



Research Article

Synthesis, Infrared Spectroscopic Characterization and Antimicrobial Studies of Co(III) Dimethylglyoximato Complexes with Aniline and Aniline-derived Axial Ligands

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ABSTRACT

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Complexes with cobalt(III) have been used as models in the study of vitamin B₁₂ chemistry. In this study, cobalt(III) complexes with dimethylglyoxime as equatorial ligand and aniline or substituted aniline as well as thiocyanate ion as axial ligands have been synthesized and characterized based on melting point, conductivity, solubility and infrared (IR) spectral studies. The complexes are formulated as [Co(Hdmg)₂(B)(SCN)] where Hdmg is dimethylglyoximato, B = aniline (A), 4-bromoaniline (4BrA), 2-nitroaniline (2NA), 4-nitroaniline (4NA) or 4-anisidine (4PA). The complexes were formed in low yields (33 - 37 %) except [Co(Hdmg)₂(A)(SCN)] which was obtained in significant yield (65 %). The percentage yield of the synthesized cobaloximes follows the order A > 4NA > 4PA > 4BrA = 2NA. They are of various colours, soluble or slightly soluble in the solvents used and have melting points in the range (77 - 120 °C). The data from IR spectra indicated that the coordination compounds coordinated via the nitrogen of the ligands. Further supportive fact of the coordination of the ligands to the metal ions was deduced from the emergence of new bands due to ν(M-N) in the metal complexes. In the proposed octahedral coordination sphere of the central cobalt atom, four coordination sites in the equatorial positions are occupied by nitrogen atoms of two dimethylglyoximate monoanions, and the other two sites are occupied by atoms of monodentate neutral ligands and thiocyanate anion. The measured molar conductance showed that the complexes are non-electrolytes, except [Co(Hdmg)₂(4BrA)(SCN)] which has conductivity of 149 Scm² mol⁻¹, hence electrolytic in nature. The *in vitro* antibacterial potency of the complexes were assayed against some strains of bacteria such as MRSA (*Methicillin Resistance Staphylococcus*) *Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus pneumoniae*, and the Gram negative bacteria, *Salmonella typhi*, *Klebsiella pneumoniae*, *Escherichia coli*, and *Pseudomonas aeruginosa*. The results of the antimicrobial assay uncovered that the complexes have more potency than their free ligands but less than that of the standard drug (Gentamicin)

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INTRODUCTION

Coordination compounds occur both naturally and synthetically. Vitamin B₁₂, haemoglobin as well as chlorophyll are among the naturally occurring coordination compounds that are biologically vital (Sitek *et al.*, 2019; Islam *et al.*, 2021). They are also found in nature as minerals (Shamim *et al.*, 2004). Penicillin, chloramphenicol, etc, are some common synthetically produced coordination compounds. These compounds have various uses in medicine, agriculture; industries etc. for example, the products obtained from amino acids are used in synthesis of drugs and cosmetics (Paul and Giann, 2006). The coenzyme cobalamin exemplified as vitamin B₁₂ has cobalt as its active center. Hence it is an essential trace dietary mineral for all animals. Cobalt in inorganic form is also a micronutrient for bacteria, algae and fungi (Krebs, 2006; Dolui *et al.*, 2020).

Dimethylglyoxime analogues of cobaloxime have been used in catalysis of strong acids. In particular, pyridine-containing cobaloxime has shown efficient activity as catalyst for proton reduction (Padma *et al.*, 2013; Fan *et al.*, 2015). When dimethylglyoxime (DMG) deprotonates, it acts as a bidentate chelating ligand capable of forming stable complexes with a number of bivalent transition metal ions (Vitiu *et al.*, 2017). In 1905, Tschugaeff for the first time observed that DMG in alkaline medium forms a bright rose-red colored precipitate with Ni²⁺, forming nickel bis(dimethylglyoximate) complex, denoted as Ni(DMG)₂ and therefore, suggested DMG for detecting and also for quantifying any traces of Ni²⁺ (Ali *et al.*, 2019).

The search for new active antimicrobial agents has been gaining growing interest because of the increasing emergence and spread of antimicrobial resistance. It has been estimated that by 2050, 10 million deaths will occur due to Antimicrobial Resistance (AMR) with a cumulative economic cost of US\$100 trillion (Iwu-Jaja *et al.*, 2021; Ohemu, 2022). Sub-Saharan Africa experienced the greatest

mortality rate from AMR in 2019. SSA had about 1.1 million deaths associated with AMR while about a quarter of a million deaths in the region were attributable to AMR in 2019 (Moyo *et al.*, 2023). Therefore, it is highly necessary to design strategies for the development of new drugs in order to target multiple cellular processes that should improve their efficiency against several microorganisms, including bacteria, viruses or fungi (Claudel *et al.*, 2020).

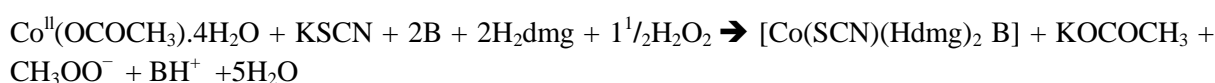
Recently, Boopalan *et al.* (2022) reported the synthesis and characterization of a new series of inorganic cobaloximes of the type [Co(X)(L)₂B], where L=Dimethylglyoxime, X=Cl⁻, Br⁻, SCN⁻, B = p-aminophenylacetic acid or p-aminobenzoic acid. The antibacterial activity of the complexes against *Methicillin Resistant Staphylococcus aureus* (MRSA) MTCC 1430 and *Acinetobacter baumannii* MTCC 1425 was studied by three different methods. All the cobaloximes were found to be active against both the tested human pathogens and comparatively showed potential inhibition of bacterial growth against gram negative bacteria. Martin and Dayalan, (2009) described cobaloximes of the types Trans-BH₂[Co(dmgH)₂X], where dmgH⁻ = Dimethylglyoximate, X⁻ = Cl⁻ or Br⁻ and Trans-[Co(dmgH)₂(H₂O)]B where, B = Piperazine (Pp) or 2-(N-Tert-butylamido)piperazine (t-Bu-PpAM) were prepared and characterized by TG/DTA, FABMS UV-visible, IR, NMR spectra and XRD studies. These cobaloximes were assayed for their antimicrobial potency against some microbes and compared with the standard drug streptomycin. The free ligands Pp was more potent than t-Bu-PpAM. The antimicrobial activity of most of the cobaloximes were found to be higher than the corresponding free ligands. For cobaloximes of piperazine, the activity for the axial halides was in decreasing order of Cl⁻ > Br⁻ > I⁻ contrary to the case of cobaloximes having 2-(N-Tertbutylamido) piperazine which follow the order Br⁻ > Cl⁻ > I⁻.

Herein, this study reports the synthesis of cobaloximes with isothiocyanate anion and aniline or substituted aniline (4-bromoaniline, 2-nitroaniline, 4-nitroaniline and 4-anisidine) as well as their antimicrobial activity against some antibiotic-resistant bacterial and fungal species.

MATERIALS AND METHODS

Chemicals and solvents used were of analytical grade, and used as supplied. These include cobalt(II) acetate tetrahydrate, dimethylglyoxime, diphenylglyoxime, aniline, 4-bromoaniline, 2-nitroaniline, 4-nitroaniline, and 4-anisidine.

Melting points were determined on a Gallenkamp G112 melting point apparatus at the Laboratory of Department of Chemistry, Kashim Ibrahim College of Education, Maiduguri, Borno State. DDS-307 conductivity meter was employed to determine the molar conductivity of the complexes at 35 °C, at Soil Laboratory, Department of Soil Sciences, University of Maiduguri. FTIR-8400S model in the range of 4500 - 450 cm⁻¹ was used to record infrared spectra of the complexes and ligands, at National Research Institute for Chemical Technology (NARICT), Federal Ministry of Science and Technology, Zaria. The percentage (%) of Co was determined by titrating a digested solution of the metal complexes against a standardized EDTA (Vogel, 2000). The solubility profile of



Where B = aniline or aniline derivatives and H₂dmg = dimethylglyoxime

Antibacterial Activity of the Complexes

Antibacterial activities of the metal complexes were evaluated against different strains of Gram positive bacteria such as *MRSA (Methicillin Resistance Staphylococcus)*, *Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus pneumoniae*, and the Gram negative bacteria such as *Salmonella typhi*, *Klebsiella pneumoniae*, *Escherichia coli*, and *Pseudomonas aeruginosa* using disc diffusion method. A suspension of the microorganism

the synthesized coordination compounds was tested in some polar and non-polar solvents which include distilled water, chloroform, benzene, ethanol and methanol. The bacterial isolates were obtained from Veterinary Teaching Hospital, University of Maiduguri.

Preparation of Dimethylglyoxime Complexes

The cobalt(III) complexes were prepared following literature procedures (Ndahi and Kolawole, 2005; Ozoemena *et al.*, 2003). Cobalt(II) acetate tetrahydrate (3 mmol, 0.7472 g) and KSCN (3 mmol) were dissolved in distilled water (30 mL) in a 250 mL quick-fit conical flask. Dimethylglyoxime (6 mmol, 0.6967 g) was dissolved in methanol (50 mL). The solution obtained from Hdmg was added to the mixture of the acetate and KSCN. The colour of the resulting mixture changed from pink to dark brown. The reaction mixture was refluxed with stirring for 2 hours after which it was cooled to room temperature. To the mixture, aniline or its derivatives (6 mmol) was added after which 30 % H₂O₂ was added and stirred at room temperature for 3 hours to effect the oxidation of Co(II) to Co(III). The product obtained was filtered and washed with a suitable solvent and dried in a desiccator over calcium chloride. The same procedure was applied to each Hdmg complex prepared. A general equation for the reaction is presented as follows:

was added to a sterile agar medium, then poured into sterile petri plates and left to solidify. The ligands and complexes in methanol with the concentrations (10, 20 and 30 µg/mL) were placed on the culture media and incubated at 37 °C for 24 hr. By measuring the diameter of the zone of inhibition (mm), the antimicrobial activities of these compounds were assayed (Waziri *et al.*, 2017; Ishola *et al.*, 2023).

RESULTS AND DISCUSSION

Physical Properties of the Ligand and its Cobalt(III) Complexes

The physical properties of the synthesized metal complexes are presented in Table 1. The ligands on interaction with Co(II) formed complexes of various colours ranging from dark brown, black, yellowish brown, and red with low yields (33 – 37 %) except [Co(Hdmg)₂(A)(SCN)] which was obtained in high yield (65 %). The colour might be due to d-d transition which is typical of transition metal complexes. All the complexes were air

stable solids of sharp melting points in the range 77 - 120 °C. This indicates that the complexes are pure (Sunil *et al.*, 2011). The molar conductance indicated that the complexes are non-electrolytic in nature, except [Co(Hdmg)₂(4BrA)(SCN)] which has conductivity value of 149 Scm² mol⁻¹ indicating electrolytic nature. The solubility of the complexes in polar and non-polar solvents was determined at room temperature (37 °C) (Table 2). Most of the complexes are either soluble or slightly soluble in the solvents used.

Table 1: Physical Characteristics of the Complexes

Compound	Molecular formula (molar mass)	Colour	Yield g (%)	Metal (%) Calc. (Found)	Melting Point (°C)	Molar Conductivity (Scm ² mol ⁻¹)
[Co(Hdmg) ₂ (A)(SCN)]	CoC ₁₅ H ₂₃ N ₆ O ₄ S (442.4)	Dark brown	7.51 (65)	13.32 (13.16)	84 – 86	29
[Co(Hdmg) ₂ (4BrA)(SCN)]	CoC ₁₅ H ₂₂ N ₆ O ₄ BrS (521.3)	Black	4.4 (33)	11.30 (11.20)	77 – 80	149
[Co(Hdmg) ₂ (2NA)(SCN)]	CoC ₁₅ H ₂₂ N ₇ O ₆ S (487.4)	Yellowish Brown	4.3 (33)	12.09 (11.98)	104 - 105	38
[Co(Hdmg) ₂ (4NA)(SCN)]	CoC ₁₅ H ₂₂ N ₇ O ₆ S (487.4)	Brown	4.8 (37)	12.09 (11.79)	120 – 122	77
[Co(Hdmg) ₂ (4PA)(SCN)]	CoC ₁₆ H ₂₅ N ₆ O ₅ S (472.4)	Dark brown	4.33 (34)	12.48 (12.38)	98 – 100	58

Table 2: Solubility of the Complexes

Compound	Distilled water		Methanol		Ethanol		Chloro- form		Methyl acetate		Petroleum ether		Benzene	
	C	H	C	H	C	H	C	H	C	H	C	H	C	H
[Co(Hdmg) ₂ (A)(SCN)]	I	SS	S	VS	S	VS	SS	S	S	VS	SS	SS	SS	SS
[Co(Hdmg) ₂ (4BrA)(SCN)]	I	SS	SS	S	SS	S	S	VS	S	VS	I	I	SS	SS
[Co(Hdmg) ₂ (2NA)(SCN)]	I	SS	SS	S	VS	VS	S	VS	S	VS	I	SS	SS	S
[Co(Hdmg) ₂ (4NA)(SCN)]	I	SS	SS	S	VS	VS	S	VS	S	VS	I	SS	I	SS
[Co(Hdmg) ₂ (4PA)(SCN)]	I	SS	S	VS	S	VS	S	VS	SS	S	SS	S	SS	S

I = insoluble, VS = very soluble, SS = slightly soluble, S = soluble, C = cold, H = hot

Infrared Spectra of the Metal Complexes

The significant vibrational frequencies of the ligands and their metal complexes are presented in Table 4 and the spectra presented in figures 1 - 4. In order to understand the mode of bonding and the effect of the metal ion on the ligand, the IR spectra of the free ligand and the metal complexes were studied

and assigned on the basis of careful comparison of their spectra with that of free ligand and also from literature report of similar compounds (Joshi *et al.*, 2006).

The band observed for the complexes are in close agreement with those reported by earlier workers (Osunlaja *et al.*, 2009; Ndahi and Kolawole, 2005). The absorption peak at 1446

cm^{-1} in the spectrum of the free H_2dmg has been ascribed to $\nu(\text{C}=\text{N})$ group. This band underwent upward shift to $1471\text{--}1701\text{ cm}^{-1}$ in all the complexes. This is a consequence of the coordination of the metal ion to the dimethylglyoximate (Adkhis *et al.*, 2003; Selvi *et al.*, 2011). The $\nu(\text{N}-\text{O})$ group absorbs strongly at 976 cm^{-1} in the ligand and are shifted to $1226\text{--}1226\text{ cm}^{-1}$ in the complexes. This could be due to change in the orientation of N-O band with respect to H in the ligand and complexes (Osunlaja *et al.*, 2009; Osunlaja *et al.*, 2011). In all the complexes, the $\nu(\text{O}-\text{H})$ bond due to $\text{O}\cdots\text{H}\cdots\text{O}$ hydrogen bridges appeared as broad bands in the range of $3615\text{--}3176\text{ cm}^{-1}$ leading to stable pseudo-macrocyclic system (Boopalan *et al.*, 2022). The IR spectra band of SCN^- group is seen in the range of $2119\text{ cm}^{-1}\text{--}2367\text{ cm}^{-1}$ which is assigned to $\nu(\text{CN})$ in all the complexes due to

SCN^- group (Fan *et al.*, 2015). The only new feature in the IR spectra of the complexes is strong and sharp absorption around $401\text{ cm}^{-1}\text{--}538\text{ cm}^{-1}$ which is assigned to $\nu(\text{Co}-\text{N})$ vibration, these bands are not found in the spectra of the ligand (Berradj *et al.*, 2016). Suggestively, the complexes are formulated as $[\text{Co}(\text{Hdmg})_2(\text{B})(\text{SCN})]$ where Hdmg is dimethylglyoximate, B = aniline, 4-bromoaniline, 2-nitroaniline, 4-nitroaniline or 4-anisidine. In the octahedral coordination sphere of the central cobalt atom, four coordination sites in the equatorial positions are occupied by nitrogen atoms of two dimethylglyoximate monoanions, and the other two sites are occupied by atoms of monodentate neutral ligands and thiocyanate anion (Berradj *et al.*, 2016). The proposed structure is depicted in figure 7.

Table 3: Relevant Vibrational frequencies of the ligand and complexes (cm^{-1})

Compounds	Wavenumber (cm^{-1})							
	$\nu(\text{OH})$	$\nu(\text{C}-\text{N})$	$\nu(\text{C}=\text{N})$	$\nu(\text{N}-\text{H})$	$\nu(\text{N}-\text{O})$	$\nu(\text{N}=\text{O})$	$\nu(\text{Co}-\text{N})$	$\nu(\text{NCS})$
Hdmg	3200	-	1446	-	976	-	-	-
$[\text{Co}(\text{Hdmg})_2(\text{A})(\text{SCN})]$	3183	1079	1471	3752	1232	-	538,440	2119
$[\text{Co}(\text{Hdmg})_2(4\text{BrA})(\text{SCN})]$	3202	1086	1490	3406	-	-	513,436	2135
$[\text{Co}(\text{Hdmg})_2(2\text{NA})(\text{SCN})]$	3176	1086	1493	3467	1236	1494	530,443	2133
$[\text{Co}(\text{Hdmg})_2(4\text{NA})(\text{SCN})]$	3219	1091	1529	3469	1226	1339	516,425	2137
$[\text{Co}(\text{Hdmg})_2(\text{PA})(\text{SCN})]$	3615	-	1701	3617	-	-	401	2367

Hdmg = Dimethylglyoxime, 4NA = 4-Nitroaniline and PA = 4- nitroaniline

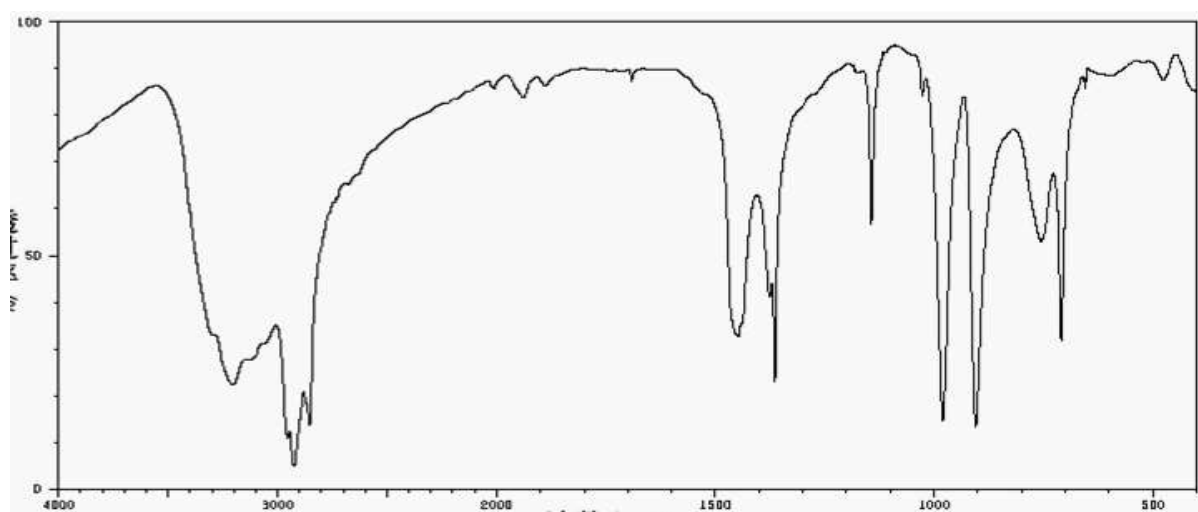


Figure 1: Infrared (IR) spectrum of dimethylglyoxime

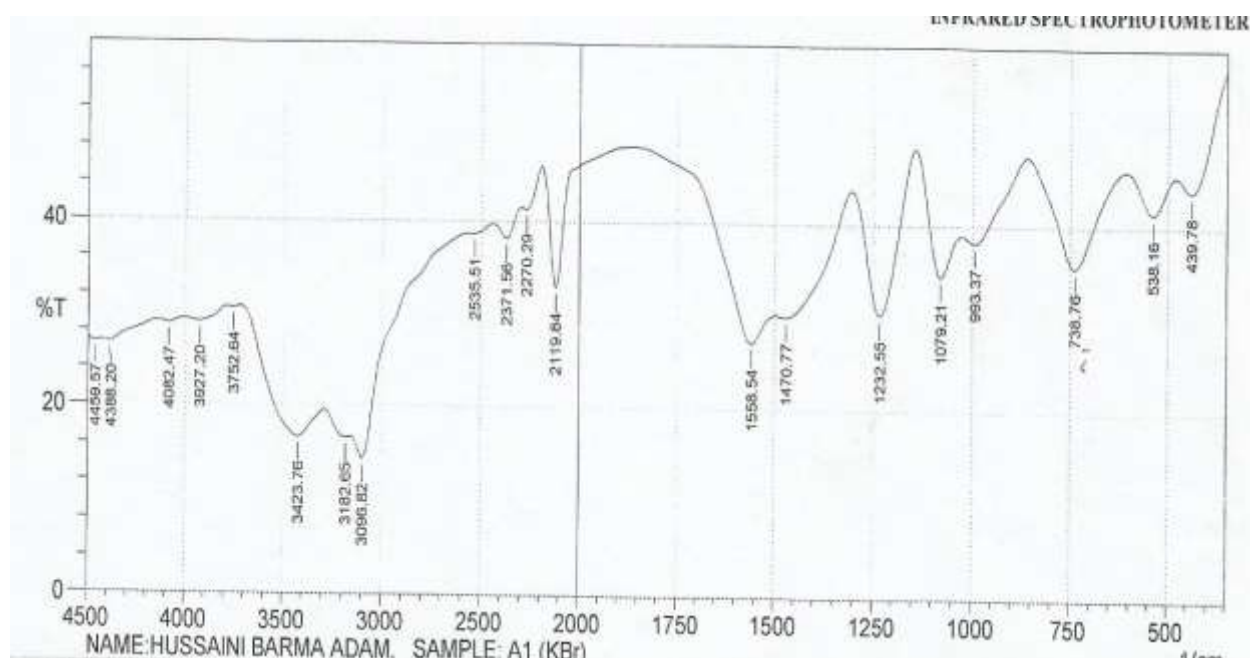


Figure 2: Infrared (IR) spectrum of $[\text{Co}(\text{Hdmg})_2(\text{A})(\text{SCN})]$

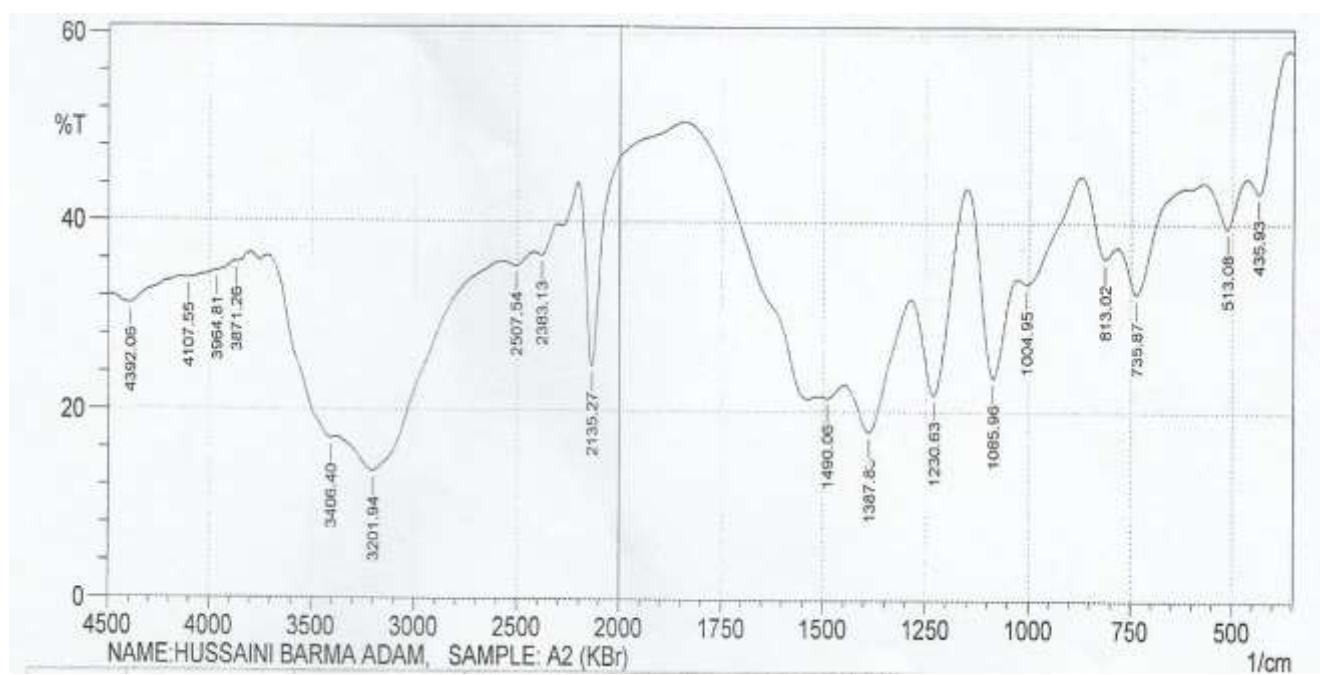


Figure 3: Infrared (IR) spectrum of $[\text{Co}(\text{Hdmg})_2(4\text{BrA})(\text{SCN})]$

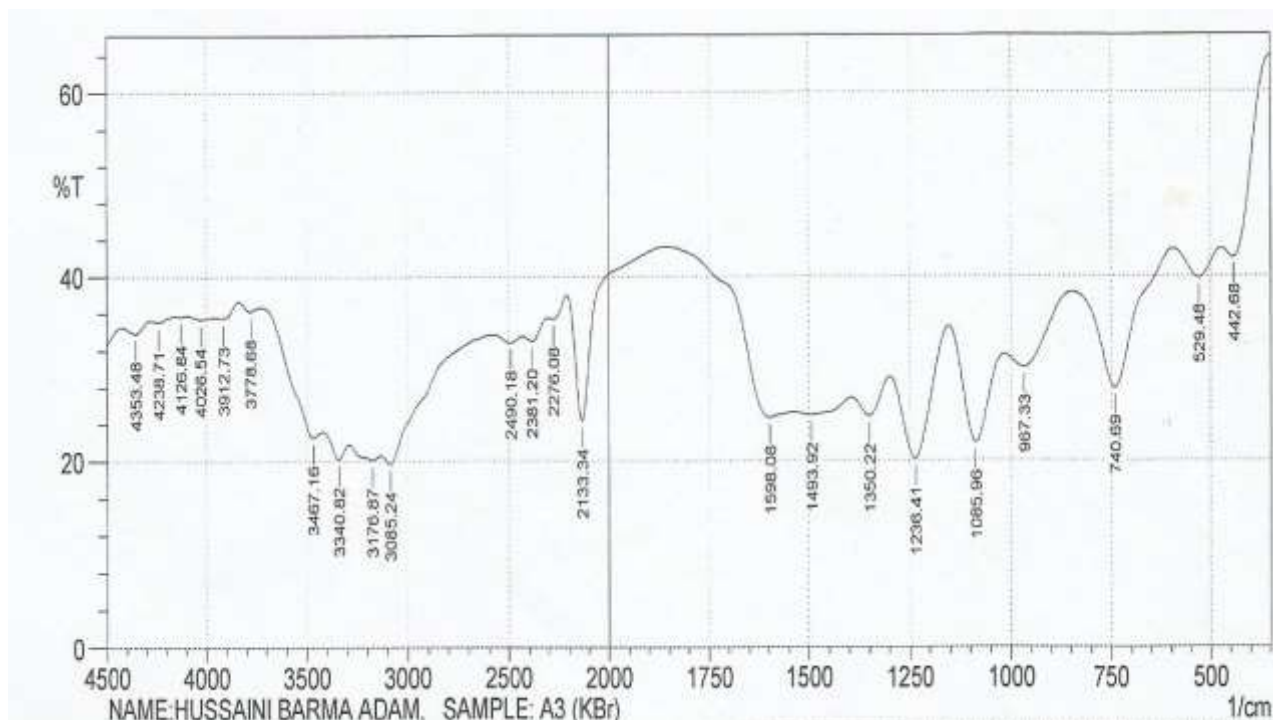


Figure 4: Infrared (IR) spectrum of [Co(Hdmg)₂(2NA)(SCN)]

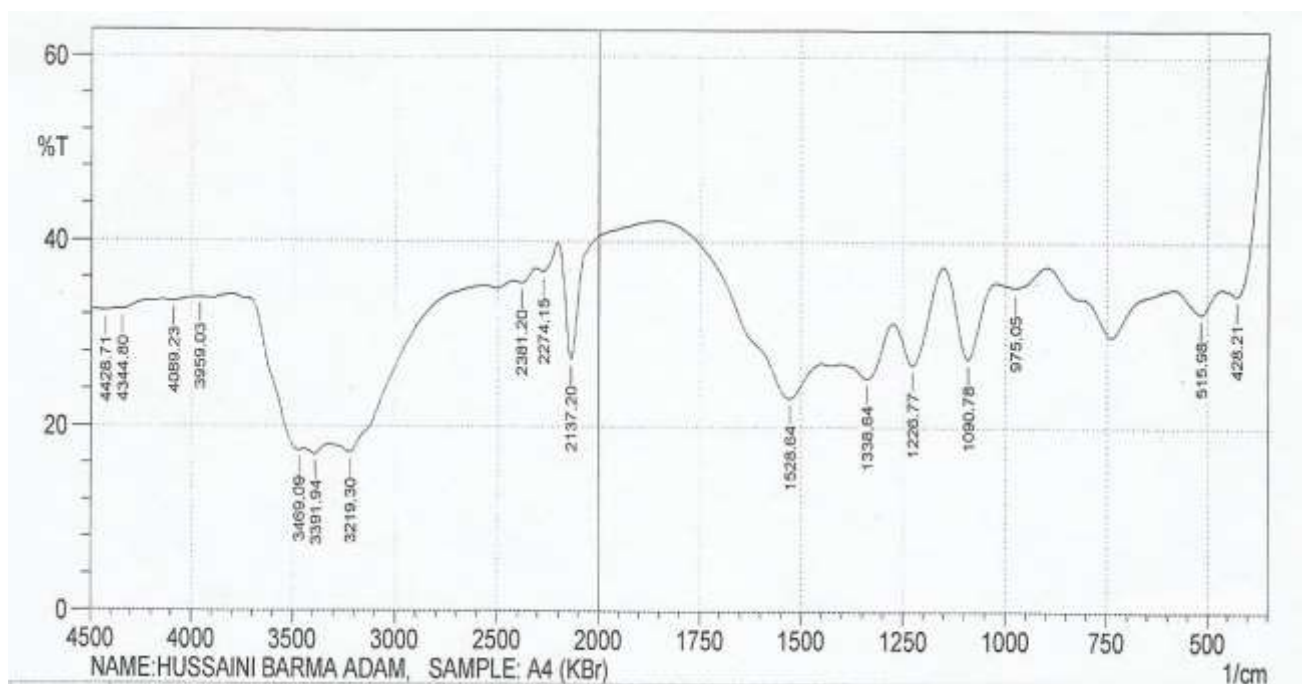


Figure 5: Infrared (IR) spectrum of [Co(Hdmg)₂(4NA)(SCN)]

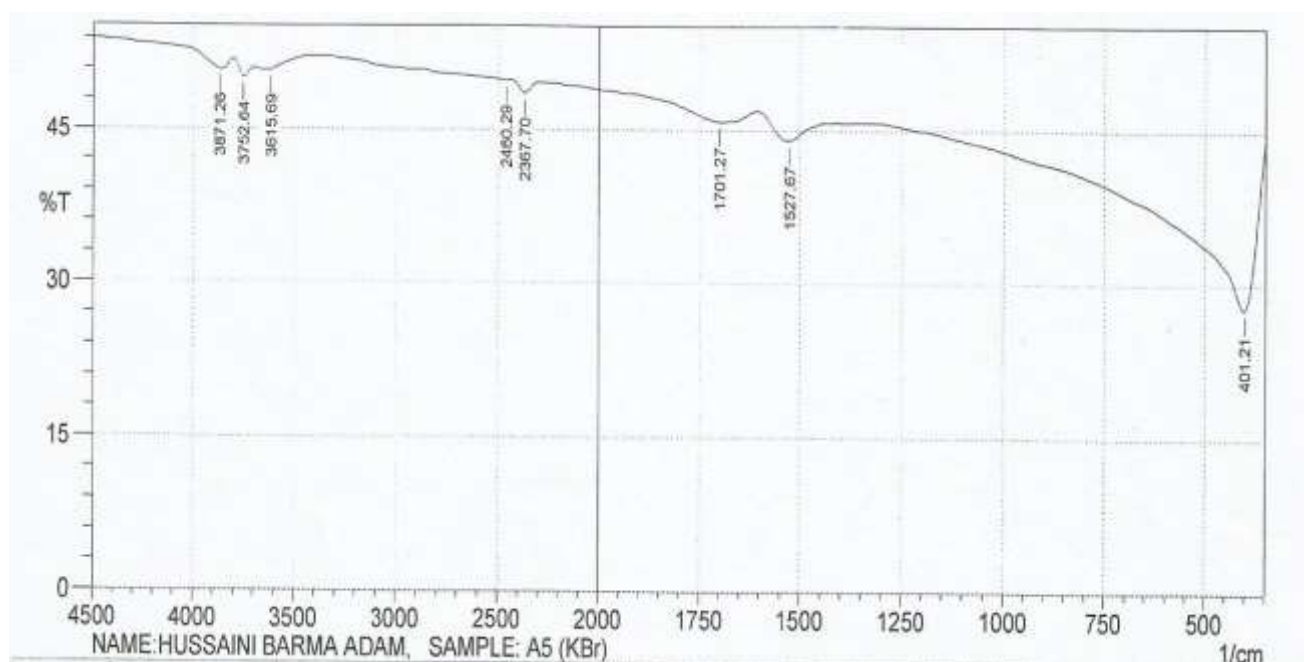
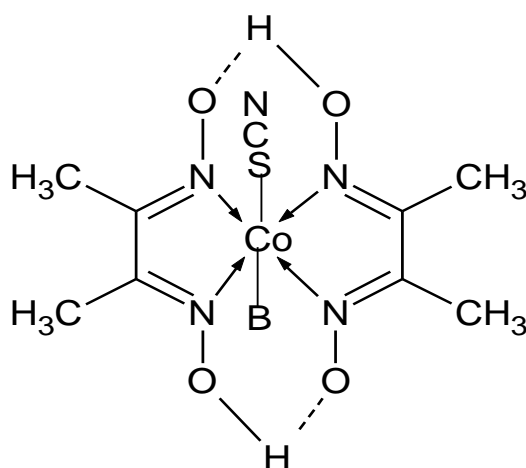


Figure 6: Infrared (IR) spectrum of $[\text{Co}(\text{Hdmg})_2(\text{PA})(\text{SCN})]$



Where B= aniline, 4-bromoaniline, 2-nitroaniline, 4-nitroaniline or 4-anisidine

Figure 7: Proposed structure of $[\text{Co}(\text{Hdmg})_2(\text{B})(\text{SCN})]$

Antimicrobial Studies

The antimicrobial activities of the ligands and metal complexes at concentration of 30 $\mu\text{g}/\text{mL}$, 20 $\mu\text{g}/\text{mL}$ and 10 $\mu\text{g}/\text{mL}$ were evaluated against Gram positive *MRSA (methicillin resistance staphylococcus)* *Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus pneumoniae*, and the Gram negative bacteria such as *Salmonella typhi*, *Klebsiella pneumoniae*, *Escherichia coli*, *Pseudomonas aeruginosa*. The results are presented in Table 4.

The metal complexes show significant activities against Gram positive bacteria with the inhibition zones ranging between 7.00 ± 0.00 – 16.67 ± 0.58 mm except *Streptococcus pneumoniae* which was resistant to the ligands and metal complexes, while no activity was recorded against the Gram negative bacteria used for the study except *Salmonella typhi* which was inhibited at ranges between 6.67 ± 0.58 – 20.67 ± 0.58 mm but dimethylglyoxime as a free ligand had no activity on all the eight (8) bacteria isolates used for this study. Therefore, the metal

complexes show significant antimicrobial activities than the free ligands and metal ion but less than the standard drug (15 mm). Based on chelation theory, the delocalization of electrons over the whole chelate increases upon chelation giving rise to enhanced penetration of the complexes into lipid membranes. Hence the metal binding sites in the enzymes of microorganisms got blocked (Lemire *et al.*, 2013).

Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of the Ligand and its Complexes

From the results of the MIC and MBC presented in Tables 5 and 6 respectively, it was observed that the broadest activity of the compounds was against the entire Gram

positive organisms used (*MRSA (Methicillin Resistance Staphylococcus aureus)*, *Bacillus subtilis*, *Streptococcus pneumoniae*) and a Gram negative organisms (*Salmonella typhi*). The MIC and MBC of the compounds varied from 6 – 10 µg/mL against the mentioned organisms. [Co(Hdmg)₂(A)(SCN)] and [Co(Hdmg)₂(4NA)(SCN)] showed no activity against all the Gram positive organisms and the Gram negative (*Salmonella typhi*).

The MIC and MBC values of the compounds against these isolates are very low with bioactive concentration of 6 µg/mL indicating their high antibacterial activities. This agrees with the findings of Peter and Omoruyi (2013).

Table 4: Antimicrobial Activities of the Ligands and their Complexes

Compounds	Bacteria								
	Conc. ($\mu\text{g/mL}$)	MRSA	<i>S. aureus</i>	<i>S. pneumonia</i>	<i>B. subtilis</i>	<i>S. typhi</i>	<i>E. coli</i>	<i>K. pneumonia</i>	<i>P. aeruginosa</i>
A	30	15.33 \pm 0.58	14.00 \pm 0.00	15.00 \pm 0.00	12.00 \pm 0.00	13.67 \pm 0.58	11.67 \pm 0.58	10.00 \pm 0.00	11.67 \pm 0.58
	20	12.33 \pm 0.58	11.00 \pm 0.00	11.33 \pm 0.58	9.00 \pm 0.00	10.67 \pm 0.58	8.67 \pm 0.58	8.67 \pm 0.58	9.00 \pm 0.00
	10	8.00 \pm 0.00	8.00 \pm 0.00	8.33 \pm 0.00	7.00 \pm 0.00	8.33 \pm 0.58	7.00 \pm 0.00	0.00 \pm 0.00	7.00 \pm 0.00
PA	30	10.33 \pm 0.58	12.00 \pm 0.00	15.00 \pm 0.00	11.67 \pm 0.58	13.67 \pm 0.58	12.00 \pm 0.00	10.00 \pm 0.00	11.67 \pm 0.58
	20	7.33 \pm 0.58	9.00 \pm 0.00	11.67 \pm 0.58	9.00 \pm 0.00	11.00 \pm 0.00	9.00 \pm 0.00	7.67 \pm 0.58	9.00 \pm 0.00
	10	0.00 \pm 0.00	7.00 \pm 0.00	9.00 \pm 0.00	7.00 \pm 0.00	8.33 \pm 0.58	7.33 \pm 0.00	0.00 \pm 0.00	7.00 \pm 0.00
H ₂ dmg	30	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	20	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	10	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
[Co(Hdmg) ₂ (A)(SCN)]	30	14.67 \pm 0.58	11.33 \pm 0.58	0.00 \pm 0.00	9.00 \pm 0.00	20.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	20	11.00 \pm 0.00	8.67 \pm 0.58	0.00 \pm 0.00	7.67 \pm 0.58	17.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	10	7.33 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	13.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
[Co(Hdmg) ₂ (4BrA)(S CN)]	30	12.67 \pm 0.58	15.33 \pm 0.58	0.00 \pm 0.00	16.00 \pm 0.00	15.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	20	9.00 \pm 0.00	11.67 \pm 0.58	0.00 \pm 0.00	10.67 \pm 0.58	11.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	10	7.00 \pm 0.00	9.00 \pm 0.00	0.00 \pm 0.00	9.33 \pm 0.58	8.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
[Co(Hdmg) ₂ (2NA)(SC N)]	30	14.67 \pm 0.58	16.67 \pm 0.58	0.00 \pm 0.00	8.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	20	10.67 \pm 0.58	12.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	10	8.33 \pm 0.58	9.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
[Co(Hdmg) ₂ (4NA)(SC N)]	30	10.00 \pm 0.00	11.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	8.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	20	8.00 \pm 0.00	9.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	6.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	10	0.00 \pm 0.00	7.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
[Co(Hdmg) ₂ (4PA)(SC N)]	30	14.33 \pm 0.58	15.67 \pm 0.58	0.00 \pm 0.00	10.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	20	11.33 \pm 0.58	12.33 \pm 0.58	0.00 \pm 0.00	8.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	10	9.00 \pm 0.58	9.67 \pm 0.58	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
Gentamicin	30	15.00 \pm 0.00	15.00 \pm 0.00	15.00 \pm 0.00	15.00 \pm 0.00	15.00 \pm 0.00	15.00 \pm 0.00	15.00 \pm 0.00	15.00 \pm 0.00

H₂dmg = dimethylglyoxime, A= aniline, PA= 4-nitroaniline, S = Susceptible, R = Resistant, NA= Not applicable, *S. aureus* = *Staphylococcus aureus*, *S. pneumonia* = *Streptococcus pneumonia*, *B. subtilis* = *Bacillus subtilis*, *S. typhi* = *Salmonella typhi*, *E. coli* = *Escherichia coli*, *K. pneumonia* = *Klebsiella pneumonia*, *P. aeruginosa* = *Pseudomonas aeruginosa*

Table 5: Minimum Inhibitory Concentration of Ligands and its Complexes

Compounds	Bacteria					
	Conc. ($\mu\text{g/mL}$)	MRSA	<i>Staphylococcus aureus</i>	<i>Streptococcus pneumoniae</i>	<i>Bacillus subtilis</i>	<i>Salmonella typhi</i>
A	10	S	S	S	NA	S
	8	S	S	S	NA	S
	6	R	R	R	NA	R
	4	R	R	R	NA	R
	2	R	R	R	NA	R
PA	10	NA	NA	S	NA	NA
	8	NA	NA	S	NA	NA
	6	NA	NA	R	NA	NA
	4	NA	NA	R	NA	NA
	2	NA	NA	R	NA	NA
H ₂ dmg	10	NA	NA	NA	NA	NA
	8	NA	NA	NA	NA	NA
	6	NA	NA	NA	NA	NA
	4	NA	NA	NA	NA	NA
	2	NA	NA	NA	NA	NA
[Co(Hdmg) ₂ (A)(SCN)]	10	NA	NA	NA	NA	S
	8	NA	NA	NA	NA	S
	6	NA	NA	NA	NA	S
	4	NA	NA	NA	NA	S
	2	NA	NA	NA	NA	S
[Co(Hdmg) ₂ (4BrA)(SCN)]	10	S	S	NA	S	S
	8	R	S	NA	S	S
	6	R	S	NA	R	R
	4	R	R	NA	R	R
	2	R	R	NA	R	R
[Co(Hdmg) ₂ (2NA)(SCN)]	10	S	S	NA	NA	NA
	8	S	S	NA	NA	NA
	6	S	R	NA	NA	NA
	4	R	R	NA	NA	NA
	2	R	R	NA	NA	NA
[Co(Hdmg) ₂ (4NA)(SCN)]	10	NA	NA	NA	NA	NA
	8	NA	NA	NA	NA	NA
	6	NA	NA	NA	NA	NA
	4	NA	NA	NA	NA	NA
	2	NA	NA	NA	NA	NA
[Co(Hdmg) ₂ (4PA)(SCN)]	10	S	S	NA	NA	NA
	8	S	S	NA	NA	NA
	6	S	S	NA	NA	NA
	4	R	R	NA	NA	NA
	2	R	R	NA	NA	NA

H₂dmg = dimethylglyoxime, A= aniline, PA= 4-nitroaniline, S = Susceptible, R = Resistant, NA= Not applicable

Table 6: Minimum Bactericidal Concentration of Ligands and its Complexes

Compounds	Bacteria used					
	Conc. ($\mu\text{g/mL}$)	MRSA	<i>Staphylococcus aureus</i>	<i>Streptococcus pneumoniae</i>	<i>Bacillus subtilis</i>	<i>Salmonella typhi</i>
A	10	S	S	S	NA	S
	8	R	R	S	NA	S
	6	R	R	R	NA	S
	4	R	R	R	NA	S
	2	R	R	R	NA	R
PA	10	NA	NA	S	NA	NA
	8	NA	NA	S	NA	NA
	6	NA	NA	R	NA	NA
	4	NA	NA	R	NA	NA
	2	NA	NA	R	NA	NA
H ₂ dmg	10	NA	NA	NA	NA	NA
	8	NA	NA	NA	NA	NA
	6	NA	NA	NA	NA	NA
	4	NA	NA	NA	NA	NA
	2	NA	NA	NA	NA	NA
[Co(Hdmg) ₂ (A)(SCN)]	10	NA	NA	NA	NA	S
	8	NA	NA	NA	NA	S
	6	NA	NA	NA	NA	S
	4	NA	NA	NA	NA	S
	2	NA	NA	NA	NA	S
[Co(Hdmg) ₂ (4BrA)(SCN)]	10	S	S	NA	S	S
	8	R	S	NA	S	S
	6	R	R	NA	S	R
	4	R	R	NA	R	R
	2	R	R	NA	R	R
[Co(Hdmg) ₂ (2NA)(SCN)]	10	S	S	NA	NA	NA
	8	S	S	NA	NA	NA
	6	R	R	NA	NA	NA
	4	R	R	NA	NA	NA
	2	R	R	NA	NA	NA
[Co(Hdmg) ₂ (4NA)(SCN)]	10	NA	NA	NA	NA	NA
	8	NA	NA	NA	NA	NA
	6	NA	NA	NA	NA	NA
	4	NA	NA	NA	NA	NA
	2	NA	NA	NA	NA	NA
[Co(Hdmg) ₂ (4PA)(SCN)]	10	S	S	NA	NA	NA
	8	S	S	NA	NA	NA
	6	R	S	NA	NA	NA
	4	R	R	NA	NA	NA
	2	R	R	NA	NA	NA

H₂dmg = dimethylglyoxime, A= aniline, PA= 4-nitroaniline, S = Susceptible, R = Resistant, NA= Not applicable

CONCLUSION

In this study, the synthesis of the glyoximate complexes using aniline and its derivatives has been described. The complexes gave sharp melting points. Molar conductivity results of most of the complexes indicated that they are non-electrolytes

[Co(Hdmg)₂(4BrA)(SCN)]. The complexes showed various colours which include dark brown, black, yellowish brown, brown, and red. This is typical of transition metal complexes. Most of the complexes were either soluble or slightly soluble in the solvents used. Infrared studies indicate that the ligands

coordinated through the nitrogen atom of the glyoxime group to the metal ions. The results of the antimicrobial study showed that the

complexes have more potent activities than the free ligands. Hence, complexation increases the antimicrobial activity.

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