

New Thiadiazole Derivatives as Effective Corrosion Inhibitors for the Control of Copper–Nickel Alloy in Sulphide Polluted Synthetic Sea Water

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Summary: Inhibitive effect of new class of thiadiazole derivatives namely 2-(benzyl thio)-5-((4-methoxybenzyl)thio)-1,3,4-thiadiazole(BTMT), 2-((2,5-dimethylbenzyl)sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4-thiadiazole(DBMT) and 2-((4-tert-butylbenzyl)Sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4- thiadiazole (TBMT) on the corrosion of copper-nickel alloy in sulphide polluted synthetic sea water has been investigated by gravimetric measurements, potentiodynamic polarization and electrochemical impedance spectroscopic techniques. Gravimetric measurements showed that, the thiadiazole derivatives exhibit excellent corrosion inhibition on the cupro-nickel alloy in sea water medium. Potentiodynamic polarization techniques revealed that, the corrosion current density decreases and inhibition efficiency increases with increasing concentration of inhibitors. Electrochemical impedance spectroscopic techniques showed that, charge transfer resistance value increases and double layer capacitance value decreases with increasing concentrations of thiadiazole compounds. Inductively coupled atomic emission spectroscopy revealed that, the thiadiazole derivatives excellently control the denickelification of copper-nickel alloy in sulphide polluted synthetic sea water.

Key words: Copper-nickel alloy, Synthetic sea water, Thiadiazole, Polarization, Impedance, ICP-AES

Introduction

Copper alloys find extensive applications in marine environment, particularly as heat exchangers and condensers in power plants, because of their good resistance to corrosion, thermal and electrical properties [1]. Copper-Nickel alloy are used in hydraulic lines, sea water pipe work, sheathing of legs and risers on offshore platforms and boat hulls, off shore fire water systems and fish cages for aquaculture. They have provided reliable service for several decades whilst offering effective solutions to today's technological challenges. Because of their high corrosion resistance, good electrical and thermal conductivities, high resistance to bio-fouling, cupro-nickel alloys are widely used in sea water cooling systems [2]. Generally, copper-nickel alloy is quite resistant to sea water. But, it is susceptible to undergo corrosion, when the sea water is polluted with sulphide ions. Hence, the corrosion of copper-nickel alloy in sulphide polluted sea water has been taken for the present investigation.

Azole compounds have been widely used as corrosion inhibitors in several environments [3, 4]. Bentiss *et al.* (2000) studied the inhibitive effect of triazole derivatives on corrosion of mild steel in acidic media [5]. Laachach *et al.* (2001) investigated the electrochemical behaviour of Cu-Ni alloy in NaCl medium polluted by sulphide and inhibiting effect of aminotriazole. The potentiodynamic and electrochemical impedance measurements showed that sulphide accelerate the corrosion of the alloy in NaCl

solution. The aminotriazole inhibited both anodic and cathodic corrosion processes. The inhibiting effect was higher when the solution contained the sulphide ion [6]. Zhang *et al.* (2004) investigated the protective action of bis-(1-benzotriazolymethylene)-2,5-thiadiazoly)-disulphide on copper in chloride media and concluded that the inhibitors effectively control corrosion [7]. Fenelon and Breslin (2001) studied the formation of BTA surface films on Copper, Cu-Zn alloy and Zn in chloride solution. The electrochemical impedance data were consistent with the formation of a polymeric BTA-containing layer for all three systems [8]. Trachli *et al.* (2002) studied the protective effect of electro polymerised aminotriazole towards corrosion of copper in 0.5M NaCl solution [9]. Maciel *et al.* (2008) studied the nature of the protective film formed on the surface of the cupro-nickel alloy by benzotriazole in sulphuric acid by electrochemical and surface characterization studies [10]. Gonçalves *et al.* (2002) investigated the effect of propargyl alcohol as corrosion inhibitor copper-nickel alloy, nickel and copper in 0.5 M sulphuric acid solution [11].

The present work aims the investigation of the corrosion behavior of copper-nickel alloy by new class of three thiadiazole derivatives namely 2-(benzylthio)-5-((4-methoxybenzyl)thio)-1,3,4-thiadiazole(BTMT), 2-((2,5-dimethylbenzyl)sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4-thiadiazole(DBMT) and 2-((4-tert-butylbenzyl)Sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4- thiadiazole (TBMT) in

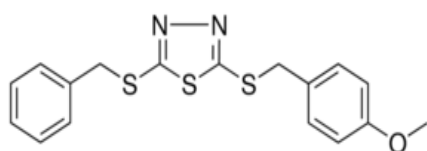
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sulphide polluted sea water environment. Gravimetric measurements and electrochemical studies such as potentiodynamic polarization method and electrochemical impedance spectroscopic techniques were used. The amount of copper and nickel leached out from the test solution were analyzed using inductively coupled atomic emission spectroscopy.

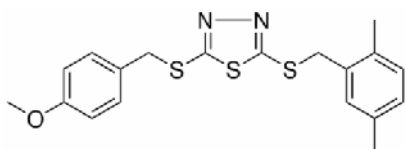
Experimental

Materials

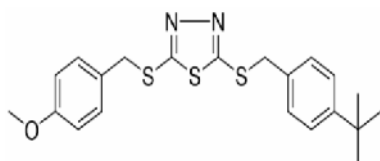
The copper-nickel alloy in the form of sheet was used as the material for this study and the chemical composition (weight percent) of the alloy was 69.78 Cu, 29.43% Ni, 0.18% Fe, 0.06 % Sn and traces of Pb, Mn, Ni, Cr, As, Co, Al & Sr. The density of the alloy is 8.92 g/cm³. Sulphide polluted synthetic was prepared by dissolving the chemicals (23.9849g NaCl, 2.44g Na₂S, 5.0290 g MgCl₂, 4.0111 g Na₂SO₄, 1.1409 g CaCl₂, 0.6986g KCl, 0.1722g NaHCO₃, 0.100 g KBr, 0.0143 g SrCl₂ and 0.0254 g H₃BO₃) in 1 litre of distilled water [12, 13]. The inhibitors 2-(benzyl thio)-5-((4-methoxybenzyl)thio)-1,3,4-thiadiazole (BTMT), 2-((2,5-dimethylbenzyl)sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4-thiadiazole (DBMT) and 2-((4-tert-butylbenzyl)Sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4- thiadiazole (TBMT) (Sigma Aldrich) and ethanol (Fischer) were used as received. The structures of these inhibitors are shown in Fig. 1.



2-(benzyl thio)-5-((4-methoxybenzyl)thio)-1,3,4-thiadiazole



2-((2,5-dimethylbenzyl)sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4-thiadiazole



2-((4-tert-butylbenzyl)Sulfanyl)-5-((4-methoxybenzyl)sulfanyl)-1,3,4- thiadiazole

Fig. 1: Structure of thiadiazole derivatives.

Methods

Gravimetric Measurements

The experiments were conducted with copper-nickel alloy specimens (3 cm x 2 cm x 0.2 cm). The alloy specimens were polished mechanically with different grades of emery papers. The specimens were degreased in acetone, thoroughly washed with double distilled water, dried and weighed. The polished alloy specimens were immersed in duplicate, in 500 ml sulphide polluted synthetic seawater with and without the addition of different concentrations of thiadiazole derivatives. After immersion for a definite period (10 days), the specimens were taken out, degreased in acetone, washed with distilled water, dried and the changes in weights were noted.

Potentiodynamic Polarization Studies

The polarization studies were carried out with copper – nickel alloy strips having an exposed area of 1 cm². The cell assembly consisted of copper – nickel alloy as working electrode, a platinum foil as counter electrode and a saturated calomel electrode (SCE) as a reference electrode with a Luggin capillary bridge. Polarization studies were carried out using the Electrochemical work station (Model: CHI 760C, CH Instruments, USA) at a scan rate of 1mV/s. The degreased working electrode is then inserted into the sulphide polluted synthetic sea water and immediately cathodically polarized at -1.0 V (SCE) for 15 minutes to reduce any oxides on the alloy surface [17]. The cathodic and anodic polarization curves for copper – nickel alloy in the test solution with and without various concentrations of the inhibitors were recorded between -700 to 700 mV at a scan rate of 1 mV/s. The inhibition efficiencies of the compounds were determined from corrosion current densities using the Tafel extrapolation method [14].

Electrochemical Impedance Studies

A.C. impedance measurements were conducted at room temperature using potentiostat/galvanostat (model PGSTAT 12) with Frequency Response Analyzer (FRA). An ac sinusoid of ± 10 mV is employed [15]. The copper – nickel alloy specimen with an exposing surface area of 1cm² is used as the working electrode. A conventional three electrode electrochemical cell of volume 300 ml is used. A saturated calomel electrode (SCE) is used as the reference and platinum electrode is used as the counter. All potentials are reported vs SCE .

Solution Analysis by Inductively Coupled Atomic Emission Spectroscopy (ICP- AES)

In this technique, the samples are introduced into the system through a nebulizer with argon gas and are dissociated into its constituent atoms and ions. These are then excited by the plasma and a characteristic radiation is emitted for each element as it falls back to the ground state. The intensity of the emission is proportional to the concentration of the element and quantitative analysis is carried out by reference to calibration curves.

The elements detected by ICP-AES in this work with the characteristic wavelengths chosen for each element viz. Cu and Ni at 325 nm and 352.4 nm respectively. The concentration of Cu and Ni in the electrolytes, after the polarisation experiments in the presence and absence of different concentrations of studied inhibitors, is determined by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICPAES). An ICP-AES (ARCOS from M/s. Spectro, Germany) is used to measure the amount of dissolution of copper and nickel from the alloy surface. The denickelification factor (n) was calculated using the equation [16].

$$n = \frac{[\text{Ni}/\text{Cu}]_{\text{soln}}}{[\text{Ni}/\text{Cu}]_{\text{alloy}}}$$

where, $[\text{Ni}/\text{Cu}]_{\text{sol}}$ and $[\text{Ni}/\text{Cu}]_{\text{alloy}}$ are the ratio between the concentrations of nickel and copper in the solution and in the alloy respectively.

Results and Discussion

Gravimetric Measurements

The corrosion rates and inhibition efficiencies of copper-nickel alloy with different concentrations of BTMT, DBMT and TBMT in sulphide polluted synthetic sea water at room temperature are given in Table-1. The corrosion rate (CR) and percentage inhibition efficiency (IE %) were calculated using the following equation [17].

$$\text{CR (mmpy)} = \frac{87.6 \times W}{D \times A \times T}$$

$$\text{IE\%} = \frac{\text{CR}_{(\text{bl})} - \text{CR}_{(\text{inh})}}{\text{CR}_{(\text{bl})}} \times 100$$

where W is the weight-loss, D is the density, T is the immersion time, A is the area of the specimen and

$\text{CR}_{(\text{inh})}$ and $\text{CR}_{(\text{bl})}$ are the corrosion rate of copper-nickel alloy in the presence and absence of inhibitors respectively. The inhibition efficiency increases with increase in concentration of the inhibitors. The maximum IE% of each compound was achieved at 10^{-2} M and a further increase in concentration showed only a marginal change in the performance of the inhibitor. The optimum of concentration of the inhibitors was found to be 10^{-2} M. It can be seen that, the values of inhibition efficiency for copper-nickel alloy obtained using these compounds in sulphide polluted synthetic sea water follow the order.

TBMT > DBMT > BTMT

Table-1: Gravimetric measurements of copper-nickel alloy at different concentrations of BTMT, DBMT and TBMT in sulphide polluted synthetic sea water

Inhibitor Concentration (ppm)	Weight loss (mg)	Corrosion Rate $\times 10^{-2}$ (mmpy ⁻¹)	Inhibition Efficiency (%)
Blank	191.1	10.86	-
BTMT			
10^{-5}	64.99	3.694	65.99
10^{-4}	37.37	2.124	80.44
10^{-3}	10.96	0.623	94.26
10^{-2}	8.13	0.462	95.75
DBMT			
10^{-5}	58.40	3.319	69.44
10^{-4}	35.42	2.013	81.46
10^{-3}	9.396	0.534	95.08
10^{-2}	6.106	0.347	96.80
TBMT			
10^{-5}	55.39	3.148	71.01
10^{-4}	33.82	1.922	82.30
10^{-3}	8.94	0.508	95.32
10^{-2}	4.12	0.234	97.85

The inhibition of corrosion by these compounds can be attributed to their adsorption on the metal surface because of the interaction between the π -electrons of the thiadiazole ring and the positively charged metal surface. The order of inhibition shown by these compounds can be mainly attributed to the electron releasing tendencies (+I effect) of different substituent present in the thiadiazole derivatives. An increase in the size of the molecule of these compounds can lead to more surface coverage and thereby more corrosion inhibition.

Inhibition of corrosion of copper-nickel alloy in sulphide polluted synthetic sea water can be explained in the following way. The adsorption of thiadiazole derivatives on the surface of alloy leads to the formation of a protective layer of Cu (I) chloride-complex on the surface of alloy. Actually, the formation of a thiadiazole film starts with the chemisorption of the inhibitor molecule on to the slightly oxidized areas of the copper surface [18]. The adsorption of thiadiazole molecules on the oxidized parts of the copper surface was found to occur much faster than on bare metal

zones. The film formed in this way has a limited hydrophobic action, which succeeds in protecting copper-nickel alloy in the corroding medium by blocking main reaction centre on the metal surface.

Potentiodynamic Polarisation Studies

The polarisation curves of copper-nickel alloy in sulphide polluted synthetic seawater in the presence and absence of different concentrations of BTMT, DBMT and TBMT are shown in Fig. 2 – Fig. 4. Electrochemical parameters obtained by extrapolation of Tafel lines are presented in Table-2. The presence of different concentrations of BTMT, DBMT and TBMT reduce the anodic and cathodic current densities, and the suppression in corrosion current increases as the inhibitor concentration increases; this indicates the inhibiting effects of the three substituted thiadiazole compounds. It can be shown from the table that with increasing inhibitor concentration, corrosion current density (I_{corr}) decreases and inhibition efficiency (IE) increases. The values of cathodic Tafel slope β_c and anodic Tafel slope β_a were found to change with increasing inhibitor concentration, which indicated that the inhibitors control both anodic and cathodic reactions [19]. The inhibitors act as relatively mixed type for copper-nickel alloy [20].

The slight shifts of E_{corr} values towards negative direction are found in the presence of various concentrations of the substituted thiadiazole derivatives in seawater. Small changes in the corrosion potential (E_{corr}) values are due to the result of the competition of the anodic and the cathodic inhibiting reactions, of the copper-nickel alloy surface condition. The corrosion rate (CR) and inhibition efficiency (IE) was calculated using the following equation [21].

$$CR = \frac{3.27 \times 10^{-3} \times I_{\text{corr}} \times EW}{D}$$

$$IE\% = \frac{I_{\text{corr}} - I_{\text{corr}}(\text{inh})}{I_{\text{corr}}} \times 100$$

where, I_{corr} and $I_{\text{corr}}(\text{inh})$ are the corrosion current density values without and with inhibitors, respectively. D is the density and EW is the equivalent weight of the copper-nickel alloy.

The inhibiting property of the studied thiadiazole derivatives is attributed to their ability to chemisorb on the surface of alloy forming few layers of self-assembled films, as sulphur containing compounds are reported to form self-assembled protective layer on the surface of alloy [22]. The values of inhibition

efficiency increase with increase in inhibitor concentration, indicating that a higher surface coverage was obtained in a solution with higher inhibitor concentration. It was confirmed that with increase in inhibitor concentration, the corrosion rate decreases.

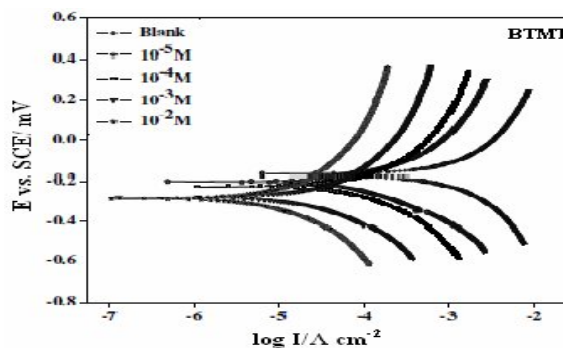


Fig. 2: Polarization curves of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of BTMT.

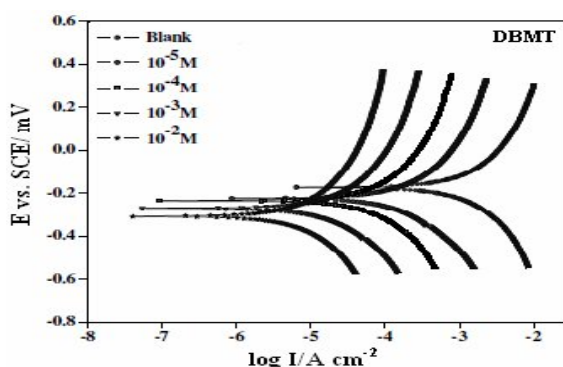


Fig. 3: Polarization curves of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of DBMT.

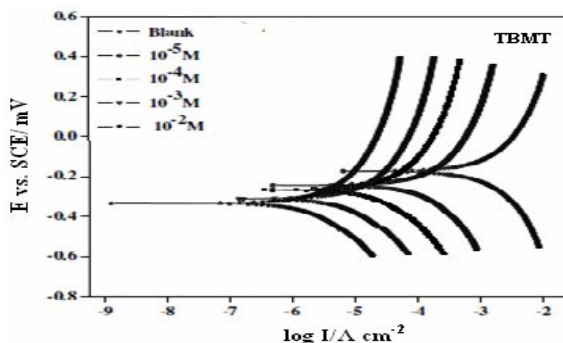


Fig. 4: Polarization curves of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of TBMT.

Table-2: Tafel polarization parameters for the corrosion of cupro-nickel alloy in sulphide polluted synthetic sea water at different concentrations of BTMT, DBMT and TBMT.

Inhibitor concentration (ppm)	I_{corr} ($\mu A\ cm^{-2}$)	$-E_{corr}$ (mV vs. SCE)	β_a	β_c	Corrosion rate $\times 10^{-2}$ (mmyr $^{-1}$)	Inhibition efficiency (%)
Blank	9.34	186	53	-132	10.62	-
BTMT						
10^{-5}	3.76	207	65	-97	4.28	59.74
10^{-4}	1.78	230	82	-86	2.03	80.94
10^{-3}	0.46	285	104	-63	0.52	95.07
10^{-2}	0.36	291	112	-56	0.41	96.15
DBMT						
10^{-5}	3.47	230	72	-92	3.95	62.85
10^{-4}	1.62	239	87	-76	1.84	82.66
10^{-3}	0.36	302	110	-54	0.41	96.15
10^{-2}	0.29	305	119	-45	0.33	96.90
TBMT						
10^{-5}	3.05	249	75	-84	3.47	67.34
10^{-4}	1.42	271	93	-63	1.62	84.80
10^{-3}	0.23	331	115	-41	0.26	97.54
10^{-2}	0.17	335	127	-34	0.19	98.18

Electrochemical Impedance Spectroscopic Studies

Electrochemical Impedance Spectroscopic technique is a powerful tool in the investigation of the corrosion and adsorption phenomena. This method explains effectively the corrosion and passivation phenomena of metals and alloys. The impedance diagrams represented in Nyquist plot obtained at open-circuit potential after one hour immersion in seawater in the presence and absence of thiadiazole derivatives are presented in Fig. 5 – Fig. 7. The percent inhibition efficiency (IE %) of alloy was calculated as follows [23]:

$$IE \% = \frac{[(R)_{ct}]^{-1} - [(R)_{ct(inh)}]^{-1}}{[(R)_{ct}]^{-1}} \times 100$$

where, $R_{ct(inh)}$ and R_{ct} are the charge-transfer resistance values with and without inhibitors respectively.

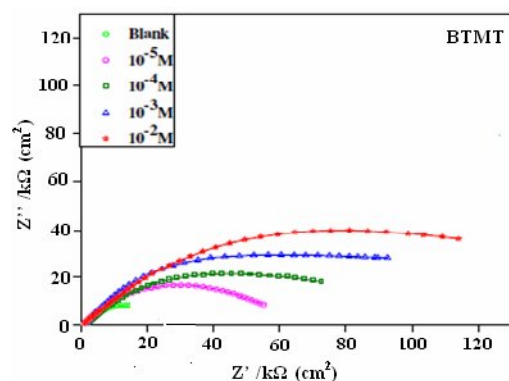


Fig. 5: Nyquist diagram of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of BTMT.

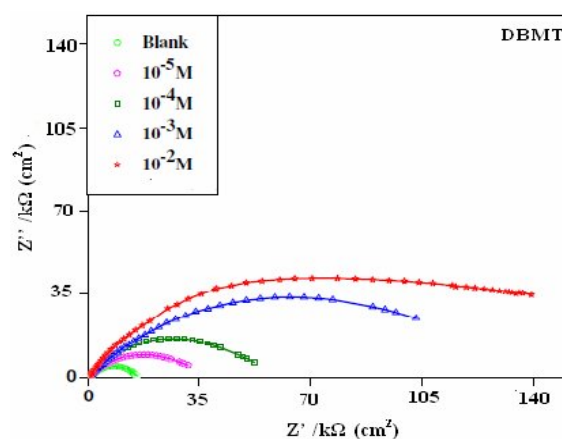


Fig. 6: Nyquist diagram of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of DBMT.

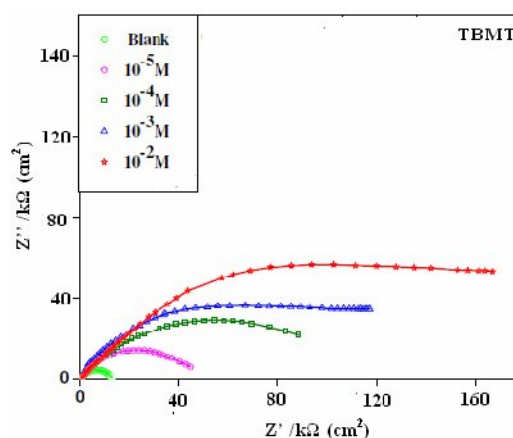


Fig. 7: Nyquist diagram of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of TBMT.

Table-3: Electrochemical impedance data of copper-nickel alloy in sulphide polluted synthetic sea water containing different concentrations of BTMT, DBMT and TBMT.

Inhibitor concentration (ppm)	R_{ct} $\times 10^4 (\Omega \text{ cm}^2)$	C_{dl} $(\mu\text{F cm}^{-2})$	R_F $\times 10^4 (\Omega \text{ cm}^2)$	C_F $(\mu\text{F cm}^{-2})$	n_{dl}	n_F	IE (%)
Blank	0.63	67.45	0.72	92.54	0.52	0.49	-
BTMT							
10^{-5}	2.16	10.36	2.97	15.24	0.63	0.54	70.83
10^{-4}	4.38	2.64	5.12	5.65	0.67	0.61	85.61
10^{-3}	14.76	0.48	16.32	1.76	0.68	0.63	95.73
10^{-2}	21.46	0.09	20.98	1.42	0.70	0.68	97.06
DBMT							
10^{-5}	2.73	7.93	3.24	13.74	0.75	0.69	76.92
10^{-4}	4.98	1.97	5.24	4.85	0.77	0.72	87.35
10^{-3}	15.96	0.34	16.97	1.42	0.78	0.74	96.05
10^{-2}	23.29	0.04	21.69	1.22	0.78	0.75	97.30
TBMT							
10^{-5}	2.96	6.24	3.97	12.57	0.82	0.76	78.71
10^{-4}	5.42	1.58	6.78	3.98	0.82	0.77	88.37
10^{-3}	16.96	0.19	18.23	1.21	0.83	0.78	96.28
10^{-2}	26.56	0.02	27.98	0.9	0.84	0.78	97.62

The calculated parameters obtained from equivalent circuit fitting analysis in the absence and presences of inhibitors in sulphide polluted synthetic seawater are given in Table-3. These Nyquist plots obtained for copper-nickel alloy in the presence of different concentrations of inhibitor exhibited different shapes, which indicated the change in corrosion mechanism due to the presence of inhibitors. It can be seen from the table that with increase in inhibitor concentration, R_{ct} value increased and C_{dl} value decreased. The decrease in C_{dl} value can result from a decrease in local dielectric constant and/or an increase in the thickness of the electrical double layer, suggests that the thiadiazole derivatives function by adsorption at the metal-solution interface [24]. The decrease in C_{dl} value upon increase in inhibitor concentration was due to reduced access of charged species to the alloy surface, as inhibitor has adsorbed and a good persistent layer of the same was formed on the alloy surface. The change in R_{ct} and C_{dl} values was caused by the gradual replacement of water molecules by the anions of the NaCl present in seawater and adsorption of the organic inhibitor molecules on the metal surface, reducing the extent of dissolution [25]. The value of Faradaic resistance (R_F) increases with increase in concentration showing that BTMT, DBMT and TBMT stabilize the corrosion products on the metal surface and the value reaches more than 42 times greater value for TBMT than that obtained for the blank solution. As the concentration of the inhibitor increases, the inhibitors get adsorbed effectively on the alloy surface which increases the R_F values and decreases the C_F values. The impedance parameters namely R_F , C_F and n_F observed for higher concentrations of the inhibitors, may be due to the complete coverage of surface of alloy. Inhibition efficiency (IE) increased with increase in inhibitor concentrations and this corresponds with increase in R_{ct} values indicating that better inhibition efficiency was obtained due to better adsorption of inhibitor molecules on the alloy surface. As the

concentration of the inhibitor increases, R_{ct} and R_F values increase steeply whereas the capacitive value decreases. The molecular structure normally determines the type of adsorption on alloy surface [26]. Thiadiazole derivatives viz., BTMT, DBMT and TBMT show differences in their inhibition efficiency due to the difference in their molecular structures of the thiadiazole derivatives studied. TBMT has the highest inhibition efficiency and this corresponds well with the polarisation measurements. The % IE calculated from EIS shows the same trend as those estimated from polarisation measurements *i.e.*, polarization measurements and EIS study complement each other well.

Solution Analysis by Inductively Coupled Atomic Emission Spectroscopy (ICP-AES)

The concentrations of copper and nickel in solutions containing different concentrations of the thiadiazole derivatives after polarisation measurements were determined from inductively coupled plasma atomic emission spectroscopic (ICP-AES) analysis. The denickelification (n) factors for cupro-nickel alloy in the absence and presence of different concentrations of BTMT, DBMT and TBMT in sulphide polluted synthetic seawater were calculated from the ICP-AES data and the results are given in Table-4. The results showed that both copper and nickel were present in the electrolyte in very small quantities and the copper to nickel ratio was found to be lesser than that of the bulk alloy. This is due to the surface barrier arising out of the growth of surface film of inhibitor on the metal surface as well as the corrosion product Cu_2O and NiO [27]. It is clear from the table that denickelification was much higher in the absence of inhibitors, while denickelification was much lower in the presence of different concentration of BTMT, DBMT and TBMT. This indicated that the BTMT, DBMT and TBMT were able to minimize the dissolution of both Cu and Ni. These values correlate with the corrosion rate and inhibition efficiency obtained by electrochemical methods.

Table-4: Effect of different concentrations of BTMT, DBMT and TBMT on the dissolution of cupro-nickel alloy in sulphide polluted synthetic sea water

Inhibitors	Solution analysis		Denickelification factor	Percent inhibition	
	Cu x 10 ⁶ (M)	Ni x 10 ⁶ (M)		Cu (%)	Ni (%)
Blank	1.24	1.60	3.06	-	-
BTMT					
10 ⁻⁵	0.52	0.59	2.69	58.06	63.13
10 ⁻⁴	0.23	0.24	2.47	81.45	85.00
10 ⁻³	0.09	0.03	0.79	92.74	98.13
10 ⁻²	0.08	0.02	0.59	93.71	98.75
DBMT					
10 ⁻⁵	0.43	0.52	2.87	65.32	67.50
10 ⁻⁴	0.20	0.22	2.61	84.11	86.25
10 ⁻³	0.07	0.03	1.02	94.11	98.12
10 ⁻²	0.06	0.02	0.79	95.0	98.75
TBMT					
10 ⁻⁵	0.37	0.48	3.08	70.16	70.00
10 ⁻⁴	0.17	0.20	2.79	86.45	87.50
10 ⁻³	0.04	0.02	1.19	96.61	98.75
10 ⁻²	0.04	0.02	1.19	96.85	98.75

Conclusions

1. Gravimetric and electrochemical methods reveal that thiadiazole derivatives were proved to be excellent corrosion inhibitors for copper-nickel alloy in sulphide polluted synthetic sea water. The inhibition efficiency increases with increasing the concentration of the inhibitor.
2. Polarization measurements showed that the organic compounds investigated are mixed type inhibitors, inhibiting the corrosion of copper-nickel alloy by blocking the active sites of the metal surface. This study also indicated that, thiadiazole derivatives considerably shifts the corrosion potential to less negative values and greatly decreases the corrosion current density.
3. Electrochemical impedance spectroscopy showed that the inhibitors increase both the charge transfer resistance (R_{ct}) and faradaic resistance (R_F) and decrease the double layer capacitance (C_{dl}) and faradaic capacitance (C_F) of the copper-nickel alloy surface. The inhibitors easily adsorb on the alloy surface at the corrosion potential and form a protective complex with the Cu ion, preventing copper-nickel alloy from corrosion.
4. ICP-AES study reveals that, the thiadiazole derivatives excellently prevent the dissolution of copper and nickel from the alloy.

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