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FULL LENGTH ARTICLE

Phytochemical screening and corrosion inhibitive behavior of *Pterolobium hexapetalum* and *Celosia argentea* plant extracts on mild steel in industrial water medium

C.B. Pradeep Kumar, K.N. Mohana *

Department of Studies in Chemistry, University of Mysore, Manasagangotri, Mysore 570 006, India

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Abstract Preliminary phytochemical screening was carried out for methanolic extracts of *Pterolobium hexapetalum* (PH) and *Celosia argentea* (CA). Methanolic extracts of PH and CA were studied as corrosion inhibitors for mild steel in industrial water medium using mass loss and electrochemical techniques. The adsorption of both PH and CA extracts on mild steel surface followed Langmuir isotherm. The electrochemical impedance spectroscopy (EIS) measurements showed that the charge transfer resistance increases with increasing concentration of extracts. Various thermodynamic parameters were evaluated and discussed. Scanning electron microscopy (SEM) was used to analyze the surface adsorbed film. Further, antioxidant activity of the plant extracts was determined and correlated with the results obtained with inhibition efficiency.

1. Introduction

Corrosion of metals is a common problem with economic implications costing billions of dollars each year. Corrosion inhibition is required by many industries, for example oil and gas exploration and production, petroleum refining and chemical manufacture [1]. The use of inhibitors is one of the most effective ways to prevent corrosion. Inhibitors are commonly used to reduce the corrosive attack of solutions to the contacted metallic materials. The majority of well-known inhibitors are organic compounds containing heteroatoms such as O, N and S with multiple bonds. The efficiency of these organic corrosion inhibitors is related to the presence of polar functional groups with S, O and N atoms in the molecule [2–6]. Nevertheless, most of these organic compounds are not only expensive but also toxic to both human beings and the environment [7]. Therefore, the investigation of new cost-effective, non-toxic and eco-friendly inhibitors is essential to get over this problem and has been addressing toward the goal of using cheap, effective compounds at low or “zero” environmental impact.

* Corresponding author.
E-mail address: drknmohana@gmail.com (K.N. Mohana).

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The plant extracts have been employed as effective inhibitors of corrosion due to their low cost, biodegradability, high availability and non-toxic nature [8,9]. So, the study of plant extracts as corrosion inhibitors has received more attention due to environmental benefits. Several naturally-occurring materials such as *Zanthoxylum alatum*, *Justicia gendarussa*, *Phyllanthus amarus*, *Opuntia*, *Mentha pulegium*, black pepper, *Datura metel*, khillah seeds, lupine, *Gossypium hirsutum* L., *Gongronema latifolium*, *Aloe vera*, zallouh root were used as possible sources of green corrosion inhibitors by several researchers [10].

Pterolobium hexapetalum (PH) is one of the important medicinal plants, the leaves and stem bark of this plant are widely used for cough in children and delivery pains all parts against a large number of therapeutic activities like fever, cough, tooth ache, chest pain, dog bite (Rabies), vomits, heat boils, diarrhea, constipation and piles, bone fracture, jaundice, ulcer, skin infection, wound healing, venereal diseases and treating ulcer [11,12]. *Celosia argentea* (CA) is also a medicinal plant, the seeds are extremely small and used traditionally for the treatment of jaundice, gonorrhea, wounds and fever. The leaves are used for the treatment of inflammations, fever and itching. It is also used in the traditional medicine for sores, ulcers, skin eruptions, mouth sores and also the plant was investigated for anti-inflammatory, antipyretic, antidiabetic, antibacterial and diuretic properties [13,14]. However, PH and CA have not been exploited as corrosion inhibitors. In the view of the results obtained by phytochemical investigation, it was found worth investigating the corrosion inhibition behavior of these plants extracts. Hence, the present paper reports the results of our investigation on the inhibitive performance of PH and CA extracts on MS at different temperatures in industrial water medium using mass loss and electrochemical techniques. The thermodynamic activation and adsorption parameters were evaluated and discussed, and isotherm behavior has been determined. The morphology of the inhibited surface was investigated by scanning electron microscopy (SEM). The antioxidant activity of the PH and CA extracts was determined and correlated with the results obtained with their inhibition efficiency (IE%).

2. Experimental

2.1. Materials

The specimens used for corrosion tests were mild steel (MS) coupons which have the following composition (wt%): 0.051 C, 0.023 Si, 0.005 P, 0.103 Al, 0.179 Mn, 0.023 S and the remainder is iron. The test solution was industrial water collected from heat exchangers and reboilers of the chemical industries in and around Mysore city, India. The chemical composition of the industrial water (ppm) obtained from ionic chromatograph was: 7500 Cl^-; 64 Ca^{2+}; 3440 SO_4^{2-}; 23 Mg^{2+}; 140 Na^+; 0.28 PO_4^{3-}. Prior to gravimetric and electrochemical measurements, the surface of the specimens was polished under running tap water using emery paper (SiC, grade 200–600), rinsed with distilled water, dried on a clean tissue paper, immersed in benzene for 5 s, dried and immersed in acetone for 5 s, and dried with clean tissue paper. Finally, the specimens were kept in desiccators until use. At the end of the gravimetric experiment, the specimens were carefully washed with acetone and benzene, dried, and then weighed. For electrochemical studies, the MS specimen was embedded in epoxy resin to expose a geometrical surface area of 1 cm^2 to the electrolyte.

2.2. Methods

2.2.1. Phytochemical screening

Mature leaves of PH and CA collected from Western Ghats, Karnataka, India, were used for the preparation of methanolic extracts. Thoroughly washed leaves were shade dried and then powdered with the help of a blender. The leaf powder was extracted with methanol using a Soxhelt extractor. The extracts were concentrated using a rotary flash evaporator and preserved at 273 ± 5 K in an airtight bottle until further use. The extracts of the dry powdered leaves were analyzed for the presence of various phytoconstituents using phytochemical procedures [15]. Total soluble phenolics in the leaf extracts of PH and CA were determined with the Folin–Ciocalteu reagent method using gallic acid as a standard phenolic compound [16]. The antioxidant activity of PH and CA extracts was also determined by DPPH and hydroxyl radical scavenging assay methods [17,18] using ascorbic acid (AA) as standard.

2.2.2. Weight loss measurements

Mass loss measurements were carried out by weighing cleaned and dried MS specimens before and after immersion in industrial water medium in the absence and presence of PH and CA extracts at different temperatures (303–333 K). The temperature of the environment was maintained by a thermostatically controlled water bath (Weiber, India) with an accuracy of ±0.2 °C under aerated condition. The mild steel specimens used were rectangular with a dimension of 1 × 1 × 0.1 cm. The initial weight of the specimen was recorded using an analytical balance (precision ±0.1 mg). After the corrosion test in industrial water with and without inhibitor, the specimens were carefully washed in double distilled water, dried and then weighed. The weight loss of the specimen was determined after an immersion period of 10–50 h at the temperature range of 303–333 K. Triplicate experiments were performed in each case and the average mass loss was reported. The corrosion rate (C.R.) and inhibition efficiency (IE%) are calculated using the Eqs. (1) and (2).

$$\text{C.R.} = \frac{\Delta w}{St} \tag{1}$$

$$\text{IE}\ \% = \frac{(\text{C.R.})_a - (\text{C.R.})_p}{(\text{C.R.})_a} \times 100 \tag{2}$$

where ΔW is the weight loss, S is the surface area of the specimen (cm^2), t is the immersion time (h), and $(\text{C.R.})_a$ and $(\text{C.R.})_p$ are corrosion rates in the absence and presence of the inhibitor, respectively.

2.2.3. Electrochemical impedance spectroscopy (EIS)

The EIS tests were performed in a three electrode assembly CH1660D instrument. The cell arrangement used was a conventional three-electrode cell with platinum counter electrode, saturated calomel electrode as reference electrode and test material (mild steel) as working electrode. All potentials are reported versus SCE. The measurements were done after