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. Natural products are nontoxic, biodegradable and readily available. They have been used widely as inhibitors. Natural products such as caffeine [1, 2] have been used as inhibitors. Natural products such as caffeine [1, 2] have been used as inhibitors. Corrosion inhibition of steel by plant extracts in acidic media has been reported [3, 4]. Scale inhibiting nature of plant extracts for various kinds of metals are summarized briefly [5]. Natural compounds as corrosion inhibitors for industrial cooling systems have been studied [6]. Aqueous extract of Rosemary leaves [7], Zanthoxylum - alatum [8] and Lawsonia [9] have been used to inhibit corrosion of metals. Corrosion inhibition of iron in hydrochloric acid solutions by naturally occurring Henna has been investigated [10]. An aqueous extract of plant material rhizome (Curcuma Longa L) powder has been used as a corrosion inhibitor for carbon steel [11]. Aqueous extracts of Onion [12], Androgaphis panizulata [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 of carbon steel in low chloride media by an aqueous extract of Hibiscus rosasinensis Linn has been evaluated by mass-loss method and electrochemical studies [16]. Investigation of natural inhibitors is particularly interesting because they are non-expensive, ecologically friendly/acceptable and possess no threat to the 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.

**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 solutions containing various concentrations of the inhibitor in the presence and absence of Zn$^{2+}$ for one day. The weight of the specimens before and after immersion was determined using Shimadzu balance, model AY 62. The corrosion products were cleansed 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>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.38</td>
</tr>
<tr>
<td>Conductivity</td>
<td>3110 $\mu$ mhos/cm</td>
</tr>
<tr>
<td>TDS</td>
<td>2013 ppm</td>
</tr>
<tr>
<td>Chloride</td>
<td>665 ppm</td>
</tr>
<tr>
<td>Sulphate</td>
<td>14 ppm</td>
</tr>
<tr>
<td>Total hardness</td>
<td>1100 ppm</td>
</tr>
</tbody>
</table>

Potentiodynamic polarization

Polarization study was carried out in Electrochemical impedance 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 double layer 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 of inhibitor systems are given in Table 2.

The aqueous extract of beet root (BR) 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) obtained by mass loss method

<table>
<thead>
<tr>
<th>BR Extract ml</th>
<th>IE %</th>
<th>CR mdd</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>71</td>
<td>13.92</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>12.00</td>
</tr>
<tr>
<td>6</td>
<td>83</td>
<td>8.16</td>
</tr>
<tr>
<td>8</td>
<td>92</td>
<td>3.84</td>
</tr>
<tr>
<td>10</td>
<td>96</td>
<td>1.92</td>
</tr>
</tbody>
</table>

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 water the corrosion potential is -517 mV vs. SCE (Saturated Calomel Electrode). The corrosion current is $1.544 \times 10^{-6}$ 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 $1.544 \times 10^{-6}$ A/cm$^2$ to $1.344 \times 10^{-5}$ 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

<table>
<thead>
<tr>
<th>BR mL</th>
<th>Zn(^{2+}) ppm</th>
<th>Ecorr mV vs. SCE</th>
<th>ba mV</th>
<th>bc mV</th>
<th>Icorr A/cm(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>-517</td>
<td>257</td>
<td>136</td>
<td>1.544x10^-6</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>-486</td>
<td>305</td>
<td>129</td>
<td>1.344x10^-6</td>
</tr>
</tbody>
</table>

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 (R\(_t\)) 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, the charge 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 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\(^{2+}\).

<table>
<thead>
<tr>
<th>BR ml</th>
<th>Zn(^{2+}) ppm</th>
<th>Nyquist plot</th>
<th>Bode plot Log(Z/ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R(_t) Ohm.cm(^2)</td>
<td>C(_{dl}) µF/cm(^2)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>293.1</td>
<td>6.551x10^-8</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>341.8</td>
<td>5.617x10^-8</td>
</tr>
</tbody>
</table>
Figure 3. AC impedance spectrum of 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)
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 and AC 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 1.544 x 10^{-5} A/cm² to 1.344 x 10^{-6} A/cm²). In AC impedance study the increase in Rt value (from 293.1 to 341.8 ohm.cm²) and the decrease in Cdl value (6.551 x 10^{-8} to 5.617 x 10^{-8} µF/cm²) 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

Acknowledgement

Authors are thankful to their Managements and University Grants Commission, India, for the help and encouragement.

References

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