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## Corrosion characteristics of 1, 2, 3 benzotriazole for carbon steel in hydrochloric acid solutions

**Dr. Harish Kumar, Manju Kumari**

### Abstract

1, 2, 3 Benzotriazole (BTA) is used as corrosion inhibitor for Carbon steel in different concentration of hydrochloric acid medium and at different temperature. Corrosion rate and Percentage Corrosion Inhibition Efficiency (PCIE) was calculated by weight loss method, electrochemical polarization experiments and Impedance spectroscopy techniques. Surface study of corroded and blank specimens was carried out by SEM and Metallurgical research Microscopy techniques. 100, 200, 400, 600, 800 and 1000 ppm of 1, 2, 3 Benzotriazole was tested in different concentration of HCl solution i.e. 2.0, 1.0 and 0.1 N. It was observed that percentage Corrosion inhibition efficiency increases with increase in concentration of corrosion inhibitor. Effect of temperature on percentage corrosion inhibition efficiency was also studied. As the temperature increases, percentage corrosion inhibition efficiency decreases. It was also observed that percentage corrosion inhibition efficiency decreases with dilution of HCl. BTA acts as a good inhibitor for Carbon Steel in different hydrochloric acid medium.

**Keywords:** Carbon steel, Weight loss, Polarization, Impedance, BTA, Corrosion...

### Introduction

Carbon steel is one of the industrially important metals and is inevitable to expose its surface to the different industrial environments while in use. The steel undergoes corrosion to different extent depending on the aggressiveness of the medium or environment. <sup>[1, 3]</sup> generally the service life of carbon steel is increased by applying various corrosion control methods. Most of the available methods for controlling corrosion are based on using corrosion inhibitor. In most of the industries like oil refineries, nuclear power plants, fertilizer and chemical etc. the steel is used as containers, steam generators, liquid carrying pipes and so on. In such cases the corrosion of steel is effectively controlled by the application of suitable inhibitors. Most of the acid corrosion inhibitors are organic compounds, such as those containing N, S, O and aromatic ring. Most of the organic inhibitors act by adsorption on the metal surface. The adsorption of organic inhibitors at metal/solution interface can markedly change the corrosion resisting properties of metals. <sup>[4,10]</sup> The protection of corroding surfaces prevents the waste of both resources and money during the industrial applications and it is vital for the extension of the life time of the equipment and limiting dissolution of toxic metals from components into environment. In continuation to our earlier study, <sup>[10, 14]</sup> in the present work, the corrosion inhibition efficiency of BTA on the acid dissolution of carbon steel was evaluated using weight loss, Electrochemical Polarization, Impedance spectroscopy and surface study by metallurgical research microscopy and SEM techniques.

Organic compounds containing electronegative functional groups and  $\pi$ -electrons in triple or conjugated double bonds are usually good corrosion inhibitors. Heteroatoms such as sulphur, phosphorus, nitrogen and oxygen as well as aromatic rings in their structure are the major adsorption centers. The compounds used as corrosion inhibitors act through a process of surface adsorption. The efficiency of an inhibitors depends on the characteristics of the environment in which it acts, the nature of the metal surface and electrochemical potential at the interface. The structure of the inhibitor itself, which includes the number of adsorption active centers in the molecule, their charge density, the molecule size, the mode of adsorption, the formation of metallic complexes and the projected area of the inhibitor on the metallic surface also has effect on the efficiency of inhibitors <sup>[14, 15]</sup>

### Materials and Methods

Carbon steel was used for the weight loss measurement contains C = 0.54%, P = 0.05%, Mn = 0.32%, S = 0.05%, Si = 0.05%, P=0.20, Ni=0.03, Cu=0.01, Cr=0.01 and iron is the remainder, of size (3.0 cm × 1.5 cm) were used. Strips were mechanically polished with different grades of emery papers and washed with acetone before use. A sheet cut of the same composition having size (1 cm × 1 cm) was used for electrochemical polarization experiments. The electrode was polished using different grades of emery papers and washed. HCl was used for preparing solutions was of AR grade. The inhibitor CTAB used was CDH made. All solutions were prepared using double distilled water. Percentage corrosion inhibition efficiencies (PCIEs) for different concentrations of the inhibitor were calculated from weight loss experiments in the absence and presence of the inhibitor at three different temperature of 25, 30, and 35 °C with the help of formula (1) & (2).

$$\text{Corrosion Rate (mpy)} = \frac{534 \cdot W}{DAT} \quad (1)$$

Where, W = weight loss (in mg), D = density of carbon steel (in g/cm<sup>3</sup>), A = area of sample (in sq. inch), T = exposure time (in hour).

$$\text{Percentage Corrosion Inhibition Efficiency (PCIE)} = \frac{(CR_0 - CR)100}{CR_0} \quad (2)$$

Where, CR<sub>0</sub> = corrosion rate in absence of inhibitor and CR = corrosion rate in presence of inhibitor.

The effect of temperature on the performance of the inhibitor and the effectiveness of the inhibitor at higher acid strength were also studied.

### Electrochemical Polarization Measurements

An electrochemical cell assembly using three electrodes based was used for electrochemical polarization experiments. Mechanically polished Carbon steel coupons itself act as working electrode. As a reference electrode, Ag/AgCl electrode was used and a platinum electrode was used as a auxiliary counter electrode. Mechanical polishing of the Carbon steel coupons was successively done with 150, 250, 350, 600 μ grade emery papers. The surface of mechanically polished surfaces Carbon steel coupons were washed with acetone in order to remove grease or oil from CS surface and then washed with plenty of double distilled water before performing the corrosion experiments. The surface area of exposure of working electrode for performing experiments was 1.0 cm<sup>2</sup> and rest of area was coated with epoxy resin. The electrochemical polarization experiments were performed on electrochemical workstation PGSTAT 128N Metrohm Autolab. Ltd., Netherland. Before starting the electrochemical polarization experiments, the working electrode i.e. CS was kept into the acidic solution as a corrosion medium for 2.0 hrs to gain the constant value of equilibrium potential. Electrochemical polarization experiments were carried out under temperature of 298.0, 303.0, 308.0 K constantly flowing water from thermostat maintained at a constant temperature. The same process is repeated in different concentration of corroding medium i.e. 2.0, 1.0, 0.1 N HCl. Electrochemical polarization experiments were performed

from -1.2 to 2.0 V at a scan rate of 0.01(V/s). The corrosion rate (CR) and PCIE was found out by the use of following equations:

The corrosion rate was observed by the Stern-Gerry equation given in equation (3) as below:

$$\text{Corrosion rate (C.R.) (mpy)} = \frac{0.1288 \cdot i_{corr} \cdot Eq. wt.}{D} \quad (3)$$

Where, Eq. Wt. is the gram eq. wt. of CS, D is the density of CS in gm/cm<sup>3</sup> and *i*<sub>corr</sub> is the corrosion current density in (μA/cm<sup>2</sup>).

$$PCIE = \frac{(CR_0 - CR)100}{CR_0}$$

Where CR<sub>0</sub> is the corrosion rate in absence of corrosion inhibitor and

CR is the corrosion rate in presence of corrosion inhibitor

### Electrochemical impedance spectroscopy

The electrochemical impedance spectroscopy measurements were carried out using classone handheld electrochemical work station Netherland under static conditions. Three electrode based double walled glass cell was used. A saturated calomel electrode (SCE) was used as reference electrode. A platinum electrode was used as auxiliary electrode of a surface area of 0.094 cm<sup>2</sup>. The working electrode was carbon steel. All potentials given in this study were referred to this reference electrode. The working electrode was immersed in the test solution for 3 min, to establish a steady state open circuit potential (E<sub>ocp</sub>). After measuring the E<sub>ocp</sub>, the electrochemical measurements were performed. Nyquist plots were plotted with the help of which R<sub>ct</sub> (charge transfer resistance) calculated. Percentage inhibition was calculated efficiency by the use of charge transfer resistance using this formula

$$I.E. \% = \frac{(R_{ct} - R_{ct}^*)}{R_{ct}} \times 100$$

Where R<sub>ct</sub> and R<sub>ct</sub>\* are the charge-transfer resistances with and without the inhibitors

### Surface Study

The test coupons of carbon steel after weight loss method in absence and presence of the BTA in 2.0 N HCl solutions at 298.0 K temperature were used for SEM. These coupons were washed with double distilled water and then with acetone. Finally metal coupons were treated for the surface study by SEM model JEOL JSM 6150 and Metallurgical research microscope.

### Result & Discussion

#### Weight loss technique

In weight loss method, PCIE increases as we increase the conc. of inhibitor from 100ppm to 1000ppm. It acts as a good inhibitor even at low concentration of inhibitor in different acidic medium. Highest PCIE is observed in 2.0N HCl at 1000 ppm. Results of Weight loss method are shown in table

**Table 1:** Weight loss, Corrosion rate and Percentage Corrosion Inhibition Efficiency (PCIE) of CTAB at different concentrations by weight loss technique at 25, 30, 35 °C temperature in 2.0, 1.0, 0.1 N HCl solution.

Conc. of BTA	Conc. of HCl	CR at 25.0 °C	PCIE at 25.0 °C	CR at 30.0 °C	PCIE at 30.0 °C	CR at 35.0 °C	PCIE at 35.0 °C
blank	2.0 N	1065.96		1147.45		1269.01	
	1.0 N	837.54	--	897.54	--	964.64	--
	0.1 N	456.84		502.40		558.36	
100 200 400 600 800 1000	2.0 N	319.47	70.02	405.67	64.64	888.30	30.00
		282.98	73.45	388.05	66.18	736.02	42.00
		255.06	76.07	361.06	68.53	609.12	52.00
		227.86	78.62	318.02	72.28	558.36	56.00
		202.18	81.03	282.14	75.32	482.22	62.00
		156.70	85.29	256.06	77.61	467.56	63.15
100 200 400 600 800 1000	1.0 N	388.86	53.57	508.70	43.32	634.50	34.09
		359.16	57.11	483.65	46.12	507.60	47.37
		333.82	60.14	456.04	49.23	558.36	42.11
		295.45	64.72	420.76	53.56	507.60	47.76
		258.02	69.19	386.01	56.67	456.84	52.23
		233.04	72.17	289.10	67.13	427.80	55.43
100 200 400 600 800 1000	0.1 N	294.10	35.62	362.80	27.65	482.22	13.08
		263.80	42.25	327.04	35.32	456.84	18.21
		208.42	54.37	261.50	48.12	406.08	27.43
		183.04	59.93	236.03	53.23	380.56	31.67
		169.89	62.81	215.04	57.04	367.78	34.07
		137.91	69.81	204.08	59.09	359.89	35.54

#### Effect of inhibitor dose and temperature on inhibition efficiency

The pattern of the inhibition efficiencies obtained from the weight loss with different inhibitor concentrations in 0.1, 1.0 and 2.0 N HCl concentration media at different temperatures (25, 30, and 35 °C) are shown in Table 1. The results show that percentage corrosion inhibition efficiency increases as the concentration of inhibitor increases from 100 to 1000 ppm at 25, 30 and 35 °C. The maximum inhibition efficiency for BTA inhibitor was found to be about 85.29% in 2.0 N HCl solution. The inhibition was estimated to be 70.02% at 25 °C even at low concentrations (100 ppm), and at 400 ppm its protection was more than 75% (25 °C). This trend may result from the fact that the amount of adsorption and the surface coverage of BTA on the Carbon-steel increase with the inhibitor concentration, thus the Carbon-steel surface is efficiently separated from the medium. Also, the inhibition efficiency decreases with an increase in corrosion temperature at the same inhibitor concentration indicating that the high temperature might result in desorption of the inhibitor molecules from the Carbon-steel surface.

#### Electrochemical polarization technique:

Table-2, 3, 4 shows electrochemical polarization data for CS in 2.0, 1.0, 0.1 N HCl solutions in presence and absence of BTA at 25, 30, 35 °C temperature. The values of OCP,  $R_p$ ,  $\beta_a$ ,  $\beta_c$  and  $I_{corr}$  and PCIE are tabulated in table 2, 3 & 4.

It is observed that the increase in conc. of BTA to the acid solution as a corroding medium increases both i.e. anodic and cathodic over-potentials but corrosion current density ( $I_{corr}$ ) decreases. The values of anodic and cathodic Tafel slopes ( $\beta_a$  and  $\beta_c$ ) confirm the adsorption of BTA on the surface of Carbon steel. It is clear from the Table-2 that cathodic hydrogen evolution and anodic metal dissolution reactions are inhibited to the same extent and the magnitude of corrosion inhibition of Carbon steel increases as the concentration of corrosion inhibitor increases in corrosive acid media. No definite trend was observed in  $E_{corr}$ . Values in presence of different concentrations of BTA in 2.0 N HCl solution. This result indicates that BTA may be regarded as mixed type of corrosion inhibitor.

**Table 2:** OCP, Corrosion Current Density ( $I_{corr}$ ), anodic Tafel slope ( $\beta_a$ ), cathodic Tafel slope ( $\beta_c$ ), resistance polarization ( $R_p$ ), corrosion rate and PCIE of BTA at different concentrations by electrochemical polarization method at 25.0 °C temperature in 2.0, 1.0, 0.1 N HCl solution

Conc. of HCl	Conc. of inhibitor (ppm)	OCP	$I_{corr}$ ( $\mu\text{A}/\text{cm}^2$ )	$\beta_a$ , (V/dec)	$\beta_c$ (V/dec)	$R_p$	CR (mpy)	PCIE
2.0 N	Blank	-0.530	5.23	2.453	3.567	$8.51 \times 10^4$	2.31	
1.0 N		-0.534	4.03	3.407	2.342	$9.79 \times 10^4$	1.78	-
0.1 N		-0.524	3.58	2.345	4.897	$7.15 \times 10^5$	1.58	
2.0N	100	-0.577	1.45	1.250	1.345	$9.51 \times 10^4$	0.65	71.86
	400	-0.579	1.29	1.104	1.306	$7.79 \times 10^4$	0.58	74.89
	1000	-0.592	1.09	1.031	1.321	$1.15 \times 10^5$	0.49	78.78
1.0N	100	-0.557	1.55	1.841	1.805	$1.20 \times 10^5$	0.69	61.23
	400	-0.686	1.46	0.537	1.827	$4.23 \times 10^4$	0.65	63.48
	1000	-0.557	1.18	0.466	1.243	$5.02 \times 10^4$	0.53	70.22
0.1N	100	-0.776	1.66	0.340	1.611	$3.27 \times 10^4$	0.74	53.16
	400	-0.686	1.48	0.527	1.832	$5.23 \times 10^4$	0.66	58.22
	1000	-0.555	1.32	1.712	2.118	$1.25 \times 10^5$	0.59	62.65

**Table 3:** OCP, Corrosion Current Density ( $I_{corr}$ ), anodic Tafel slope ( $\beta_a$ ), cathodic Tafel slope ( $\beta_c$ ), resistance polarization ( $R_p$ ), corrosion rate and PCIE of BTA at different concentrations by electrochemical polarization method at 30.0 °C temperature in 2.0, 1.0, 0.1 N HCl solution

Conc. of HCl	Conc. of inhibitor (ppm)	OCP	$I_{corr}$ ( $\mu\text{A}/\text{cm}^2$ )	$\beta_a$ (V/dec)	$\beta_c$ (V/dec)	$R_p$	CR (mpy)	PCIE
2.0 N	Blank	-0.530	6.13	2.156	3.786	$4.27 \times 10^4$	2.70	
1.0 N		-0.527	4.98	3.087	2.645	$5.13 \times 10^5$	2.20	
0.1 N		-0.524	3.76	3.214	4.937	$3.05 \times 10^4$	1.66	
2.0 N	100	-0.570	2.37	1.456	2.056	$3.27 \times 10^4$	1.06	60.70
	400	-0.567	1.97	1.977	1.987	$4.03 \times 10^5$	0.88	67.40
	1000	-0.564	1.85	1.204	1.834	$4.25 \times 10^4$	0.83	69.25
1.0 N	100	-0.584	2.09	1.456	0.456	$4.07 \times 10^5$	0.94	57.27
	400	-0.573	1.86	0.957	2.917	$5.23 \times 10^4$	0.83	62.27
	1000	-0.564	1.63	1.214	2.134	$4.25 \times 10^5$	0.73	66.81
0.1 N	100	-0.580	1.70	1.406	0.416	$2.27 \times 10^5$	0.76	54.21
	400	-0.567	1.57	1.067	1.077	$4.13 \times 10^4$	0.70	57.83
	1000	-0.554	1.35	1.034	1.134	$3.25 \times 10^5$	0.60	63.85

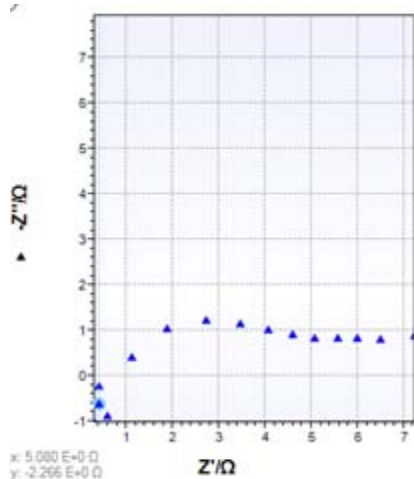
**Table 4:** OCP, Corrosion Current Density ( $I_{corr}$ ), anodic Tafel slope ( $\beta_a$ ), cathodic Tafel slope ( $\beta_c$ ), resistance polarization ( $R_p$ ), corrosion rate and PCIE of BTA at different concentrations by electrochemical polarization method at 35.0 °C temperature in 2.0, 1.0, 0.1 N HCl solution

Conc. of HCl	Conc. of inhibitor (ppm)	OCP	$I_{corr}$ ( $\mu\text{A}/\text{cm}^2$ )	$\beta_a$ (V/dec)	$\beta_c$ (V/dec)	$R_p$	CR (mpy)	PCIE
blank		-0.524	6.86	3.671	4.784	$9.01 \times 10^4$	3.03	
		-0.484	5.23	2.562	5.675	$6.79 \times 10^4$	2.31	
		-0.512	4.76	4.567	3.654	$1.05 \times 10^5$	2.10	-
2.0N	100	-0.566	2.52	1.320	1.365	$9.41 \times 10^5$	1.13	62.70
	400	-0.569	2.18	1.104	1.336	$7.79 \times 10^4$	0.98	67.65
	1000	-0.592	1.95	1.211	1.331	$1.25 \times 10^5$	0.87	71.28
1.0N	100	-0.547	2.47	1.821	1.605	$1.10 \times 10^5$	1.11	51.94
	400	-0.680	2.33	0.507	1.737	$5.03 \times 10^4$	1.04	54.97
	1000	-0.553	1.93	0.476	1.253	$5.12 \times 10^4$	0.86	62.77
0.1N	100	-0.780	2.15	0.350	1.621	$3.17 \times 10^4$	1.19	48.09
	400	-0.681	2.08	0.517	1.832	$5.13 \times 10^4$	0.91	56.66
	1000	-0.541	1.97	1.702	2.038	$1.25 \times 10^5$	0.85	59.52

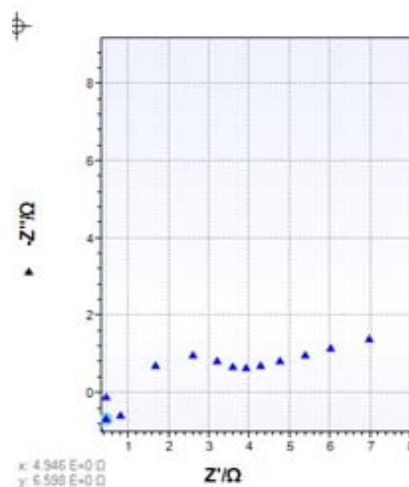
**Electrochemical Impedance Spectroscopy:**

Impedance spectroscopy technique was used to study the electrode/electrolyte interface behavior of the electrode and corrosion processes occurring on the surface of Carbon steel in presence and absence of Corrosion inhibitor. For understanding the phenomenon, electronic structure of electrified interface formed at the surface of working electrode and surface processes, EIS experiments were carried out at equilibrium potential in frequency range i.e. 10,000 to 0.1 Hz at 298.0 K, 303.0 K, 308.0 K. Figure 3 shows EIS plots for CS coupons dipped in 2.0 N, 1.0 N, 0.1N HCl medium at 298.0 K

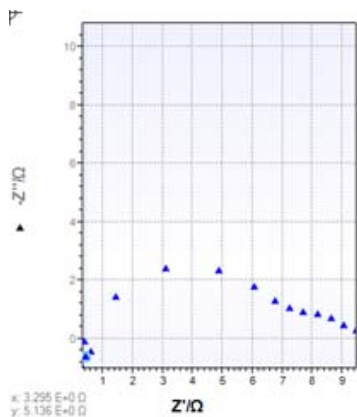
with and without corrosion inhibitor at the OCP. It is also observed from Nyquist plots that the diameter of the semicircle augment with the augment in concentration of BTA in the corroding medium, which indicates an increase in resistance to corrosion. It is observed from electrochemical impedance data presented in the Table-5. Table data point out that both  $R_{ct}$  and PCIE were found to increase with increase in the concentration. The present behavior can be accredited due to either decrease in the dielectric constant value or may be due to increase in the width of the electrical double layer of the electrified interface, represents good corrosion inhibitor.



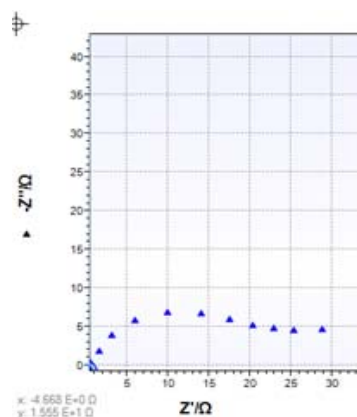
Nyquist plot of Blank 2.0 N HCl



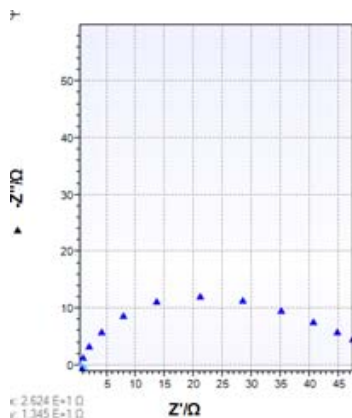
Nyquist plot of Blank 1.0 N HCl



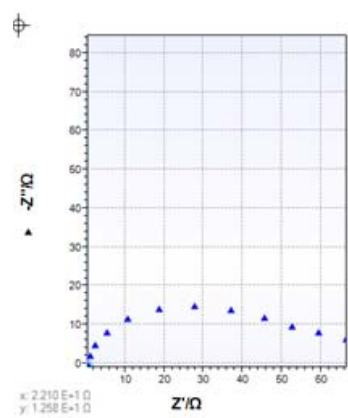
Nyquist plot of Blank 0.1N HCl



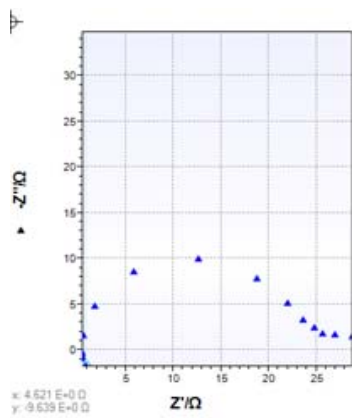
Nyquist plot of BTA in (100ppm) 2N HCl



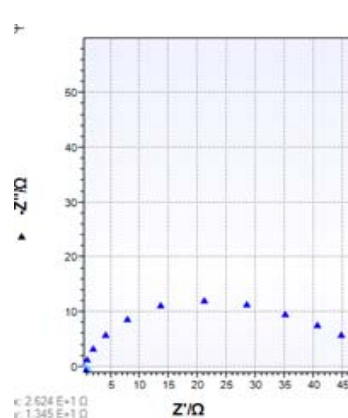
Nyquist plot of BTA (400ppm) in 2N HCl



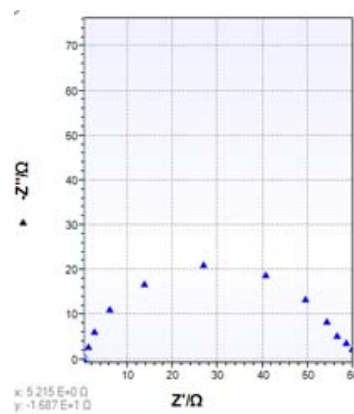
Nyquist plot of BTA (1000 ppm) in 2N HCl



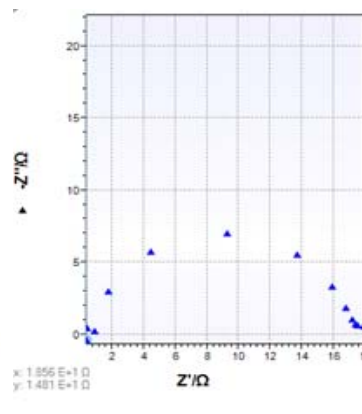
Nyquist plot of 100 ppm BTA in 1N HCl



Nyquist plot of 400 ppm BTA in 1N HCl

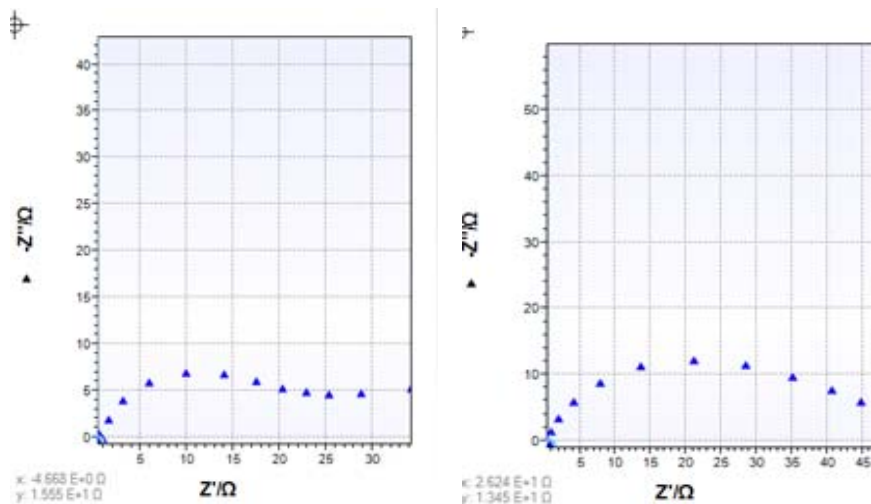


Nyquist plot of BTA(1000 ppm) in 1N HCl



Nyquist plot of BTA(100ppm) in 0.1N HCl





Nyquist plot of BTA(400ppm) in 0.1N HCl Nyquist plot of BTA(1000ppm) in 0.1N HCl

**Fig 1:** Nyquist plots (EIS) of Carbon steel immersed in 2.0, 1.0, 0.1 N HCl in absence and presence of different concentrations of BTA at 298.0 K temperature

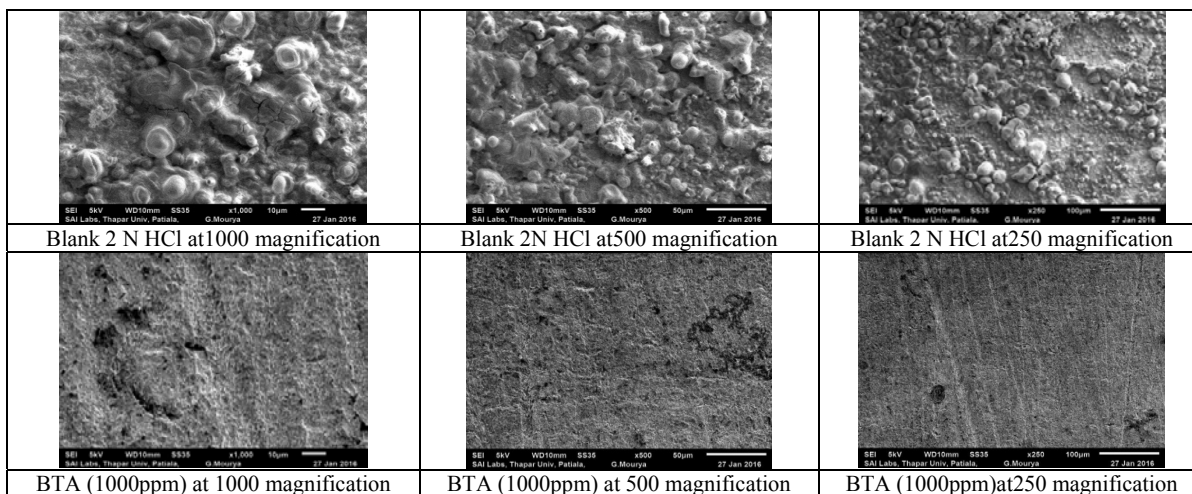
**Table 5:** Electrochemical impedance parameters for Carbon steel samples in 2.0, 1.0, 0.1 N HCl solution in absence and presence of different concentrations of BTA at 25.0, 30.0, 35.0 °C temperature

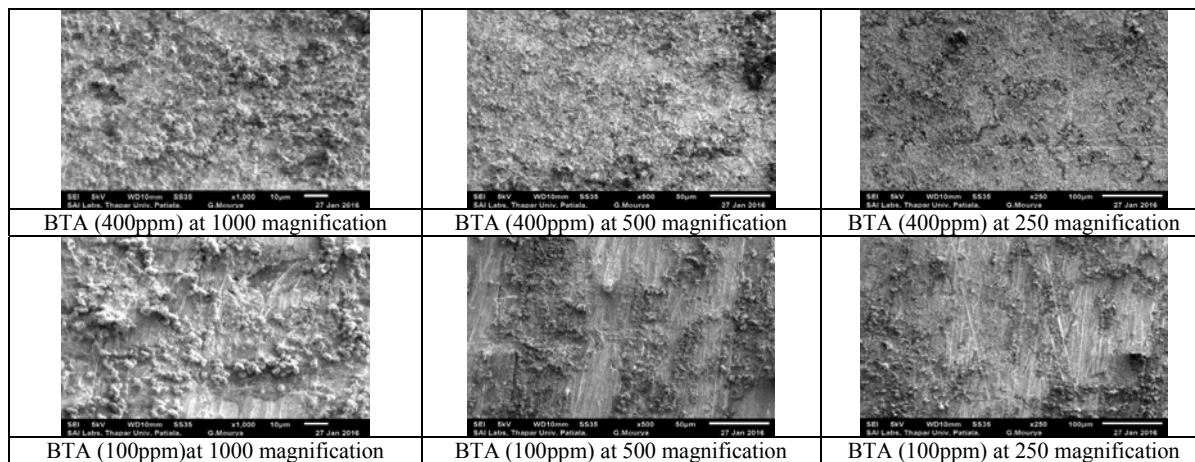
Conc. of inhibitor	Conc. of HCl	Rct at 25 °C	% I.E. at 25 °C	Rct at 30 °C	% I.E. at 30 °C	Rct at 35 °C	% I.E. at 35 °C
Blank	2.0 N	7.8	-	7.2	-	6.9	-
	1.0 N	9.2	-	8.8	-	8.2	-
	0.1 N	10.5	-	10.2	-	9.8	-
100	2.0 N	38.11	79.53	28.13	74.40	20.14	65.73
400		47.59	83.61	32.52	81.50	24.23	79.80
1000		66.60	87.68	43.83	85.25	32.78	82.20
100	1.0 N	28.76	68.01	23.03	61.80	16.01	48.78
400		47.67	80.83	40.56	77.17	23.45	65.03
1000		60.60	84.81	46.03	80.88	38.01	78.42
100	0.1N	18.21	42.23	14.15	27.90	12.20	25.75
400		38.11	72.44	28.67	45.30	18.78	37.89
1000		47.70	78.03	32.82	68.92	25.52	61.59

**SEM**

Morphology of the Carbon steel coupons was studied by scanning electron microscopy (SEM) using scanning electron microscope. This technique provides the evidences in support of the inhibition data of different corrosion inhibitor in different environment and for the mechanism of inhibition. In this technique, the samples, after treating with the weight loss test, were studied at different resolutions on the different spots on the carbon steel coupons for complete detail about the

inhibition mechanism. SEM of the blank Carbon steel coupons were also taken for the comparative study of metal specimens which are shown in Fig 2 SEM of the blank coupons clearly provides the evidence of the more extent of corrosion in corroding medium. Pits and brown rust particles are clearly visible in blank Carbon steel coupons dipped in 2.0 N HCl solution at 1000 and 500 magnification. Carbon steel surface becomes more and smoother with increase in concentration.



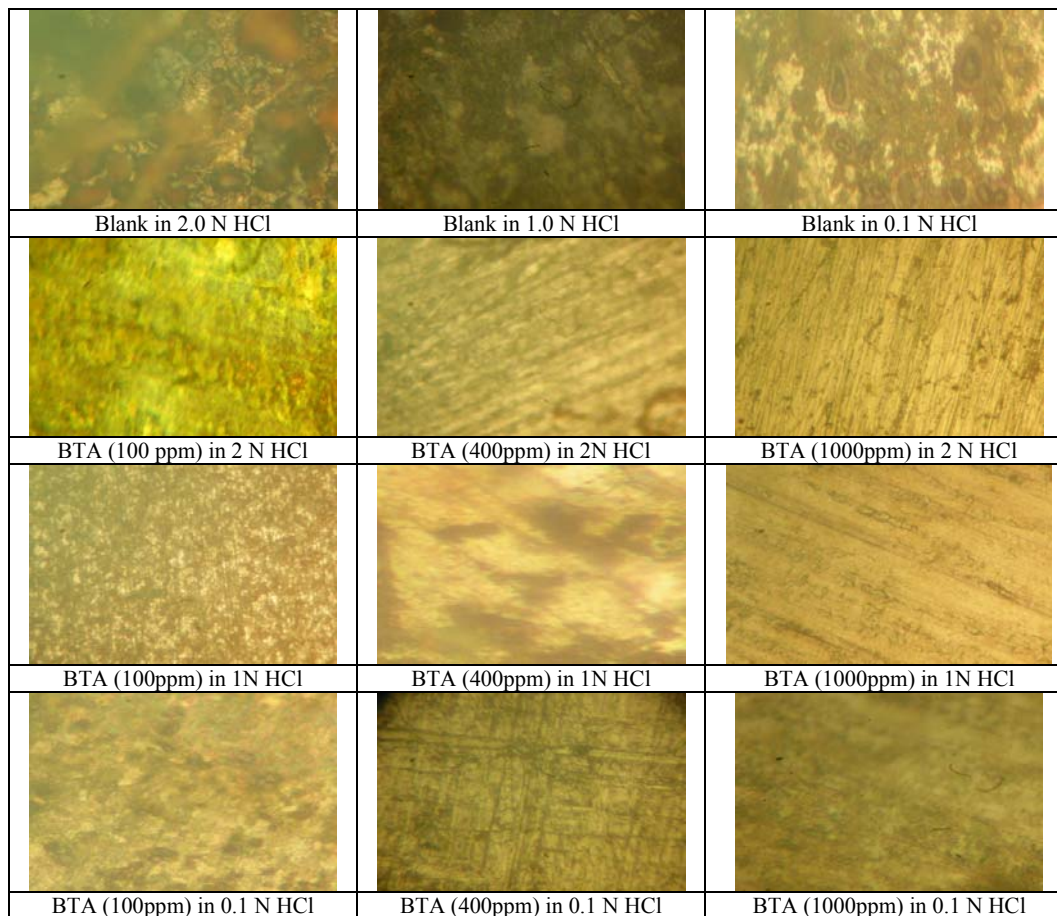


**Fig 2:** SEM images of Carbon steel samples with and without BTA at different concentrations.

**Metallurgical Research Microscopy Technique**

This test was carried out in order to know about the nature and extent of corrosion using Trinocular inverted metallurgical research microscope. To explain the corrosion inhibition efficiency of BTA, micrographs of the corroded coupons treated with BTA were subjected to porosity study, Coating thickness, length of pores and morphology of surface. By the obtained results of porosity and surface morphology, the information about the size of pores, percentage porosity and area covered by the pores on the surface of sample after the weight loss test was calculated. Percentage porosity (PP) shows the roughness of surface. While maximum perimeter and maximum area covered provide the information about the

size and depth of the pores on the surface of Carbon steel. Micrographs of blank corroded coupons were taken after exposure of different concentration of HCl for 2 hours are shown in figure 3 and data obtained from metallurgical research microscopy of blank Carbon steel sample after weight loss experiments are reported in table 6 from which it is clear that after weight loss test in different conc. of acidic medium due to uniform corrosion in humid environment surface become porous after exposing specimen in corroding medium.. As the conc. of BTA increases, porosity of surface decreases. Coating thickness also measured which increases with increase in conc. of BTA.



**Fig 3:** Trinocular Inverted Metallurgical Research Micrographs of different Carbon steel samples with and without BTA at different concentration.

**Table 6:** Coating thickness, percentage porosity and pore length of Carbon steel coupons with and without corrosion inhibitor

onc. Of BTA	Conc. of HCl	% age porosity	Max. Perimeter (micron)	Max. area (micron square)	Length of pore (micron)	Coating thickness (micron)
Blank	2.0 N	89.34	6543.67	26785.64	590.45	32.56
	1.0 N	84.53	5887.64	24567.98	394.67	28.45
	0.1 N	72.56	4321.91	23145.89	298.56	24.67
100	2.0 N	10.45	7220.5438	14346.5607	168.75	203.50
400		8.32	4436.8000	15489.6589	142.34	1509.45
1000		5.78	1560.657	12346.7865	81.527	2596.23
100	1.0 N	17.59	2857.231	20506.4367	172.98	112.34
400		12.12	2105.26	18524.6589	152.56	1350.34
1000		8.90	2175.26	11052.7896	98.796	2314.45
100	0.1 N	20.59	2857.231	22502.4320	178.45	82.13
400		16.81	9356.758	20524.6549	153.46	172.45
1000		10.27	2862.861	15504.9087	106.519	1800.76

### Conclusion

BTA acts as very good inhibitor for the corrosion of C-steel in 2.0N, 1.0N and 0.1 N HCl solutions, and the maximum corrosion inhibition efficiency is about 87% in 2.0 N HCl solution. The inhibition efficiency values increase with the increase in inhibitor conc., but decrease with the increase in temperature. The corrosion rate of C-steel in the presence and absence of BTA acts as a function of inhibitor conc. Increase in the conc. resulted in increasing the inhibition efficiency. The weight loss and the electrochemical polarization studies are in good agreement. BTA acts as a mixed-type inhibitor in 2.0, 1.0 and 0.1 N HCl. The inhibitive mechanism was proposed. When BTA introduced into 2.0, 1.0 and 0.1 N HCl solutions a film formed on the C-steel surface, causes the decrease of the C-steel roughness and effectively protect the C-steel from corrosion. Results obtained from SEM & metallurgical research microscopy techniques further supports the weight loss and electrochemical experiments.

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