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ORIGINAL ARTICLE

Corrosion inhibition by leaves and stem extracts of *Sida acuta* for mild steel in 1 M H_2SO_4 solutions investigated by chemical and spectroscopic techniques

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Abstract Corrosion inhibition of mild steel in 1 M H_2SO_4 by leaves and stem extracts of *Sida acuta* was studied using chemical (weight loss and hydrogen evolution) and spectroscopic (AAS, FTIR and UV-V) techniques at 30–60 °C. It was found that the leaves and stem extracts of *S. acuta* inhibited the acid induced corrosion of mild steel. The inhibition efficiency increases with increase in concentration of the extracts but decrease with rise in temperature. Inhibitive effect was afforded by adsorption of the extracts' components which was approximated by Freundlich adsorption isotherm. Inhibition mechanism is deduced from the temperature dependence of the inhibition efficiency and also from spectroscopic results.

1. Introduction

Pure metals and alloys react chemically/electrochemically with corrosive medium to form a stable compound, in which the loss of metal occurs. The compound so formed is called corrosion product and metal surface becomes corroded. Corrosion involves the movement of metal ions into the solution at active areas (anode), passage of electrons from the metal to an acceptor at less active areas (cathode), an ionic current in the solution and an electronic current in the metal. The cathodic process requires the presence of an electron acceptor such as oxygen or oxidizing agents or hydrogen ions (Bentiss et al., 2000; Hukovic-Metikos et al., 2002; Lagrenee et al., 2001; Sinko, 2001; Raja and Sethuraman, 2008). Corrosion of metals is a major problem that must be confronted for safety, environment, and economic reasons. It can be minimized by suitable strategies which in turn stifle, retard or completely stop the anodic or cathodic reactions or both (Raja and Sethuraman, 2009a). Among the several methods of corrosion control and prevention, the use of corrosion inhibitors, is very popular. Most of the efficient inhibitors are organic compounds that contain in their structures mostly nitrogen, sulfur or oxygen atoms.

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Unfortunately, the use of some chemical inhibitors have been limited because of some reasons namely their synthesis is very often expensive and they can be toxic and hazardous for human beings environment as well (Halambek et al., 2010). This has prompted the search for eco-friendly corrosion inhibitors as an alternative to replace inorganic and organic inhibitors to foster sustainable greenness to the environment. These nontoxic, benign, inexpensive, renewable and readily available alternative corrosion inhibitors have been found in different parts of plant extracts (Okafor et al., 2008, 2010; Oguzie, 2008). The use of plant products as corrosion inhibitors are justified by the phytochemical compounds present therein, with molecular and electronic structures bearing close similarity to those of conventional organic inhibitor molecules (Oguzie et al., 2010).

Scientific corrosion literature has descriptions and lists of numerous plant products that exhibit inhibitive properties for mild steel in acidic solutions. However, the latest reports include the inhibitive effect of *Andrographis paniculata* (Singh et al., 2010a), *Spirulina platensis* (Kamal and Sethuraman, 2010), *Jasminum nudiflorum* L. (Li et al., 2010), *Pongamia pinnata* (Singh et al., 2010b), *Bridelia retusa* (Patela et al., 2010), *Dacryodis edulis* (Oguzie et al., 2010), aqueous extracts of mango, orange, passion fruit and cashew peels (da Rocha et al., 2010), *Artemisia pallens* (Kalaiselvi et al., 2010), *Gongronema latifolium* (Eddy and Ebenso, 2010), *Murraya koenigii* (Quraishi et al., 2010), *Azadirachta indica* [(Okafor et al., 2010; Nahlé et al., 2010; Sharma et al., 2010), *Ananas comosus* L. (Ekanem et al., 2010), *Heinsia crinata* (Eddy and Odiongenyi, 2010), *Garcinia kola* and *Cola nitida* (Eddy, 2010), *Kopsia singapurensis* (Raja et al., 2010), *Fenugreek* seeds extract (Bouyanzer et al., 2010)], *Ocimum gratissimum* (Eddy et al., 2010), *Nauclea latifolia* (Uwah et al., 2010), *Salvia aucheri mesatlantica* essential oil (Znini et al., 2010) *Ocimum sanctum* (Kumpawat et al., 2010) and *Emblica officinalis* (Saratha and Vasudha, 2010).

Sida acuta Brum. f (*Malvaceae*) is a shrub indigenous to pantropical areas, widely distributed in these regions and widely used in traditional medicine. The aerial part of the plant is the most frequently used part. In central America, the plant is used to treat asthma, renal inflammation, colds, fever, headache, ulcers and worms (Caceres et al., 1987; Coee and Anderson, 1996). In Colombia the plant is used to treat snake bites. The ethanolic extract of the plant have an effective moderate activity against the venom of *Bothrox athrox* (Otero et al., 2000a,b). Among the compounds isolated from *S. acuta*, its alkaloids appeared to be of great interest in pharmacological studies. For example, Cryptolepine 5-méthylindolo (2-3b)-quinolic and Quindoline, two main alkaloids from the plant have been isolated, characterized and well investigated for its various biological properties and has been reported to enhance antibacterial activity in Burkina Faso (Karoul et al., 2006). In Nigeria, the leaves and stem of the plant are used by the local populace for the treatment of whitlow and other skin diseases (Ekpo and Etim, 2009). Preliminary phytochemical screening of the ethanolic extracts of *S. acuta* in our laboratory and reports of other authors (Edeoga et al., 2005; Akaneme, 2007) have revealed that the extracts is a complex mixture of various phytochemical components like saponins, flavanoids, tannis, alkaloids, organic acid and anthraquinones in the leaves and tannins, alkaloids, and anthraquinones only present in the stem extract.

The present work continues to focus on the application of plant extracts for metallic corrosion control and reports on the inhibiting effects of the leaves and stem extracts of *S. acuta* for mild steel (1005 AISI Grade) corrosion in acidic solution at 30–60 °C using weight loss, hydrogen evolution and atomic absorption spectrophotometry techniques. UV–Vis spectroscopy together with FTIR was further employed to provide additional insights into the mechanism of inhibitory action.

2. Experimental

2.1. Materials

The mild steel sheets used for this study were sourced locally. Each sheet was 0.04 cm in thickness and has the following composition (wt.%): C = 0.13; Si = 0.18; Mn = 0.39; P = 0.40; S = 0.04; Cu = 0.025 and the balance Fe. It was mechanically press cut into 5×4 cm coupons. They were abraded with different grades (#400, 600, 800 and 1000) silicon carbide paper, degreased in absolute ethanol, dried in acetone and stored in a moisture-free dessicator prior to use. The corrosive medium was 1 M H_2SO_4 prepared from 98% analytical grade supplied by Sigma–Aldrich. Deionised water was used for the preparation of all reagents.

2.2. Preparation of the *S. acuta* extracts

The leaves and stem of *S. acuta* were collected from Ikot Osong Iman, Etinan, Akwa Ibom, Nigeria, rinsed with distilled water, sun dried and ground to powder using a manual blender. One kilogram of the dry powered samples was extracted using absolute ethanol for 48 h. The extract was concentrated initially using vacuum evaporator and finally by evaporation to dryness on a steam bath to obtain a solid residue devoid of ethanol. From the solid residue, different concentrations (0.1–0.5) g were weighed and then dissolved in 1.0 L of 1 M H_2SO_4 solution for weight loss and hydrogen evolution measurements.

2.3. Weight loss measurements

Experiments were conducted under total immersion in stagnant aerated condition using 250 mL capacity beakers containing 200 mL test solution at 30–60 °C maintained in a thermostated water bath. The mild steel coupons were weighed and suspended in the beaker with the aid of rod and hook. The coupons were retrieved at 2 h interval progressively for 10 h, appropriately cleaned, dried as previously reported (Umoren et al., 2010) and reweighed. The weight loss, (in grams), was taken as the difference in the weight of the mild steel coupons before and after immersion in different test solutions. The tests were performed in triplicate to guarantee the reliability of the results, and the mean value of the weight loss is reported. The reproducibility of the experiment was higher than 95%. From the weight loss values, corrosion rates were computed accordingly using the expression:

$$v = \frac{\Delta W}{At} \quad (1)$$