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Scientific paper
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Corrosion inhibition by spirulina

An environmental friendly green inhibitor namely an aqueous extract of spirulina has been used to prevent the corrosion of carbon steel in aqueous solution containing 60 ppm of Cl^- ion. Inhibition efficiencies of various concentrations of a 0.5% aqueous solution of spirulina have been evaluated by weight loss method and electrochemical studies such as polarization study and AC impedance spectra. As the concentration of spirulina increases, inhibition efficiency (IE) increases. As the value of pH increases, the IE of spirulina increases. As the duration of immersion increases, IE decreases. 6ml of spirulina solution offers inhibition efficiency greater than 80%. At pH 11 6ml of spirulina solution offers 90% corrosion inhibition efficiency. Electrochemical studies confirm the formation of a protective film on the metal surface.

Keywords: *Corrosion and oxidation, metal and alloys, green inhibitor, spirulina, carbon steel*

1. INTRODUCTION

Once inhibitors such as chromate were used to prevent corrosion of metals. The use of chromate was banned due to environmental hazards. Hence, environmental friendly inhibitors have attracted several researchers. Nontoxic natural products have been widely used as corrosion inhibitors. The use of natural products as corrosion inhibitors has been reviewed [1,2]. Natural products such as tannins [3], pomegranate [4], swertia aungustitolia [5], curcuma longa L [6], caffeine [7,8], garlic [9,10], onion [10,11] Hibiscus rosa-sinensis L [12], and henna leaves [13] have been used as corrosion inhibitors. Spirulina is a tiny aquatic plant, that has been eaten by human since prehistoric times. It is a vegetable with more protein than soy, more vitamin A than carrots and more iron than beef. It is low in fat. It is good for the brain, heart and immune system [14]. The present work is undertaken

(i) to evaluate the inhibition efficiency of an aqueous solution of spirulina in controlling corrosion of carbon steel in an aqueous solution containing 60ppm of Cl^-,

(ii) to investigate the influence of pH and duration of immersion on the inhibition efficiency of spirulina and

(iii) to study mechanism of corrosion inhibition by electrochemical studies such as polarization and AC impedance.

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2. EXPERIMENTAL

2.1. Preparation of spirulina solution

As aqueous solution of spirulina was prepared by dissolving 0.5 g of dry spirulina powder in 100 ml of double distilled water. This solution was used as corrosion inhibitor.

2.2. Preparation of metal specimens

Carbon steel of composition 0.026% S, 0.06% P, 0.4% P, 0.4% Mn, 0.1% C and the rest iron, was used . Carbon steel specimens of dimension 1 x 4 x 0.2 cm were used for weight loss study. Carbon steel encapsulated in Teflon, with an exposed surface area of 0.5cm^2 was used for electrochemical studies.

2.3. Weight loss method

Carbon steel specimens were polished to a mirror finish and degreased with trichloroethylene. Three specimens were immersed in 100ml of test solutions for a period of three days. After three days the metal specimens were taken out washed with double distilled water and dried. The corrosion products were cleaned with Clarke's solution [15]. The weights of the specimens before and after immersion were determined in a Shimadzu AY62 balance. The corrosion inhibition efficiency (IE) of spirulina was calculated using the relation.

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

where W_1 = weight loss in the absence of inhibitor

W_2 = weight loss in the presence of inhibitor

2.4. Electrochemical studies

Potentiodynamic polarization study and AC impedance study were employed. Carbon steel was used as working electrode. Platinum was used as counter

electrode. Saturated calomel electrode (SCE) was used as reference electrode. Electrochemical studies were carried out in an H and CH electrochemical workstation impedance analyzer model CHI 660A

3. RESULTS AND DISCUSSION

3.1 Weight loss method

The inhibition efficiencies of (IE) of various concentration of a 0.5% aqueous solution of spirulina, in controlling corrosion of carbon steel immersed in an aqueous solution containing 60 ppm of Cl^-, for a period of 3 days, are shown in Fig.1. It is observed that as the concentration of spirulina increases IE also increases. 6 ml of spirulina gives a maximum IE of 82%. Further increases in the concentration of spirulina lowers the IE. This may be due to the fact that the protective film formed on the metal surface is broken and goes into solution. The passive film formed upto 6 ml of spirulina goes into trans passive region at 7 ml.

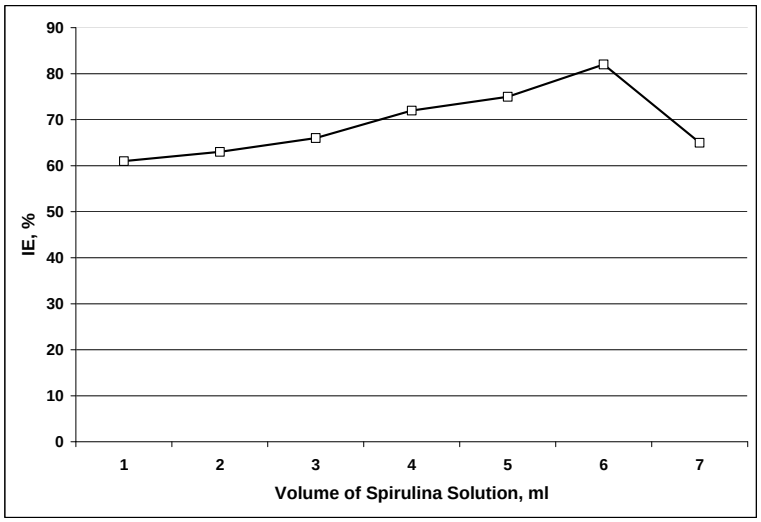

Fig. 1: Inhibition efficiencies of various concentrations of 0.5% aqueous solution of spirulina

3.1.1 Influence of pH on the inhibition efficiency of spirulina

Influence of pH on the inhibition efficiency of 6ml of spirulina solution is shown in Fig.2. It is observed that the IE of spirulina is pH dependent. As the value of pH increases, IE also increases. A maximum of 90% IE is obtained at pH 11 (NaOH). This is due to the fact that as the value of pH increases, a more stable compact protective film is formed on the metal surface.

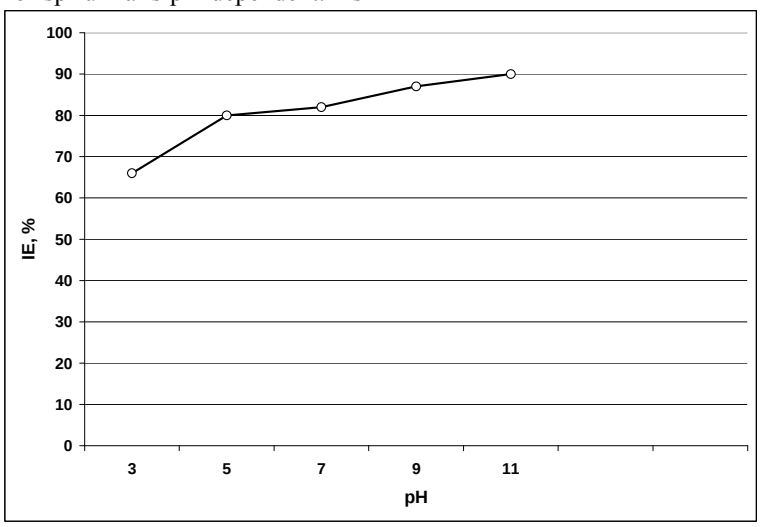

Fig. 2: Influence of pH on the inhibition efficiency of 6 ml of spirulina solution

3.1.2. Influence of immersion period on the inhibition efficiency of spirulina

Influence of immersion period on the inhibition efficiency of spirulina at pH 11 is shown in Fig 3. It is observed that as the duration of immersion increases, the IE decreases. On the first day, very high IE was observed. However, as the duration of immersion increases, the protective film is broken by the Cl^- ion present in the solution. On the ninth day the IE decreases to 80%.

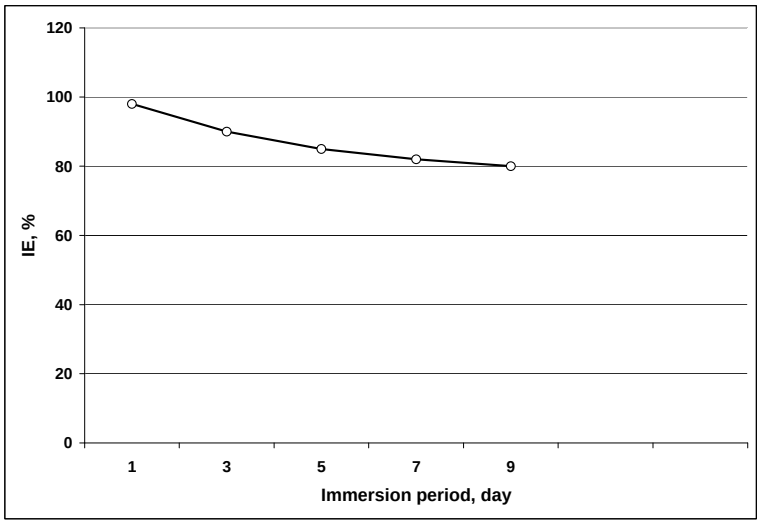

Fig. 3: Influence of immersion period on the inhibition efficiency of 6 ml of spirulina solution at pH 11

3.2. Electrochemical studies

3.2.1 Potentiodynamic polarization study

The corrosion parameters derived from the polarization study are given in Table 1. When carbon steel is immersed in an aqueous containing 60 ppm Cl^- at pH 11 (NaOH), the corrosion potential is -485mV vs SCE. Upon addition of 6ml of spirulina solution the potential shifts to the noble side (-409 mV vs SCE). This suggests that a protective film is formed on the metal surface. Further, the linear polarization resistance (LPR) value increases from 3.916×10^3 to 21.43×10^3 ohm cm^2, the corrosion current decreases from 1.215×10^{-5} to 0.1996×10^{-5} A/0.5cm^2. These results suggest that a protective film (Fe^{2+}-spirulina complex) is formed on the metal surface. This protects the metal from corrosion.

3.2.2. Analysis of AC impedance spectra

The AC impedance parameters derived from AC impedance spectra are given in Table 1. It is observed that when 6ml of spirulina is added to an aqueous solution containing 60 ppm of Cl^-, the change transfer resistance (R_t) increases from 249.58 to 271.93 ohm cm^2; the double layer capacitance (C_{dl}) decreases from 3.629×10^{-8} to 3.330×10^{-8} μF/0.5 cm^2. These results confirm the formation of a protective film on the metal surface.

Table 1*: Corrosion parameters of carbon steel immersed in various test solutions, obtained from polarization study and AC impedance spectra pH11*

Cl^- ppm	Spirulina solution, ml	E_{corr} mV vs SCE	b_c mV/decade	b_a mV/decade	I_{corr} A/0.5 cm^2	LPR ohm cm^2	R_t ohm cm^2	C_{dl} μF/0.5cm^2
60	0	-485	187	263	1.215×10^{-5}	3.916×10^3	249.58	3.629×10^{-8}
60	6	-409	152	278	0.1996×10^{-5}	21.43×10^3	271.93	3.330×10^{-8}

4. CONCLUSION

Inhibition efficiencies of various concentration of a 0.5% aqueous solution of spirulina have been evaluated by weight loss method and electrochemical studies such as polarization study and AC impedance spectra. The present study leads to the following conclusions

- As the concentration of spirulina increases, inhibition efficiency (IE) increases.
- As the value of pH increases, the IE of spirulina increases.
- As the duration of immersion increases, IE decreases.
- Electrochemical studies confirm the formation of a protective film on the metal surface

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