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Hibiscus EXTRACT AS AN ECO-FRIENDLY AND EFFICIENT CORROSION INHIBITOR FOR ALUMINIUM IN ACIDIC ENVIRONMENT

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ABSTRACT

The study's objective was to determine whether *Hibiscus* flower extract (HSFE) could prevent aluminum from corroding in 1 M HCl. Understanding the rusting behavior of aluminum, a material that is utilized extensively in the construction of industrial vessels, will give industrialists crucial knowledge on the selection of protective techniques that will extend the material's lifespan. Corrosion inhibition behaviour of *Hibiscus* flower extract in 1 M HCl has been analysed at room temperature on aluminium metal surface through the mass loss method. Weight loss results disclosed that inhibitory efficacy improved with extract concentration. The maximum degree of inhibitory effectiveness was noted at greater doses of the extract. The results obtained in this research showed that *Hibiscus* extract acts as an eco-friendly, cost-effective, and good inhibitor with an efficiency of 75% at a concentration of 1000 ppm. The metal surface was studied under a metallurgical research microscope. The development of an armouring layer on the surface of aluminum was demonstrated by surface morphology analysis, verifying the extract's active ingredients' adsorption. This coating reduces the interaction between the metal and the acidic, corrosive media by acting as a barrier.

Keywords: *Hibiscus*, Corrosion Inhibitor, Aluminium, Weight Loss, Inhibitor Efficiency, SDG-13

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INTRODUCTION

Aluminum is one of the most important and extensively utilized metals in a variety of sectors, including electricity production, transportation, aviation, and construction. It is a positively charged, robust, and hard metal. Because of its thin, sticky, and positive surface, aluminum's ability to withstand corrosion is its most significant characteristic. However, in manufacturing operations where acidic products are usually utilized for making pickles, industrial acid washing, oil well oxidation, acid cleansing, and chemical and electrochemical etching of aluminum, the oxide on the metal exterior dissolves and leaves the metal surfaces vulnerable to damage in aggressive media, which typically results in significant metal loss from rusting.[1] Corrosion inhibition can be achieved through various methods, with the use of anti-corrosion agents being one of the most widely adopted approaches. Inhibitors are those substances that, when added in small concentrations to a corrosive medium, inhibit the reaction or media with metal. Many units, such as oil and gas production units, refinery units, cooling systems, chemical units, and so forth.[2] The chemical structure of corrosion inhibitors usually consists of many bonds and heteroatoms like oxygen, nitrogen, and sulphur. These features facilitate the adhesion of the inhibitor to the metallic surface. Adsorption behaviour depends on the electron density at the donor atom and the functional group. Although many synthetic compounds have a good anti-corrosive nature, on the other hand, these synthetic compounds are highly toxic to living beings. Due to environmental threats, the use of these inhibitors is limited.[30] Toxicity may be manifest during either during preparation of the compounds or during application. The detrimental impacts of chemical inhibitors prompted the researchers to investigate various natural products as potential corrosion inhibitors.[3,4] Plant extracts have become important inhibitors as these are easily accessible, reasonably priced, eco-friendly, and renewable sources of resources. Plant products contain constituents including flavonoids, tannins, amino acids, and alkaloids.[4]

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Most important thing about plant extract is that it can be taken off with a simple, low-cost technique.[28,29] Focusing on SDG-13, this study reduces the waste and harmful gases emitted from the burning of waste in the environment in a greener way.[31] In this work, the authors have studied the flower part of the *Hibiscus* plant on aluminium metal in an acidic medium.

Fig.-1: The *Hibiscus* Plant and Dried Flowers

Goweri *et al.* employed the weight-loss method to estimate the corrosion prevention effectiveness of the L-Arginine–Zn^{2+} system on carbon steel in seawater. A mixture containing 250 ppm of L-Arginine and 25 ppm of Zn^{2+} exhibited an inhibition efficiency of 91%. This system primarily acts as an anodic inhibitor, mainly suppressing the anodic reaction. According to Sabbah et al., the liquid extract of ginger (AEG) was assessed using common methods like mass reduction, open circuit voltage, linear polarization, and Tafel polarization as a potential eco-friendly anti-corrosion solution for mild steel in 1 M HCl over a temperature range of 25–55 °C. Lower temperatures and greater inhibitor concentrations resulted in an improvement in inhibition efficiency. It was identified that the Langmuir adsorption isotherm applied to the adsorption of AEG on the stainless-steel surface. Analysis of polarization showed that AEG operates as a mixed-type inhibitor. According to Sharma *et al., Brassica juncea root* extract (BJRE) was investigated as a green anticorrosion agent on mild steel (MS) in 1 M HCl through weight reduction and electrochemical techniques. The root extract data demonstrated that the inhibitory efficacy rose as the concentration rose and decreased as the temperature rose. Based on polarization research, B. juncea is a mixed-type inhibitor. Sharma *et al.* investigated the anticorrosion properties of *Brassica juncea* leaf extract (BJLE) on aluminium (Al) in 1 M HCl across a temperature range of 293–313 K, using weight reduction measurements and polarization techniques. The results indicated that the inhibition efficacy (IE) increased with rising extract concentrations. The highest efficiency of 80% was attained at 1000 parts per million. Latha *et al.* used a flower extract from *Hibiscus* rosa-sinensis as an anti-corrosion agent to stop mild steel from rusting in simulated oil well water. The weight loss technique shows that mild steel submerged in SOWW is inhibited by 82% when 10% v/v of the extract is added. Using polarization studies and AC impedance spectra, the mechanism of the corrosion-inhibiting activity has been investigated. Jeyasundari *et al.* used the mass-loss technique to assess the anti-corrosion efficiency of a water-soluble extract of *Hibiscus* rosa-sinensis (white) in preventing rusting of aluminium at pH 12, both with and without Zn^{2+}. The mixture created with 50 ppm of Zn^{2+} and 8 mL of flower extract (FE) showed a 98% inhibitory effectiveness. This mixture worked as a cathodic inhibitor, according to a polarization investigation. The existence of a protective coating on the metal body was demonstrated by AC impedance spectra. A study by Gaidhani *et al.*[11] found that *Hibiscus* leaf extract inhibited mild steel in an acidic medium with an average efficacy of 89% after one day, which decreased to 80% after four days. The inhibitory mechanism was determined to be physical adsorption, and the adsorption outcomes showed a strong correlation with the Langmuir isotherm.

EXPERIMENTAL

Extract Preparation

The flower part of the *Hibiscus* plant was collected, dried in a shaded area, and powdered with a mortar pestle. About 5 g of powder was taken in a 100 ml beaker with an adequate amount of ethanol to prepare the extract. The extract was concentrated by heating, and the desired concentration of extract was prepared with a 1 M HCl solution. The schematic preparation of the extract was shown in Fig.-2.

Specimen Preparation

Commercially available aluminium foil was used for coupon preparation. Aluminium sheet cut into 3 cm × 2 cm dimensions and polished with different grade emery paper ranging from 100, 300, 600, 1000 grade, purified using distilled water, and rinsed with acetone, subsequently dried and measured.

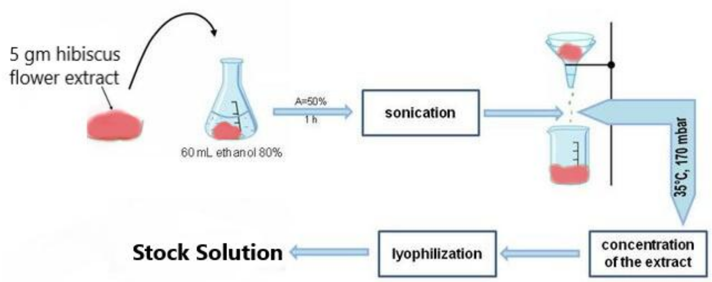

Fig.-2: Schematic Protocol of *Hibiscus* Flower Ethanolic Extract Preparation

RESULTS AND DISCUSSION

Weight Loss

Figure-3 (a) shows the plot of concentration vs. inhibition efficiency, and Fig.-3 (b) shows the plot of concentration vs. corrosion rate. Based on the plots, it has been discovered that the corrosion rate decreases, and the degree of anticorrosion efficacy improves with increasing extract concentration. The highest possible inhibitory efficiency was achieved at approximately 75%. Various parameters, such as rate of corrosion (Cr) and effectiveness of inhibition, were calculated using the following equations[7,8]

$$C_r = \frac{KW}{ATD} \tag{i}$$

$$\eta = \frac{C_r - inhC_r}{C_r} \tag{ii}$$

K = 8.76(constant)

D = 7.86 g/cm^{-3}density

Where Cr and inhCr are the corrosion rate (mmy^{-1}) of mild steel in the blank corrosive solution and in the presence of inhibitor, respectively. W is the weight loss of the specimen in grams, A is the area in cm^{2,} and t is the submersion time in hours.

Table-1: Weight Loss Data of *Hibiscus* Extract on Al in 1 Molar HCl

Concentration	Corrosion rate	Inhibition efficiency (IE)
0	0.0304	
400 ppm	0.0200	34.21%
600 ppm	0.0150	50.65
800 ppm	0.0112	63.15
1000 ppm	0.0075	75.32

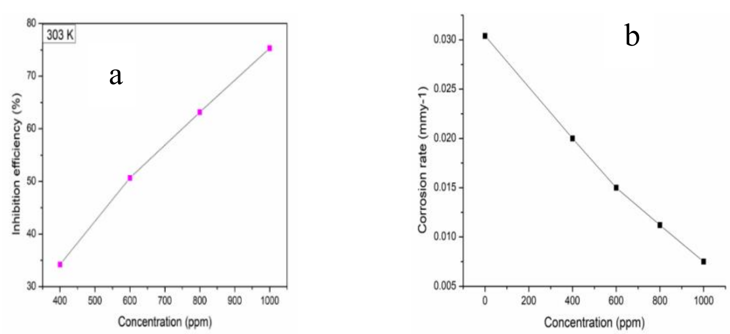

Fig.-3: (a) Conc. Vs Inhibition Efficiency, (b) Concentration. Vs Corrosion

Surface Study

The external characteristics of the corroded aluminum coupons were analyzed using a metallurgical research microscope, which was attached to a computer, and micrographs were recorded. Figure-4 (a)

represents the surface morphology of corroded Al coupons without an inhibitor, and (b) represents the same coupons with 1000 ppm inhibitor concentration.
The various toxic gases, such as CO_2, nitrogen oxides, have been diminished by using plant waste (HSFE) as anti-corrosion agents for this research work. In this way, our research work tries to achieve SDG 13 on a smaller scale.

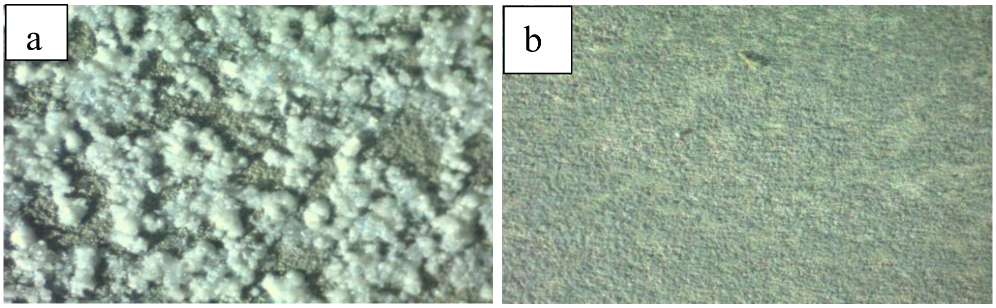

Fig.-4: (a) Without Inhibitor, (b) with Inhibitor

Comparative Study
The results obtained from the literature have been summarized in Table-2.

Table-2: Inhibition Efficiency of Green Inhibitor in Acidic Medium

Environment	Inhibitor	Techniques applied	Inhibitor Concentration	Efficiency
1M H_2SO_4	Leaves Stem extract of *Sida acuta*	Weight loss, spectroscopic (AAS, FTIR, UV)	0.1-0.5 g	85%, 52% respectively [12]
3.5% NaCl	Henna and Rosemary extracts,	Weight Loss Electrochemical	1g/L	92.7% and 90.2% respectively [13]
0.5 NaOH	*Tridax procumbens leaves*	Weight Loss Electrochemical	900 ppm	93.35% [14]
0.5 M HCl	*Cola acuminata leaves*, Tobacco	Weight-loss electrochemical	10 ml	81.27 and 97.02 %, respectively [15]
1 M HCl	Chitosan	Weight-loss electrochemical	150 mg/L	98% [16]
0.5 M HCl	*Swietenia macrophylla leaf extract*	Weight-loss Electrochemical	100 mgdm^{-3}	73.95% [17]
0.5 M HCl	*Dillenia Pentagyna*	Weight-loss Electrochemical	0.8g/L	92.29% [18]
1 M HCl	*Canarium swinfarthii*	Weight-loss Electrochemical	1g/L	75.39% [19]
0.1 M HCl	*Nicotiana tabacum*	Weight-loss Electrochemical	1200 mg/l	80% [20]
1 M HCl	*Brassica juncea* root extract	Weight-loss Electrochemical	1000 ppm	83% [7]
1 M HCl	*Brassica juncea* Leaf extract	Weight-loss Electrochemical	1000 ppm	80% [8]
0.5 M HCl	*Heterophragma adenophyllum*	Weight-loss Electrochemical	600 ppm	98% [21]
1 M HCl	*Tamarindus indica* extract	Weight-loss Electrochemical	600 ppm	88% [22]
1 M HCl	*Ziziphus jujuba*	Weight-loss	8%V/V	88.54% [23]
1 N HCl	*Mimusaps Elangi*	Weight-loss	20 ppm	98.50% [24]

		Electrochemical		
1M H2SO4	Soyabean Extract	Weight-loss Electrochemical	300 mg/l	98% [25]
0.5 M HCl	*Salsola oppositifolia* extract	Weight-loss Electrochemical	1000mg/l	91.86% [26]
10% H2SO4	Tulsi and green tea	Weight-loss Electrochemical	10% extract	85.71 and 71.43% respectively [27]

CONCLUSION

The extract of *Hibiscus* flower has been used to investigate the corrosion inhibition behaviour of Al metal in 1 M HCl. The results of this study showed that the prepared extract of *Hibiscus* flower acts as an efficient corrosion-controlling agent. The percentage of inhibition efficiency improved as the concentration increased from 400 ppm to 1000 ppm, with inhibition efficiencies of 34%, 50%, 63% and 75% as obtained by the weight-loss method. Inhibition efficacy was illustrated to be inversely related to temperature and directly proportional to extract concentration. Surface study demonstrated that the surface becomes smoother than the surface of metal in an acidic medium. A barrier film is formed over the surface of the metal, providing functional inhibition against corrosion. Plant waste acts as an anti-corrosion agent following SDG-13.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-13: Climate Action*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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