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ORIGINAL ARTICLE

# A thermodynamical, electrochemical and surface investigation of Bis (indolyl) methanes as Green corrosion inhibitors for mild steel in 1 M hydrochloric acid solution

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**Abstract** The influence of three Bis (indolyl) methanes (BIMs) namely, 3,3′-((4-nitrophenyl) methylene) bis (1H-indole) (BIM-1), 3,3′-(phenyl methylene) bis (1H-indole) (BIM-2) and 4-((1H-indol-2-yl)(1H-indol-3-yl) methyl) phenol (BIM-3) on the mild steel corrosion in 1 M HCl was studied by weight loss, electrochemical, scanning electron microscopy (SEM), and dispersive X-ray spectroscopy (EDX) methods. Results showed that BIM-3 shows maximum inhibition efficiency of 98.06% at 200 mg $L^{-1}$ concentration. Polarization study revealed that the BIMs act as mixed type inhibitors. Adsorption of BIMs on the mild steel surface obeyed the Langmuir adsorption isotherm. The weight loss and electrochemical results were well supported by SEM and EDX studies.


## 1. Introduction

Organic compounds particularly, N-heterocyclic have been reported as effective corrosion inhibitors for mild steel against corrosion during several industrial processes (Solmaz, 2014; Musa et al., 2012; Mahdavian and Ashhari, 2010; Ozkir et al., 2012). Ultrasound irradiation has immerged as a powerful technique for the synthesis of various heterocyclic compounds of industrial and biological interest (Goharshad et al., 2009) due to their shorter reaction time, simple operating procedure, high yield, high selectivity and clean reaction (Joshi et al., 2010).

Indole and its derivatives have received considerable attention of synthetic chemists due to their several biological applications such as antibacterial, cytotoxic, antioxidative, insecticidal activities and bioactive metabolites of terrestrial and marine origin (Surasani et al., 2013). In our present investigation we have synthesized and studied the corrosion inhibition efficiency of three Bis (indolyl) methanes on mild steel corrosion in 1 M HCl. The criteria behind selecting these compounds as corrosion inhibitors were that: (a) they can be easily synthesized from commercially available and relatively cheap starting materials (b) contain –OH, $–NO_2$ and heteroaromatic rings through which they can adsorb and inhibit corrosion (c) they were effective even at low concentration and (d) they were highly soluble in testing medium. Previously, few

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authors reported the corrosion inhibition efficiency of the indole and its derivatives in acid solution for different metals (Norr, 2008; Popova and Christov, 2006; Lowmunkhong et al., 2010; Quartarone et al., 2008).

## 2. Experimental section

### 2.1. Material

The mild steel specimens having composition (wt.%): C = 0.076, Mn = 0.192, P = 0.012, Si = 0.026, Cr = 0.050, Al = 0.023, and remainder Fe were used in present study. The test solution (1 M HCl) was prepared by dilution of analytical grade HCl (MERK, 37%) in double deionized water.

### 2.2. Synthesis of inhibitors (BIMs)

In the present study Bis (indolyl) methanes (BIMs) were synthesized as described earlier (Sonar et al., 2009). The synthetic rout for BIMs is shown in Scheme 1. The purity of products was determined by TLC method. The characterization data of the synthesized compounds are as follows: BIM-1 (3,3′-((4-nitrophenyl) methylene) bis (1H-indole, –R = –Ph (4-$NO_2$))): MP: 223-224 °C, IR (KBr, $cm^{-1}$): 3428, 2829, 2245, 1680–1660, 1522, 1230, 845, 739, 641. BIM-2 (3,3′-(phenyl methylene) bis (1H-indole) –R = Ph): MP: 125–127 °C, IR (KBr, $cm^{-1}$): 3465, 2811, 2275, 1482, 1130, 825, 758, 611. BIM-3 (4-((1H-indol-2-yl)(1H-indol-3-yl) methyl) phenol, –R = Ph(4-OH)): MP: 123–125 °C, IR (KBr, $cm^{-1}$): 3623, 3475, 2831, 2356, 1453, 1238, 845, 734, 623.

### 2.3. Gravimetric experiment

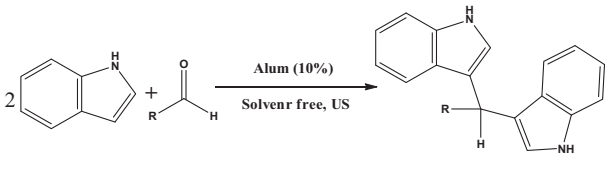
The weight loss experiments in the absence and the presence of different concentrations of BIMs were carried out to optimize the concentration of BIMs as described earlier (Verma et al., 2014). The corrosion rate ($C_R$), percentage inhibition efficiency ($\eta\%$) and surface coverage ($\theta$) were calculated using following equations.

$$C_R = \frac{87.6W}{A\ t\ d} \quad (1)$$

$$\eta\% = \frac{C_R - C_{R(i)}}{C_R} \times 100 \quad (2)$$

$$\theta = \frac{C_R - C_{R(i)}}{C_R} \quad (3)$$

where, $W$ is the weight loss in mg, $A$ is the area ($cm^2$) of the mild steel sample exposed to 1 M HCl, $t$ is the immersion time (3 h), $d$ is the density of mild steel (g $cm^{-3}$) and $C_R$ and $C_{R(i)}$ are the corrosion rates in the presence and the absence of BIMs, respectively.




**Scheme 1** Synthetic route for investigated BIMs.

### 2.4. Electrochemical experiments

As described earlier (Verma et al., 2014a), a typical three electrodes glass cell consisting of a highly pure platinum mesh as counter electrode, a saturated calomel as reference electrode and mild steel specimen as working electrode was used for electrochemical studies. The Tafel and EIS measurements were carried out using a Gamry Potentiostat/Galvanostat (Model G-300) with EIS Software Gamry Instruments Inc., USA. Echem Analyst 5.0 Software package was applied to analyze the electrochemical data. The cathodic and anodic Tafel slopes were recorded by changing the electrode potential inevitably from −0.25 to +0.25 V vs. corrosion potential ($E_{corr}$) at a constant sweep rate of 1.0 mV $s^{-1}$. The EIS studies were carried out under potentiostatic condition in a frequency range of 100 kHz–0.01 Hz. The amplitude of the AC sinusoid wave was 10 mV. All the Tafel and EIS studies were performed in naturally aerated solution of 1 M HCl in the absence and the presence of 200 mg $L^{-1}$ concentration of BIMs after 30 min immersion time.

### 2.5. SEM/EDX analysis

The SEM model Ziess Evo 50XVP instrument was used for the mild steel surface analysis with and without BIMs using accelerating voltage of 50 kV at 500× magnifications. Before SEM and EDX analysis the mild steel samples were immersed for 3 h in the absence and the presence of BIMs. The elemental composition was determined using energy dispersive X-ray spectroscopy (EDX) coupled with SEM.

## 3. Result and discussion

### 3.1. Weight loss measurements

#### 3.1.1. Effect of concentration

Variation of the inhibition efficiency ($\eta\%$) at different studied concentrations of BIMs is shown in Fig. 1. It is obvious that

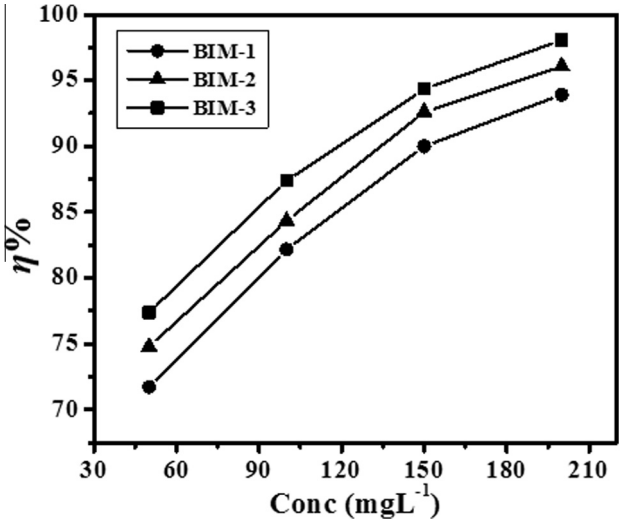



**Figure 1** Variation of inhibition efficiency with BIMs concentration of mild steel immersed in 1 M HCl obtained by weight loss measurement.

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