

SARACA INDICA (ASOKA) LEAVES EXTRACT AS CORROSION INHIBITOR FOR MILD STEEL IN POTABLE WATER- A BIOREMEDIATION METHOD

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ABSTRACT

The inhibitive effect of the Saraca Indica (Asoka) leaf extract on the corrosion of mild steel in potable water was investigated by using weight loss, open circuit potential measurements and potentiostatic polarization techniques. The threshold concentration of the inhibitor was found to be 500 ppm. At stagnant condition, this concentration of inhibitor shows an inhibition efficiency of 92.4%. The inhibitor was suitable for protecting the mild steel under stimulated conditions also. The corrosion rate was measured at different intervals of immersion of mild steel sample in electrolyte to understand the mechanism of inhibition. The organic part of the leaf extract adsorbed on the surface of the metal and makes a complex on the surface of the metal. This layer will adhere firmly on the metal surface and not depleted with time, temperature and turbulence conditions.

INTRODUCTION

Corrosion of metals is a serious problem in water distribution systems. Corrosion increases the operational difficulties, maintenance cost and reduces the service life of the system. The corrosion product in water will affect the quality of water and also result in increased pipeline chocking (Buchweishaija and Mhinzi, 2008; Aiman and Ehab, 2007; Shams, 1986). Corrosion leads to pipeline leakages which require plugging or replacement of corroded pipes. There are many techniques used to prevent corrosion of mild steel in aqueous environment and most common technique is the use of corrosion inhibitors. Organic

compounds, especially those having N, S and O showed significant inhibition efficiency. The organic compounds adsorbed on the metal surface and there by forming a protective layer which prevents further oxidation of the metal (Sharma *et al.* 2009; Abd El-Rehim *et al.* 1999). Unfortunately most of these compounds are not only expensive but also toxic to living beings (Raja and Sethuraman, 2008). Plant extracts have become important as an environmentally acceptable, biodegradable, readily available and renewable source for wide range of inhibitors (Saratha *et al.* 2009). The corrosion inhibition effect of many naturally occurring substances had been reported in literature (Broo *et al.* 1999; Orubite *et al.* 2004; Olusegun *et al.*

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2009; Chauhan *et al.* 2007; Saratha and Meenakshi, 2010; Smita and Mehta, 1999; Beenakumari, 2010, 2011). The present research work focused to develop a safe and cheap corrosion inhibitor for drinking water systems. The inhibitor selected for the present study was the extract of the asoka leaf, which is environmental friendly, and also has some good medicinal value (Pradha *et al.* 2009). In many cases, the presence of *E. Coli* bacteria is reported in drinking water. The asoka leaf extract can act against *E. Coli* bacteria present in water (Sarojini *et al.* 2011; Seetharam *et al.* 2003). Hence addition of asoka leaf extract on drinking water distribution system not only inhibit the corrosion of pipe line but also improve the quality of drinking water. The corrosion rate was measured at different intervals of immersion of mild steel sample in electrolyte to understand the mechanism of inhibition.

Experimental Methods

Material

The specimens (2 × 1 × 0.2 cm) were produced from strips of mild steel. The composition of the metal is given in Table 1. The specimen were polished by using different metalo-graphic grade of emery papers, ultrasonically degreased by using isopropanol, cleaned by water, dried and store in desiccators.

The medium selected for study

The medium selected for the study was ordinary tap water used for drinking purpose. The characteristics of water are given in Table 2. The calcium and magnesium present in the water sample were analyzed by EDTA titration. The iron present in the water was analyzed by Atomic Absorption techniques using Atomic Absorption Spectrophotometer of Perkin Elmer (AA200). The anions like, chloride ion present in the medium was analyzed by titration with silver nitrate and sulphate by turbidimetric method using Thoshniwall turbidimeter.

The Inhibitor selected

The corrosion inhibitor used was the extract of the asoka leaf. The asoka leaf contain tannin, flavanoids, carbohydrates, glycosides, proteins, steroids, alkanoids and amino acids (Saha *et al.* 2012). The concentration of the inhibitor varies from 0 to 1000 ppm (v/v). For each experiment fresh water solutions as well as freshly polished metallic samples were used. The experiment was duplicated to get the concordant

results.

Electrochemical measurements

Cathodic and anodic polarization curves were recorded on the metal electrode surface (1cm²) immersed in aerated drinking water by sweeping at a rate of 1 mV/s over a range of 100 mV vs. Saturated Calomel Electrodes (SCE) where Platinum foil (20 cm²) act as counter electrode. The open circuit potential was measured as V vs. SCE.

Corrosion rate measurement

Weight loss method

The accurately weighed mild steel specimens (2 × 1 × 0.2 cm) were immersed in 500 mL of water for a period of 30 days. After 30 days of exposure in aqueous environment, the specimen were taken out cleaned by using pickling solution dried and weighed, corrosion rate is measured from the difference in weight of the specimen before and after immersion in water. The inhibition efficiency (IE) was calculate by using the formula

$$IE (\%) = \frac{(\text{corrosion rate without inhibitor} - \text{corrosion rate with inhibitor}) \times 100}{\text{Corrosion rate without inhibitor}}$$

Polarization method

The set up of polarization is already given in section 2.4. From the polarization graph, the corrosion current density (i_{corr}) is calculated. The inhibitor efficiency (IE) is calculated using the equation

$$IE (\%) = \frac{(i_{\text{corr}} \text{ at blank inhibitor} - i_{\text{corr}} \text{ at inhibitor}) \times 100}{i_{\text{corr}} \text{ at blank inhibitor}}$$

Corrosion at different duration of immersion

The corrosion experiment set up is same as above (weight loss method). 1mL of electrolyte is taken from the corrosion cell at regular intervals of time. The iron present in the electrolyte was analyzed using AAS method. From the quantity of iron in the solution at definite intervals of time, the corrosion rate is calculated.

Stimulated condition

High temperature studies were carried out by placing the corrosion cell on a hot plate. The turbulence was made by stirring the solution by using a hot plate with magnetic stirrer, which rotates at a speed of 100 rpm.

Table 1. Composition of the Metal Specimen.

Sl. No.	Elements	Quantity (%)
1.	Carbon	0.1
2.	Silicon	0.1
3.	Manganese	0.7
4.	Chromium	0.02
5.	Nickel	0.01
6.	Molybdenum	0.10
7.	Fe	Balance

Table 2. Characteristics of Typical Potable Water.

Sl. No.	Parameter	Value
1.	pH	7.2
2.	Residualchlorine (ppm)	0.2
3.	Chloride (ppm)	200
4.	Sulphate (ppm)	200
5.	Iron (ppm)	0.3
6.	Turbidity (NTU)	5
7.	Total Hardness (as CaCO ₃ (ppm)	300
8.	Calcium (ppm)	75
9.	Magnesium (ppm)	30

Table 3. Corrosion of Mild steel in Drinking Water with Different Inhibitor Concentration.

Concentration of inhibitor (ppm)	OCP (V vs SCE)	Corrosion rate (mpy)	IE (%)
0	-0.510	2.65	0
100	-0.465	2.0	24.5
200	-0.410	1.32	50.1
300	-0.362	0.70	73.5
400	-0.298	0.40	84.9
500	-0.292	0.20	92.4
1000	-0.290	0.20	92.4

Composition of scale

The metal constituents present on the scale formed on the surface of samples were analyzed by AAS. The carbon content present in the scale was estimated by using Leco- Carbon Analyzer.

RESULTS AND DISCUSSION

Weight loss methods

Stagnant condition and room temperature

An ability of the inhibitor is determined by calculating the ratio of its efficiency to concentration in

medium. Table 3 summarizes the weight loss experimental results conducted by immersing the mild steel coupons at 30°C for an exposure of 30 days with different inhibitor load. The OCP values shifted to more anodic region with increase in inhibitor concentration in the corrosion cell. The shift of OCP to anodic region shows the inhibition efficiency of the inhibitor to protect the metal in the electrolyte medium. The corrosion rate also decreases with increase of inhibitor in the electrolyte. The corrosion rate decreased to a value of 0.20 mpy when the system contains 500 ppm of the inhibitor. Increase of the inhibitor above this will not have any improvement in corrosion rate value. Hence 500 ppm can be selected as the optimum inhibitor concentration.

Stimulated condition

The corrosion rate of mild steel at different conditions (electrolyte at room temperature and at 80 °C with and without stirring) were evaluated and given in Table 4. The inhibitor shows very good inhibition properties to protect mild steel even under stimulated conditions. The corrosion rate shows a slight increase under stimulated conditions. This is due to more time required for adsorption of the inhibitor on the surface of mild steel under stimulated conditions.

Electrochemical Methods

Polarization method

The data obtained from potentiostatic polarizations experiments were given in Table 5. The corrosion potential (E_{corr}) shifted to anodic region when the system contains corrosion inhibitors. The anodic potential shift shows the effectiveness of the inhibitor to protect the metal from corrosion. At stimulated conditions, the E_{corr} value was found to be in cathodic regions compared to the corrosion system under room temperature. The polarization experiments were conducted in mild steel specimen just after 30 minutes of exposure in electrolyte medium. Since in stimulated conditions, more time is required for effective adsorption of the inhibitor, less anodic potential shift in E_{corr} value for the metal compared to mild steel under room temperature and stagnant condition. The corrosion rate is high at elevated temperature and stirring conditions. But it was noticed that, even at high temperature and stirring conditions, the inhibitor loaded system is found to be more anodic compared to blank at stagnant conditions. The corrosion current density (i_{corr}) decrease

Table 4. Corrosion Rate of Mild Steel under Stimulated Condition.

Concentration of inhibitor (ppm)	Conditions	OCP (V vs SCE)	Corrosion rate (mpy)	IE (%)
0	Stagnant at 30 °C	-0.510	2.65	0
500	Stagnant at 30 °C	-0.292	0.20	92.4
500	Stagnant at 80 °C	-0.365	0.65	75.0
500	Stirred at 30 °C	-0.298	0.33	87.5
500	Stirred at 80 °C	-0.390	0.85	67.9

Table 5. Polarization Results of Corrosion of Mild Steel in Drinking Water.

Concentration of inhibitor (ppm)	Conditions	Ecorr (V vs SCE)	Icorr ($\mu\text{A}/\text{cm}^2$)	IE (%)
0	Stagnant at 30 °C	-0.560	5.20	0
500	Stagnant at 30 °C	-0.305	0.49	90
500	Stagnant at 80 °C	-0.375	0.88	83
500	Stirred at 30 °C	-0.345	0.75	86
500	Stirred at 80 °C	-0.395	1.03	80

Table 6. Corrosion Rate of Mild Steel under Stimulated Conditions

Concentration of inhibitor (ppm)	Conditions	Corrosion rate (mpy)				
		1 hour	2 hour	6hour	24 hour	48 hour
500	Stagnant at 30 °C	1.20	1.10	0.80	0.65	0.40
500	Stagnant at 80 °C	1.45	1.40	1.15	1.00	0.95
500	Stirred at 30 °C	1.32	1.26	1.03	0.88	0.60
500	Stirred at 80 °C	1.85	1.60	1.42	1.25	1.10

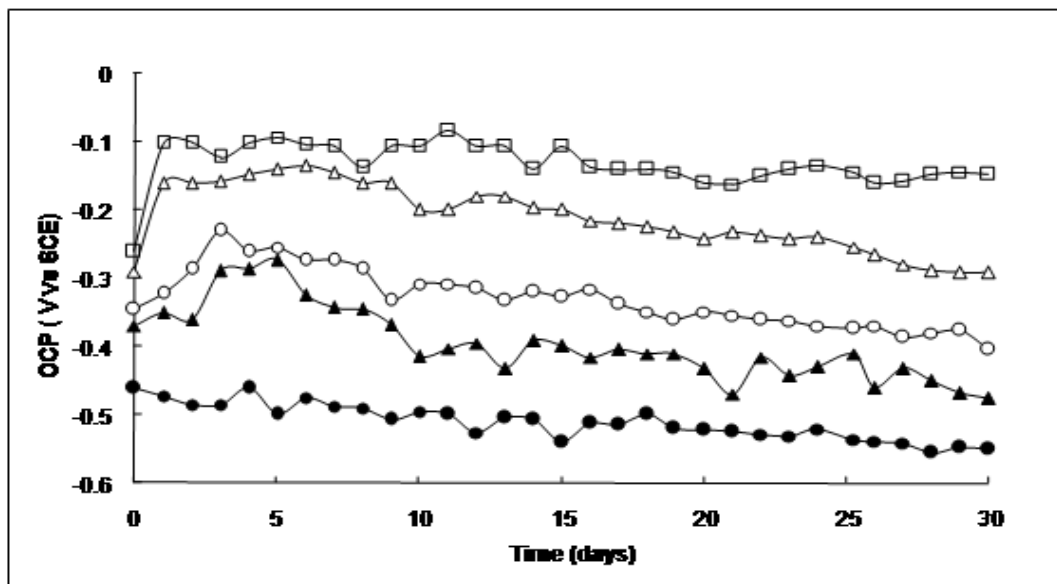


Fig. 1 OCP decay of mild steel samples under different conditions and at different inhibitor load
 ● - stagnant, 30 °C, 0.0 ppm inhibitor; □ - stagnant, 30 °C, 500 ppm inhibitor; ▲ - stirred, 80 °C, 500 ppm inhibitor
 ○ - stagnant, 80 °C, 500 ppm inhibitor; △ - stirred, 30 °C, 500 ppm inhibitor

Table 7. Constituents Present in the Scale

Sl. No.	Constituents	Quantity (ppm)
1.	Calcium	800
2.	Magnesium	420
3.	Organic as Carbon	3000
4.	Iron oxide	balance

as the inhibitor concentrations increases. The polarization results show that the inhibitor is found to be a very effective for protecting the mild steel in potable water even under stimulated conditions.

OCP Decay study

Figure 1 shows the open circuit potential (OCP) decay of mild steel specimen in water with inhibitor at different conditions. The OCP of the mild steel in blank are also given for comparison. In all cases, the electrolyte with inhibitor, the OCP shifts to anodic regions and remains more or less constant for 30 days. The initial anodic shift of OCP is due to the adsorption of the inhibitor on the surface of the metal sample. The steady nature of OCP value for 30 days shows that the adsorbed film will remains well adhered on the metal surface even under stimulated conditions.

Corrosion at different duration of immersion

The corrosion rate was calculated for metal samples at different duration of immersion in electrolyte medium containing the inhibitor under different conditions. The corrosion rate calculation at different duration was carried out as explained in experimental section 2.5.3 and the corrosion rate is given in Table 6.

The corrosion rate decreased with increase in the period of immersion. As duration of immersion increases, the quantity of inhibitor adsorbed on the metal surface increases and there by decrease the exposure area of the metal. Hence the corrosion rate decreases with time.

Composition of the scale

The scale formed on the surface of the mild steel specimen immersed in electrolyte medium with inhibitor for 30 days of exposure was scratched out from the surface of the mild steel sample and analyzed for its constituents. The composition of the scale is given in Table 7. The calcium and magnesium present in the water make complexes with organic part present in the leaf extract (inhibitor). The complex will adhere on the surface of the mild steel

and prevent the corrosion of the mild steel.

Mechanism of Inhibition

The OCP values of the mild steel sample becomes anodic when the electrolyte contains inhibitor showing that the inhibitor is adsorbed on the metal surface and prevent the for exposure of metal surface to the electrolytic medium. The corrosion rate decreases with increase in the time of immersion. As duration of immersion increases, the quantity of inhibitor adsorbed on the metal surface also increases. The carbon content present in the scale confirmed that an organic part of the leaf extract forms a film on the surface of the metal by adsorption process. This layer will adhere firmly and not depleted with time, temperature and agitated conditions. The formation of this layer is responsible for corrosion prevention of mild steel.

CONCLUSION

The asoka leaf extract is found to be good eco-friendly inhibitor to prevent the corrosion of mild steel in drinking water environment. The threshold concentration of the inhibitor was found to be 500 ppm. At stagnant condition, this concentration of inhibitor shows an inhibition efficiency of 92.4%. The inhibitor was found to be suitable for protecting the mild steel under stimulated conditions also. The inhibitor adsorbed on the surface of the metal and there by reducing the exposure of surface area of mild steel in the electrolytic medium. The quantity of inhibitor adsorbed increases with increase of time of exposure of mild steel in electrolyte. The organic part of the leaf extract is adsorbed on the surface of the metal and makes a complex on the surface of the metal. This layer will adhere firmly and not depleted with time, temperature and turbulence conditions. The formation of this layer is responsible for corrosion prevention of mild steel.

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