

SYNTHESIS, STRUCTURAL AND ANTIBACTERIAL STUDIES OF NEW DITHIOCARBAMATE COMPLEXES OF Sb(III) AND Bi(III)

(Sintesis, struktur dan kajian antibakteria kompleks baru ditiokarbamat Sb(III) dan Bi(III))

Nur Amirah Jamaluddin¹, Ibrahim Baba^{1*}, Nazlina Ibrahim²

¹School of Chemical Sciences and Food Technology,

²School of Biosciences and Biotechnology,

Faculty of Science and Technology,

Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

*Corresponding author: aibi2005@gmail.com

Abstract

Six new dithiocarbamate complexes from three different amines, e.g. N-ethylethanol-, N-butylethyl- and N-benzylmethylamine were successfully prepared using *in situ* method. All complexes were characterized by elemental analysis, IR, UV-Vis, ¹³C and ¹H NMR. Elemental analysis data (C, H, N and S) showed an agreement with the general formula of MCl(S₂CNR'R'')₂ (M = Sb(III), Bi(III); R' = ethyl, butyl and benzyl; R'' = ethanol, ethyl and methyl). The complexes had been characterized by infrared spectroscopy that showed a thioureide bands, ν(C≡N) in the region of 1427 - 1490 cm⁻¹ followed by ν(C=S) bands that can be seen in the region of 935 - 1060 cm⁻¹ and ν(M-S) bands existed in the region of 350 - 392 cm⁻¹. Maximum wavelength absorption for ultraviolet-visible spectroscopy for N=C=S group was at 254 nm which indicates π→π* transition. Data from ¹³C NMR showed a signal in the region of 198.39 - 199.44 ppm that corresponded to the NCS₂ group. The crystal structure of bis(N,N'-butylethylthiocarbamato)chlorido antimony(III), SbCl[S₂CN(C₄H₉)(C₂H₅)]₂ demonstrated a five-coordination geometry, triclinic system, space group P1 with a = 10.0141(8) Å, b = 10.1394(7) Å, c = 11.8665(9) Å, α = 67.960(2)°, β = 87.616(2)° and γ = 80.172(2)°. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) tests were done using five dithiocarbamate complexes which are BiCl[S₂CN(C₂H₅)(C₂H₄OH)]₂, SbCl[S₂CN(C₂H₅)(C₂H₄OH)]₂, BiCl[S₂CN(C₄H₉)(C₂H₅)]₂, SbCl[S₂CN(C₄H₉)(C₂H₅)]₂, BiCl[S₂CN(C₇H₇)(CH₃)]₂ towards *S. aureus*, *S. epidermidis*, *E. aerogenes* and *E. coli*. It was found that all four complexes were active against *S. aureus* except SbCl[S₂CN(C₂H₅)(C₂H₄OH)]₂ while BiCl[S₂CN(C₇H₇)(CH₃)]₂ and BiCl[S₂CN(CH₃)(C₆H₁₁)]₂ complexes were active against *S. epidermidis* with MIC value of 5.0 mg/mL and 2.5 mg/mL respectively and MBC value of 5.0 mg/mL for both compounds. Only BiCl[S₂CN(C₂H₅)(C₂H₄OH)]₂ was active against *E. aerogenes* with MIC, 1.25 mg/mL and MBC, 10 mg/mL. All complexes were less active as antibacterial agent against *E. coli* strain.

Keywords: Dithiocarbamate, antimony(III), bismuth(III), antibacterial

Abstrak

Enam sebatian ditiokarbamat baru daripada tiga jenis amina yang berbeza, iaitu N-etilaminoetanol, N-butiletetil, N-benzilmetil telah berjaya disediakan dengan menggunakan kaedah *in situ*. Kesemua sebatian telah dicirikan dengan analisis unsur, IR, UV-Vis, ¹³C dan ¹H NMR. Data analisis unsur (C, H, N dan S) bagi kesemua sebatian menepati formula umum MCl(S₂CNR'R'')₂ (M = Sb(III), Bi(III); R' = etil, butil dan benzil; R'' = etanol, etil dan metil). Kompleks dicirikan menggunakan kaedah spektroskopi inframerah menunjukkan jalur tioreida, ν(C≡N) berada dalam julat 1427 - 1490 cm⁻¹ diikuti jalur ν(C=S) yang diperhatikan dalam julat 935 - 1060 cm⁻¹ dan jalur logam sulfur, ν(M-S) berada dalam julat 350 - 392 cm⁻¹. Serapan jarak gelombang maksimum untuk spektroskopi ultraembayung-nampak untuk kumpulan N=C=S ialah pada 254 nm yang menunjukkan peralihan π→π*. Data daripada ¹³C NMR menunjukkan isyarat dalam julat 198.39 - 199.44 ppm merujuk kepada kumpulan NCS₂. Struktur hablur bis(N,N'-butiletilditiokarbamato)klorido stibium(III), SbCl[S₂CN(C₄H₉)(C₂H₅)]₂ menunjukkan geometri lima koordinatan, sistem *triklinik*, kumpulan ruang P1 dengan a = 10.0141(8) Å, b = 10.1394(7) Å, c = 11.8665(9) Å, α = 67.960(2)°, β = 87.616(2)° and γ = 80.172(2)°. Ujian kepekatan minimum perencatan (MIC) dan kepekatan minimum bakterisidal (MBC) telah dijalankan menggunakan lima sebatian ditiokarbamat, iaitu BiCl[S₂CN(C₂H₅)(C₂H₄OH)]₂, SbCl[S₂CN(C₂H₅)(C₂H₄OH)]₂, BiCl[S₂CN(C₄H₉)(C₂H₅)]₂, SbCl[S₂CN(C₄H₉)(C₂H₅)]₂, BiCl[S₂CN(C₇H₇)(CH₃)]₂ terhadap *S. aureus*, *S. epidermidis*, *E. aerogenes* and *E. coli*. Kesemua empat sebatian adalah aktif terhadap *S. aureus* kecuali

$\text{SbCl}[\text{S}_2\text{CN}(\text{C}_2\text{H}_5)(\text{C}_2\text{H}_4\text{OH})]_2$ manakala sebatian $\text{BiCl}[\text{S}_2\text{CN}(\text{C}_7\text{H}_7)(\text{CH}_3)]_2$ dan $\text{BiCl}[\text{S}_2\text{CN}(\text{CH}_3)(\text{C}_6\text{H}_{11})]_2$ aktif terhadap *S. epidermidis* dengan nilai MIC masing-masing ialah 5.0 mg/mL dan 2.5 mg/mL manakala nilai MBC 5.0 mg/mL untuk kedua-dua sebatian. Hanya sebatian $\text{BiCl}[\text{S}_2\text{CN}(\text{C}_2\text{H}_5)(\text{C}_2\text{H}_4\text{OH})]_2$ yang aktif terhadap *E. aerogenes* dengan nilai MIC, 1.25 mg/mL dan nilai MBC, 10 mg/mL. Kesemua sebatian kurang aktif sebagai agen antibakteria terhadap strain *E. coli*.

Kata kunci: Ditiokarbamat, stibium(III), bismuth(III), antibakteria

Introduction

Dithiocarbamate is a type of ligand with S donor ligand that can act as monodentate or bidentate mode of complexation towards metal. Dithiocarbamate compounds are strong metal chelators, exhibiting interesting chemical characteristics [1]. There are many applications of dithiocarbamate complexes mainly in rubber industry, analytical chemistry, biology, medicine, agriculture and chemical industries [2]. Dithiocarbamates are considered privileged scaffolds in drug discovery with a wide array of biological activities [3]. The use of antimony and bismuth dithiocarbamate compounds were widely reviewed due to their varied applications. Extensive literatures were available on the tris(dithiocarbamato)bismuth(III) and tris(dithiocarbamato)antimony(III) complexes [4] and only a few reports on the closely related bis(dithiocarbamato)chloro bismuth(III) and bis(dithiocarbamato)chloro antimony(III) complexes. The tris(dithiocarbamato)bismuth(III) and tris(dithiocarbamato)antimony(III) complexes generally have the chelated metal atom with a capped octahedral geometry, since the lone pair of electrons was stereochemically active [5, 6]. The sulphur atom has a vacant $d\pi$ orbital, and can therefore form multiple π -bonds. The additional π -electrons available between nitrogen and sulphur, via a planar delocalized π -orbital system, result in dithiocarbamates being strong electron donors [7]. The (*N,N*-diethyldithiocarbamato- $\kappa^2\text{S:S'}$)phenylbismuth(III)- μ -chlorido (Figure 1) is an example of dithiocarbamate complex with one chlorine attached to bismuth and with five-coordinated and the geometry between trigonal bipyramidal and square pyramidal with the slight tendency towards the former [8].

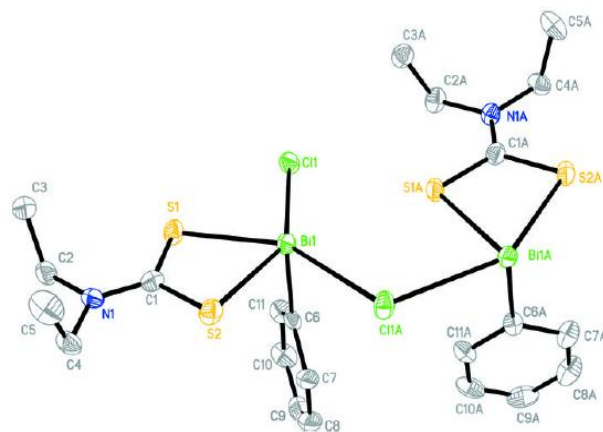


Figure 1. ORTEP plot of (*N,N*-diethyldithiocarbamato $\kappa^2\text{S:S'}$)phenylbismuth(III)- μ -chlorido at the 50% probability level.

Materials and Methods

Materials

All chemicals and solvents that have been used in these experiments e.g. *N*-ethylaminoethanolamine, *N*-butylethylamine, *N*-benzylmethylamine, bismuth(III) trichloride, antimony(III) trichloride, carbon disulphide, chloroform and ethanol (Merck) are pure and used as supplied.

Instrumentations

Melting point was measured on Electrotherma IA 9100 apparatus. Elemental Analysis data was measured on Fisons EA1108 instrument. The infrared data was recorded on Fourier Transform Infrared (FTIR) Perkin-Elmer Spectrum

GX spectrophotometer. Ultraviolet (UV) spectra were recorded on Cary 100 spectrophotometer. Nuclear Magnetic Resonance (NMR) spectra, ^1H and $^{13}\text{C}\{^1\text{H}\}$, were recorded on Joel JNM-ECP 400 spectrometer.

Synthesis of complexes

All the complexes were prepared using direct reaction by mixing metal and ligand with molar ratio 1:2. The ligand was prepared by addition of carbon disulphide, CS_2 to an ethanolic solution of selected amine (N-ethylethanol-, N-butylethyl- or N-benzylmethylamine) in a same molar ratio. The mixture was stirred for one hour at temperature 277 K. After one hour of stirring, the solution was added by dropwise to a solution of antimony(III) trichloride in 20 mL of ethanol. The mixture was stirred again for another one hour. The white precipitate was filtered and washed with cold ethanol and dried in desiccator. The similar steps was used to prepare bismuth(III) dithiocarbamate complexes with yellow colour precipitate. Recrystallization was carried out by using ethanol and chloroform solvents at ratio 1:2.

Crystallographic studies

Crystals for compound **3**, bis(*N,N'*-butylethyldithiocarbamato)chlorido antimony(III) was obtained by slow evaporation of the mixture of ethanol and chloroform solution with ratio 1:2. Intensity data for the compound **3** was measured at 173 K on a Bruker APEX-II CCD fitted with Mo $\text{K}\alpha$ radiation. Data processing (APEX2 and SAINT [9]) and absorption correction (SADABS [10]) were accomplished using routine methods. Details of cell data, X-ray data collection, and structure refinement are given in Table 4. The structures were solved by direct methods [11]. Full-matrix least-squares refinement on F^2 with anisotropic displacement parameters for all non-hydrogen atoms was performed [11].

Antibacterial Tests

All six dithiocarbamate complexes synthesized were tested for antibacterial activities except for **5**. The test organisms chosen for the antibacterial activity were two gram positive (*Staphylococcus aureus* and *Staphylococcus epidermidis*) and two gram negative (*Escherichia coli* and *Enterobacter aerogenes*). The screening properties were done by minimum inhibitory concentration (MIC) and minimum bacterial concentration (MBC) methods.

Results and Discussion

Six new antimony(III) and bismuth(III) dithiocarbamate compounds have been prepared by using the insertion technique [5], which involves the reaction between metal(III) trichloride (SbCl_3 and BiCl_3), amines and carbon disulphide at 277 K in ethanol to give stable compounds. General scheme for the reaction involved in the synthesis is shown in Figure 2. All compounds exhibit as solid powder either white or yellow in colour. Elemental analysis (C, H, N and S) showed that the experimental values are in agreement with theoretical values based on their general formula (Table 1).

A summary of the main peak positions on the IR spectra of the metal complexes is shown in Table 2. All synthesized complexes showed thioureide band $\nu(\text{C}=\text{N})$ in $1450\text{--}1550\text{ cm}^{-1}$ range and $\nu(\text{C}=\text{S})$ band in $950\text{--}1050\text{ cm}^{-1}$ [12] proving that there were dithiocarbamate groups in the compounds. Compound (**1**) and (**2**) showed broad and intense peak at 3360 and 3294 cm^{-1} respectively which indicated the presence of hydroxyl, (OH) group. These were lower than the stretching of free hydroxyl group which was at 3640 cm^{-1} . This proved that there was a possibility of the formation intermolecular hydrogen bonding in the complex [13].

Bidentate nature of the chelation with dithiocarbamate ligands can be seen in the region of $959\text{--}1003\text{ cm}^{-1}$ with the existence of non-splitting $\nu(\text{C}=\text{S})$ band and monodentate if splitting [14]. The presence of metal-sulphur, (M-S) bond was observed around $350\text{--}398\text{ cm}^{-1}$ [15].

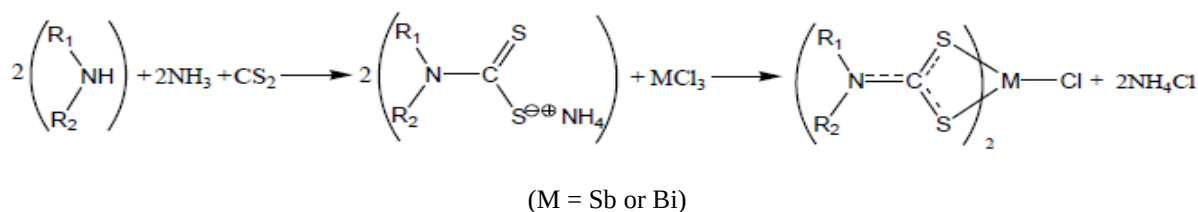


Figure 2. General reaction between secondary amine, carbon disulphide and metal(III) trichloride (M = Sb or Bi).

Table 1. Physical and elemental analysis of complexes

No.	Complex	Percentage yield (%)	Melting point (°C)	%				
				C	H	N	S	M
1	SbCl[S ₂ CN(C ₂ H ₅)(C ₂ H ₄ OH)] ₂	78	135-136	24.32 24.73	3.19 4.15	6.29 5.77	24.83 26.40	24.30 25.07
2	BiCl[S ₂ CN(C ₂ H ₅)(C ₂ H ₄ OH)] ₂	80	128-131	22.25 20.96	3.63 3.52	5.88 4.89	20.23 22.39	35.11 36.47
3	SbCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂	87	95.4-95.1	32.49 32.98	5.17 5.54	5.50 5.49	24.52 25.16	23.05 23.88
4	BiCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂	89	102-104	28.16 28.00	4.73 5.32	3.69 3.26	21.48 21.03	35.00 34.14
5	SbCl[S ₂ CN(C ₇ H ₇)(CH ₃)] ₂	88	139-140	34.09 35.00	3.41 3.56	4.01 4.30	17.60 19.67	28.20 29.55
6	BiCl[S ₂ CN(C ₇ H ₇)(CH ₃)] ₂	89	131-133	40.17 39.32	3.80 3.67	5.29 5.09	22.09 23.33	25.85 26.34

bold = theoretical values

Table 2. FT-IR and UV spectral data for all dithiocarbamate complexes

No.	Complex	Infrared				Ultraviolet-visible
		Wavenumber (cm ⁻¹)				Wavelength (nm)
		ν(C ---- N)	ν(C ---- S)	ν(-OH)	ν(M-S)	
1	SbCl[S ₂ CN(C ₂ H ₅)(C ₂ H ₄ OH)] ₂	1498s	976s, 994s	3360b	351s	261
2	BiCl[S ₂ CN(C ₂ H ₅)(C ₂ H ₄ OH)] ₂	1480s	955s, 980s	3294b	354m	361, 260
3	SbCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂	1464s	971s	-	352s	255
4	BiCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂	1466s	957s	-	352s	361, 259
5	SbCl[S ₂ CN(C ₇ H ₇)(CH ₃)] ₂	1452s	960s	-	358s	355, 255
6	BiCl[S ₂ CN(C ₇ H ₇)(CH ₃)] ₂	1452s	953s	-	355s	355, 255

s = strong; b = broad; m = medium

Deduced from ultraviolet spectra of antimony complexes, the maximum absorption occurred in the range of 251 - 254 nm for $\pi \rightarrow \pi^*$ transition of N-C-S group due to the intramolecular charge transfer of the ligand [16]. At the vicinity of 287 nm and above, $n \rightarrow \pi^*$ transition of the non-bonding electron on sulfur atoms to the conjugated system in $N \equiv C \equiv S$ group occurred. The analytical data indicated that there was characteristic of double bond character between carbon and nitrogen and between carbon and sulfur [17]. Singh and Kaushik [18] stated that chromophore group of NCS_2 in complexation will cause the absorption band shift to lower wavelength.

Table 3. 1H -NMR spectral data for all dithiocarbamate complexes

No.	Complex	Chemical shift, δ (ppm)	
		-NR' ; R' =, C_2H_5 C_4H_9 , C_7H_7	-NR'' ; R'' = C_2H_4OH , C_2H_5 , CH_3
1	$SbCl[S_2CN(C_2H_5)(C_2H_4OH)]_2$	1.36(t), 3.89(q)	3.93(t), 4.67(s)
2	$BiCl[S_2CN(C_2H_5)(C_2H_4OH)]_2$	1.34(t), 3.91(q)	3.95(t), 4.39(s)
3	$SbCl[S_2CN(C_4H_9)(C_2H_5)]_2$	0.91(t), 1.31(m), 1.64(q), 3.79(t)	2.5(t)
4	$BiCl[S_2CN(C_4H_9)(C_2H_5)]_2$	0.95(t), 1.35(s), 1.75(q), 3.69(t)	3.32(s)
5	$SbCl[S_2CN(C_7H_7)(CH_3)]_2$	3.80(s), 5.07(s), 5.34(s), 7.36(s)	1.62(s)
6	$BiCl[S_2CN(C_7H_7)(CH_3)]_2$	2.68(s), 3.21(s), 4.37(s), 5.00(s)	1.81(s)

q = quartet; t = triplet; s = singlet

Table 4. ^{13}C -NMR spectral data for all dithiocarbamate complexes

No.	Complex	Chemical shift, δ (ppm)		
		$N^{13}CS_2$	-NR' ; R' = C_2H_5 , C_4H_9 , C_7H_7	-NR'' ; R'' = C_2H_4OH , C_2H_5 , CH_3
1	$SbCl[S_2CN(C_2H_5)(C_2H_4OH)]_2$	196.14	11.32, 50.89	55.62, 58.63
2	$BiCl[S_2CN(C_2H_5)(C_2H_4OH)]_2$	201.64	11.46, 50.59	55.29, 59.02
3	$SbCl[S_2CN(C_4H_9)(C_2H_5)]_2$	197.59	12.18, 42.57	50.63, 58.48
4	$BiCl[S_2CN(C_4H_9)(C_2H_5)]_2$	199.32	13.81, 20.12, 28.93, 56.66	41.74
5	$SbCl[S_2CN(C_7H_7)(CH_3)]_2$	198.00	48.58, 56.56, 77.31, 134.25	11.74
6	$BiCl[S_2CN(C_7H_7)(CH_3)]_2$	201.50	40.94, 128.14 129.18, 134.37	31.99

The 1H - and ^{13}C -NMR spectral data of all complexes were shown in Table 3 and Table 4 respectively. Deuterated $DMSO_{d6}$, CD_2Cl_2 and $CDCl_3$ solvents were used for this analysis. The resonance frequencies of the protons of the aromatic rings were observed in complexes 5 and 6. The higher peaks ascribed to the protons that were ortho to the carbon of the thioureide group. They were more deshielded due to the electronegativity of the nitrogen atom and the proximity to the CS_2 group, while the lower resonance frequency was due to the proton on the meta carbon [19]. A

signal in the region of 199.13 – 199.66 ppm was observed due to the NCS₂ carbon atoms of dithiocarbamate moieties [20]. Table 4 below discussed the ¹³C NMR spectra data of all six dithiocarbamate compounds (δ, ppm) in details.

Crystal structure and data of bis(N,N'-butylethyldithiocarbamato)chlorido antimony(III), SbCl[S₂CN(C₄H₉)(C₂H₅)]₂

Compound **4** was successfully crystallized and analyzed by using Bruker APEX-II CCD fitted with Mo Kα radiation. Figure 3 showed ORTEP plot of bis(N,N' butylethyldithiocarbamato)chlorido antimony(III) in the unit cell which showed that the antimony atom was five-coordinated and geometry between trigonal bipyramidal and square pyramidal with the slight tendency towards the former. The crystallographic data and refinement detail for compound **4** were given in Table 5 including selected bond lengths in Table 6. The Sb-S distances can be described as short bond [Sb-S1 = 2.5456(10) Å], [Sb-S2 = 2.615(2) Å], [Sb-S3 = 2.852(2) Å] and [Sb-S4 = 2.463(2) Å]. Compound **4** had short thioureide C-N distance, 1.299(9) and 1.324(10) Å, suggesting a partial double bond character [21]. The coordination geometry around antimony atom can be described as a pyramidal geometry because of the asymmetrically coordinated dithiocarbamate ligands. The S atoms in these complexes lie in the equatorial plane, with S-Sb-S angles distorted significantly from 90°.

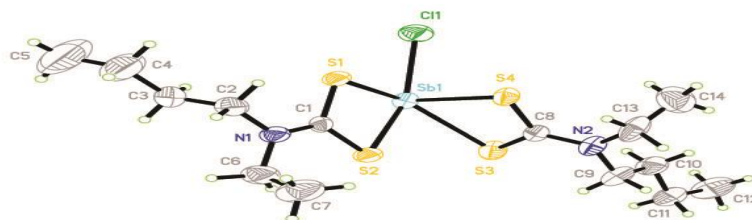


Figure 3. ORTEP plot of bis(N,N'-butylethyldithiocarbamato)chlorido antimony(III) at the 50% probability level.

Table 5. Crystal data for bis(N,N'-butylethyldithiocarbamato)chlorido antimony(III)

Complex	SbCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂
Empirical formula	C ₁₄ H ₂₈ ClN ₂ S ₄ Sb
Formula weight	509.82
T (K)	301(2)
Crystal system	Triclinic
Space group	P1̄
a (Å)	10.0141(8)
b (Å)	10.1394(7)
c (Å)	11.8665(9)
α (°)	67.960(2)
β (°)	87.616(2)
γ (°)	80.172(2)
V (Å ³)	1100.12(14)
Z	2
Calculated density, Mg/m ⁻³	1.539
F(000)	16
θ Range (0°)	2.7 - 25.5°
R Indices(final) F ² > 2σ(F ²)	R ₁ = 0.0569, wR ₂ = 0.1502
R indices (all data)	R ₁ = 0.0665, wR ₂ = 0.1727

Table 6. Selected bond lengths (Å) and angles (°) for bis(*N,N'*-butylethylthiocarbamate) chlorido antimony(III) complex

Sb(1)-S(1)	2.5456(19)	S(1)-C(1)	1.733(7)
Sb(1)-S(2)	2.615(2)	S(2)-C(1)	1.726(7)
Sb(1)-S(3)	2.852(2)	S(3)-C(8)	1.703(8)
Sb(1)-S(4)	2.463(2)	S(4)-C(8)	1.736(8)
Sb(1)-Cl(1)	2.637(2)	N(1)-C(1)	1.299(9)
S(4)-Sb(1)-S(1)	93.22(7)	N(2)-C(8)	1.324(10)
S(4)-Sb(1)-S(2)	90.54(7)	S(1)-Sb(1)-S(2)	69.33(6)
S(4)-Sb(1)-Cl(1)	86.11(8)	S(1)-Sb(1)-Cl(1)	80.01(7)
S(2)-Sb(1)-Cl(1)	148.92(7)	C(1)-N(1)-C(2)	121.9(7)
C(6)-N(1)-C(2)	115.9(7)	C(8)-N(2)-C(9)	120.9(7)

Antibacterial studies of synthesized dithiocarbamate complexes

All six dithiocarbamate complexes synthesized were tested as antibacterial agent using MIC and MBC tests. Compounds were dissolved in 10% DMSO with 20 mg/mL as starting concentration. Two gram positive bacteria which were *Staphylococcus aureus* and *Staphylococcus epidermidis* and two gram negative bacteria, *Escherichia coli* and *Enterobacter aerogenes* were selected. Compounds were dissolved in 10% DMSO with 20 mg/mL as starting concentration. The bacterial single colony were maintained in nutrient agar and were subcultured in Mueller-Hinton broth for tests. There were ten times dilution, duplicated, apart from having positive and negative control as comparison using 96 well plate. Two types of commercial antibacterial agent used i.e. Penicillin for gram positive bacteria and Kanamycin for gram negative species. Results were tabulated in Table 7. Ajibade [22] reported that a value greater than the dilution concentration of 20 mg/mL shows that it was the least active complex that can act as antimicrobial agent. In Table 7, some of the complexes were found to be moderate active against bacteria. Compound **1** was active against *E. aerogenes* while compound **2** was active against *S. aureus*. Compound **6** was active against *S. epidermidis* because of the electron withdrawing group which increases the activity of antibacterial. The velocity of compound to diffuse into membrane cell depends on the density of electron in the compound. The faster the compound diffuse into the membrane cell, the more active antibacterial activity of the compound [23].

Table 7. Results of MIC and MBC tests using dithiocarbamate complexes

No.	Complex	<i>S. aureus</i>		<i>S. epidermidis</i>		<i>E. coli</i>		<i>E. aerogenes</i>	
		MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
1	SbCl[S ₂ CN(C ₂ H ₅)(C ₂ H ₄ OH)] ₂	10.0	10.0	20.0	>20	20.0	20.0	1.25	1.25
2	BiCl[S ₂ CN(C ₂ H ₅)(C ₂ H ₄ OH)] ₂	1.25	1.25	20.0	>20	>20	ND	>20	ND
3	SbCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂	>20	ND	>20	ND	>20	ND	5.00	10.0
4	BiCl[S ₂ CN(C ₄ H ₉)(C ₂ H ₅)] ₂	10.0	20.0	>20	ND	>20	ND	>20	ND
6	BiCl[S ₂ CN(C ₇ H ₇)(CH ₃)] ₂	>20	ND	5.0	5.0	20.0	20.0	>20	ND

*values are in mg/mL, ND = not determined

Conclusion

Six new dithiocarbamate complexes using antimony(III) and bismuth(III) trichloride were successfully synthesized and characterized. The structure of bis(*N,N'*-butylethyldithiocarbamato)chlorido antimony(III), $\text{SbCl}[\text{S}_2\text{CN}(\text{C}_4\text{H}_9)(\text{C}_2\text{H}_5)]_2$, demonstrated a five-coordination geometry, *triclinic* system with space group *P1*. MIC and MBC tests done on five complexes showed that dithiocarbamate complexes are good antibacterial agents towards certain bacteria.

Acknowledgement

The authors gratefully acknowledge Prof Dr Bohari Mohd Yamin for crystal data and financial support from Science Fund (06-01-02-SF0887) and MyMaster Higher Education Ministry of Malaysia scholarship given to Nur Amirah binti Jamaluddin. Highest gratitude towards School of Chemical Science and Food Technology, Science and Technology Faculty, Universiti Kebangsaan Malaysia.

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