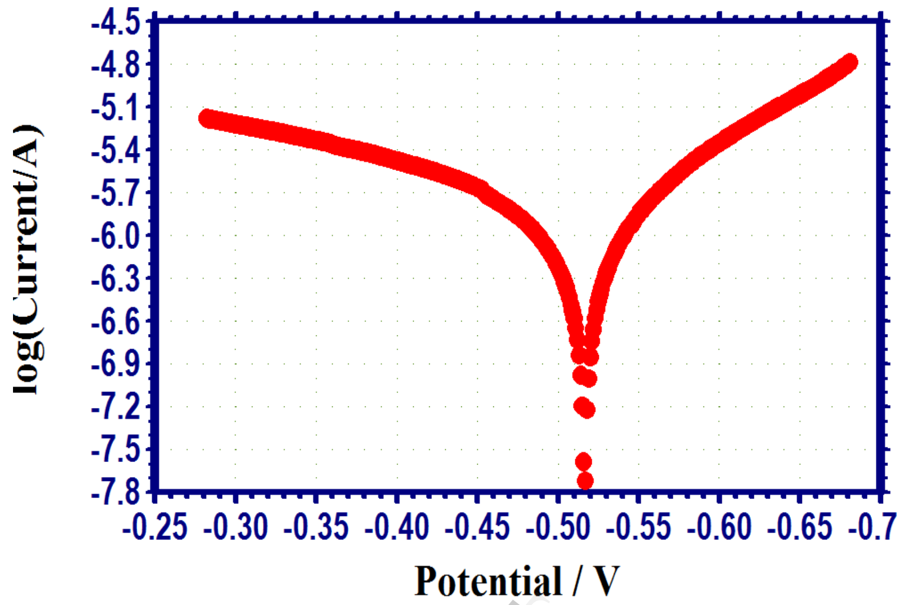

Figure 1.Polarization curves of mild steel immersed in SCPS prepared in well water

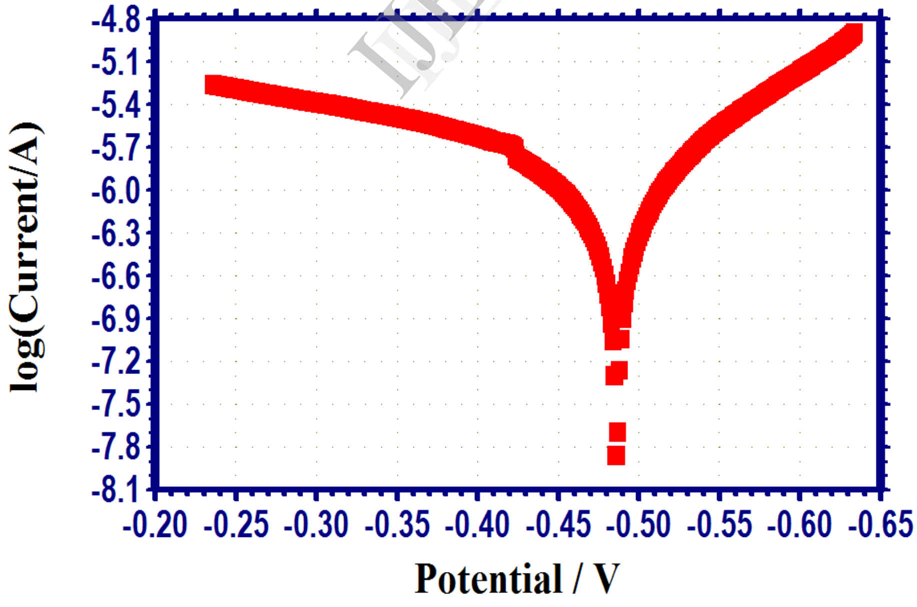

Figure 2 Polarization curves of mild steel immersed in SCPS prepared in well water +10ml BR Extract + 10ppm Zn^{2+}

Table 3.Corrosion parameters of mild steel immersed in SCPS prepared in well water in the absence and presence of inhibitors. Inhibitor system: BR Extract + Zn^{2+} system

BR mL	Zn^{2+} ppm	Ecorr mV vs. SCE	ba mV	bc mV	Icorr A/cm2
0	0	-517	257	136	1.544x10-6
10	10	-486	305	129	1.344x10-6

Analysis of AC impedance spectra

The AC impedance spectra of mild steel immersed in well water, prepared in scps in the absence and presence of inhibitors are shown in Fig. 3 to 6 . The AC impedance parameters such as charge transfer resistance (Rt) and double layer capacitance (C_{dl}) are given in Table 4. The values are derived from nequist plot and bode plot When carbon steel is immersed in the solution containing scps in well water, thecharge transfer resistance R_t is 293.1ohm.cm^2 the double layer capacitance C_{dl} is 6.551x10-8 F/cm^2. When the formulation consisting of BR Extract and Zn^{2+} is added, the $R_t$value 341.8ohm.cm^2 increases and C_{dl} value is 5.617551x10$^{-8\mu}$F/cm^2 decreases.The impedance value increases 2.69 to 2.73 This confirms that a protective film is formed on the metal surface.

Table 4. AC impedance parameters of mild steel immersed in SCPS prepared in well water in the absence and presence of inhibitors. Inhibitor system: SCPS + 10ml BR Extract +10ppm Zn^{2+}.

BR ml	Zn^{2+} ppm	Nyquist plot		Bode plot Log(Z/ohm)
		R_t Ohm.cm^2	C_{dl} µF/cm^2	
0	0	293.1	6.551x10-8	2.69
10	10	341.8	5.617x10-8	2.73

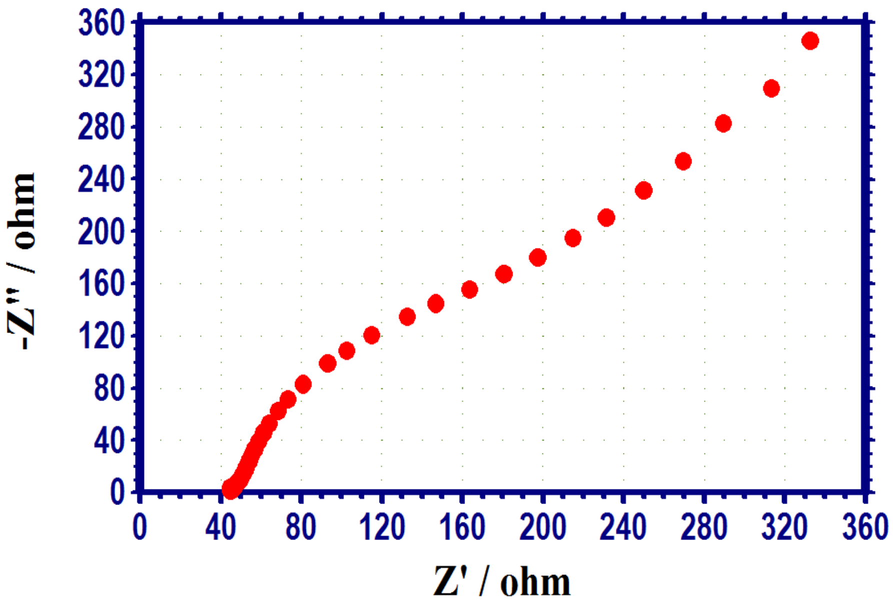

Figure 3 . AC impedance spectrum mild steel immersed in SCPS prepared in well water (Nyquist plot)

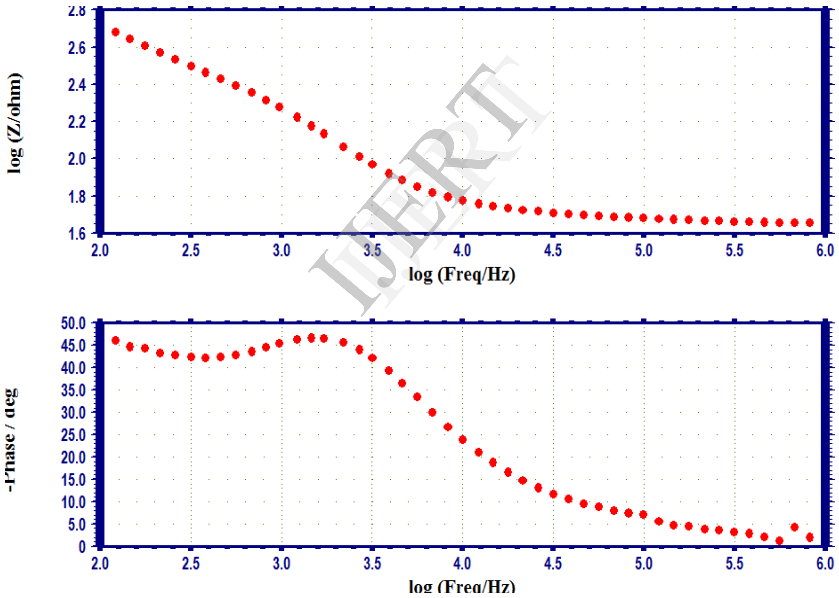

Figure 4 . AC impedance spectrum of mild steel immersed in SCPS prepared in well water (Bode plot)

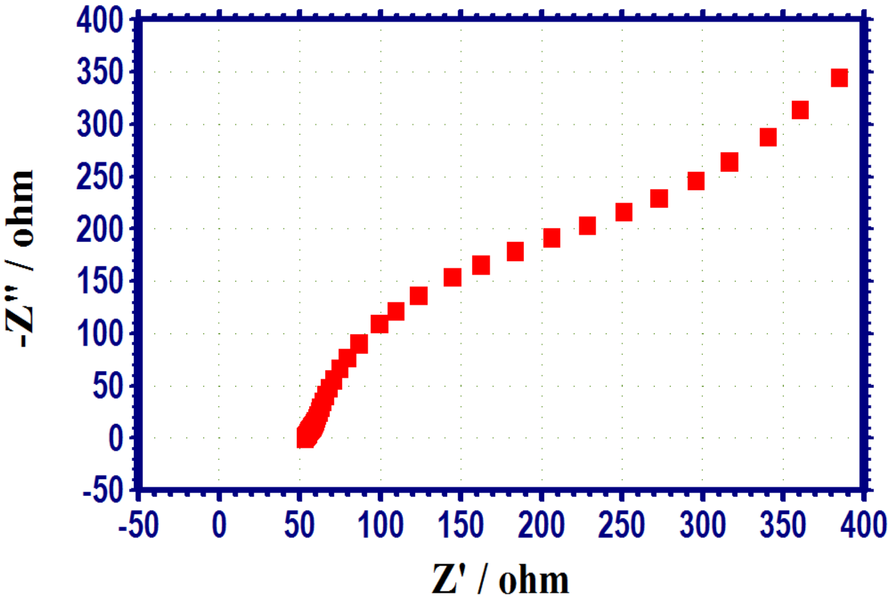

Figure 5 . AC impedance spectrum of mild steel immersed in SCPS +10ml BR Extract +10ppm Zn^{2+} (Nyquist plot)

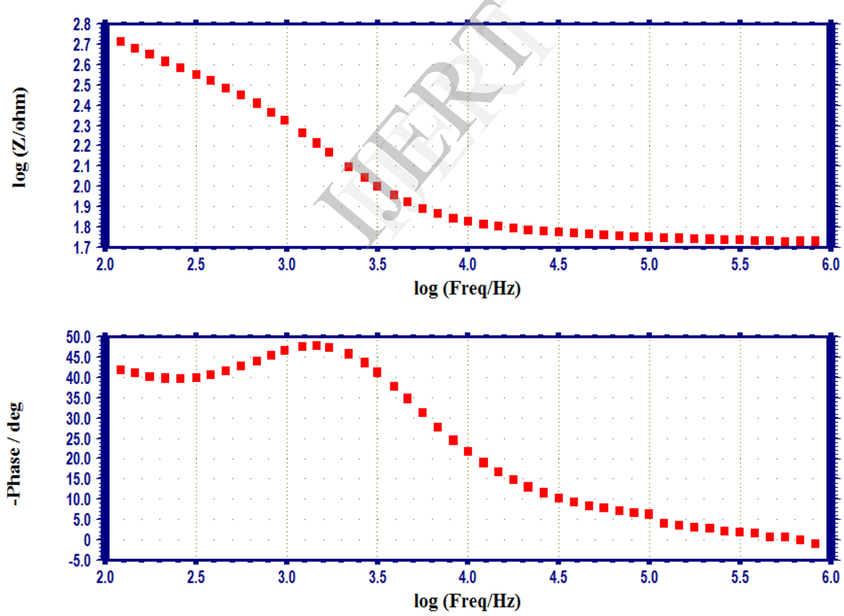

Figure 6 . AC impedance spectrum of mild steel immersed in SCPS +10ml BR Extract +10ppm Zn^{2+} (Bode plot)

Comparison of results of mass loss method and electrochemical studies

In the present work mass loss study was carried out keeping the duration of immersion as 24 hours. It the electrochemical studies such as polarization andAC impedance, the instantaneous corrosion process is studied.The mass loss study shows a tremendous difference between the corrosion rate of the blank system (SCPS prepared in well water only) and the inhibitor system (scps prepared in well water+ BR 10 mL +Zn2+ 10 ppm); 97% IE is obtained. In polarization study the corrosion current is decreased only to a small extent (from 1.544x105A/cm^{2}to1.344x10.6 A/cm^2). In AC impedance study the increase in Rt value (from 293.1 to341.8 ohm.cm2) and the decrease in C_{dl} value (6.551 x 10^{-8} to 5.617 x 10^{-8} µF/cm^2) are very small. This is attributed to the various ions such as Ca^{2+} and Mg^{2+}, apart from chloride ion and sulphate ion. The various ions present in well water instantaneously form a protective film on the metal surface. But this film is broken in due course.

Conclusions

The present study leads to the following conclusions

1. The formulation consisting of 10 mL BR extract and 10 ppm of Zn2+ offers 97% inhibition efficiency to carbon steel immersed in SCPS prepared in well water
2. BR – Zn2+ system shows excellent IE
3. Polarization study reveals that this formulation controls the cathodic reaction predominantly
4. AC impedance spectra reveal that a protective film is formed on the metal surface

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