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Copper(II) mixed-ligand complexes containing 1, 10-phenanthroline, adenine and thymine: Synthesis, characterization and antibacterial activities

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ABSTRACT

New copper complexes, $[Cu(phen)_2(Thy)]2Cl$ and $[Cu(phen)_2(Ad)]2Cl$ (phen = 1,10-phenantroline, Ad (Adenine, a purine nucleobase) and Thy (Thymine, a pyrimidine nucleobase)), were synthesized and characterized by atomic absorption spectroscopy (AAS), conductivity measurement, UV-visible and infrared (IR) techniques. The complexes were tested for their antimicrobial activity against two gram positive and two gram negative bacterial strains. The results of *in vitro* antimicrobial activities were compared with the commercially available antimicrobial agents (ciprofloxacin and chloramphenicol). This comparative study has demonstrated that $[Cu(phen)_2(Thy)]2Cl$ inhibited the growth of methicillin resistant *Staphylococcus aureous* (MRSA), *Escherichia coli* (*E. coli*) and *Klebsiella pneumoniae* (*K. pneumonia*) better than chloramphenicol by 11.25%, 19.41% and 25.35%, respectively. It also showed better activities than ciprofloxacine on MRSA and *K. pneumoniae* by 2.50% and 12.13%, respectively. Similarly, $[Cu(phen)_2(Ad)]2Cl$ demonstrated better inhibitions than chloramphenicol against MRSA, *E. coli* and *K. pneumoniae* by 11.24%, 2.48% and 9.06%, respectively. Therefore, after in vivo cytotoxicity investigations, these complexes could be considered as potential antimicrobial agents.

Capsule Summary: Copper complexes i.e., $[Cu(phen)_2(Thy)]2Cl$ and $[Cu(phen)_2(Ad)]2Cl$ were synthesized and characterized along with antimicrobial acivities evaluation. In comparison to standard antimicrobial agents, the synthesized complexes showed promising antimicrobial acivities.

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INTRODUCTION

The rapid increase in the number of multidrug-resistant bacteria is fast becoming a global concern (Henderson, 2006). Thus, the discovery of novel active compounds against new targets is a matter of urgency. The conventional approach to address this impulse employing materials originating from wild growing material have shortened the life span of the sources. This problem has magnetized attention of the scientific community in general to consider and investigate transition metal compolexes as alternative solutions for this problem(Bruijnincx and Sadler, 2009; Vela et al., 2011; Mishra et al., 2012; Suntharalingam et al., 2013,

Patil et al. 2015). From this perspective, so many studies have been done on the syntheis, structure, chemical properties and antimicrobial activity of several metal complexes (Rafique et al., 2010; Motswainyana and Ajibade, 2015). The study results demonstrated the therapeutic and diagnostic properties of transition metal complexes which have attracted considerable attention, leading to their application in many areas of modern medicine. In this regard, they served as anticancer (Clair et al., 2016), antinfection agents (Mukherjee et al., 2013) and anti-inflammatory (Weder et al., 2002). These outcomes encouraged the researchers to fine tune the properties and actions of the metal complexes by coordinating the metal ions with a variety of ligands (Rafique et al., 2010; Buchtik et al., 2011; Devi and Batra, 2015; Motswainyana and Ajibade, 2015). This is because; the ligands have the ability to tune on the chemical properties of metal ions (Sears et al., 2010; Wilkins, 1974). This include stabilization of different oxidation states[Boyer et al., 2010) and modulation of the solvophilicity, electrophilic and nucleophilic properties of the metal (Goo et al., 2015; Tolman, 1977).

Copper is one of the metals acting as an essential trace element involved in cellular respiration, antioxidant defense, neurotransmission, connective tissue biosynthesis and cellular iron metabolism (Babu et al., 2007; Culotta, 2010). Moreover, several investigations provide evidence that copper ions are capable of interacting directly with nuclear proteins and DNA, causing site-specific damage (Kang et al., 2004, Gou et al., 2015). In addition**,** it has been reported that copper compounds delay cell-cycle progression and increase cell death in different cell cultures (Paul et al., 2014). Copper (II) ions binding to specific sites can modify conformation of proteins, polynucleotides, or membranes. Cu (II) binds to DNA with high degree of affinity and thus promotes DNA oxidation (Chaviara et al., 2005; Marzano et al., 2006; Marzano et al., 2009). From this perspective copper (II) complexes have become the targets in addressing certain cancer problems **(**Gou et al., 2015). In this regard, complexes of copper containing 1, 10-phenanthroline (phen) as a ligand mixed with other types of ligands stirred great interests since they exhibit numerous biological activities such as antitumor, antibacterail (Zoroddu et al., 1996), and anti-candida activity (Ranford, 1993).

1,10-phenanthroline has a rigid framework and possesses a superb ability to chelate many metal ions via its two nitrogen centers. The resulting complexes show potential for various applications due to their high charge transfer mobility, among other attractive properties (He et al., 2009). Although a number of copper (II) complexes containing phenanthroline mixed with other ligands previously appeared in the literature (Dede et al., 2009; Jennifer and Muthiah, 2014; Ganeshpandian et al., 2014; Rajarajeswari et al., 2014), there is still a gap to design and study new ones. In view of the importance of such complexes, we describe here the synthesis, characterizations and the biological (antibacterial) activities of mixed-ligand complexes of Cu (II) containing 1,10-phenantroline adenine (Ad) and thymine (Thy) (purine and pyrimidine nucleobases, respectively). The purpose of this investigation is to let adenine and thymine get coordinated with the metal ion through their Lewis basic nitrogen to form three dimentional regid structure. Consequently, the complexes present the adenine and thymine along with 1, 10-phenanthroline so that the counter nucleobase residue of the genetic material in microbes recognizes and interacts in a certain fashion. The latter phenomenon ultimately is expected to result in strong antimicrobial activity of the complex.

MATERIAL AND METHODS

Chemical, reagents and instrumnation

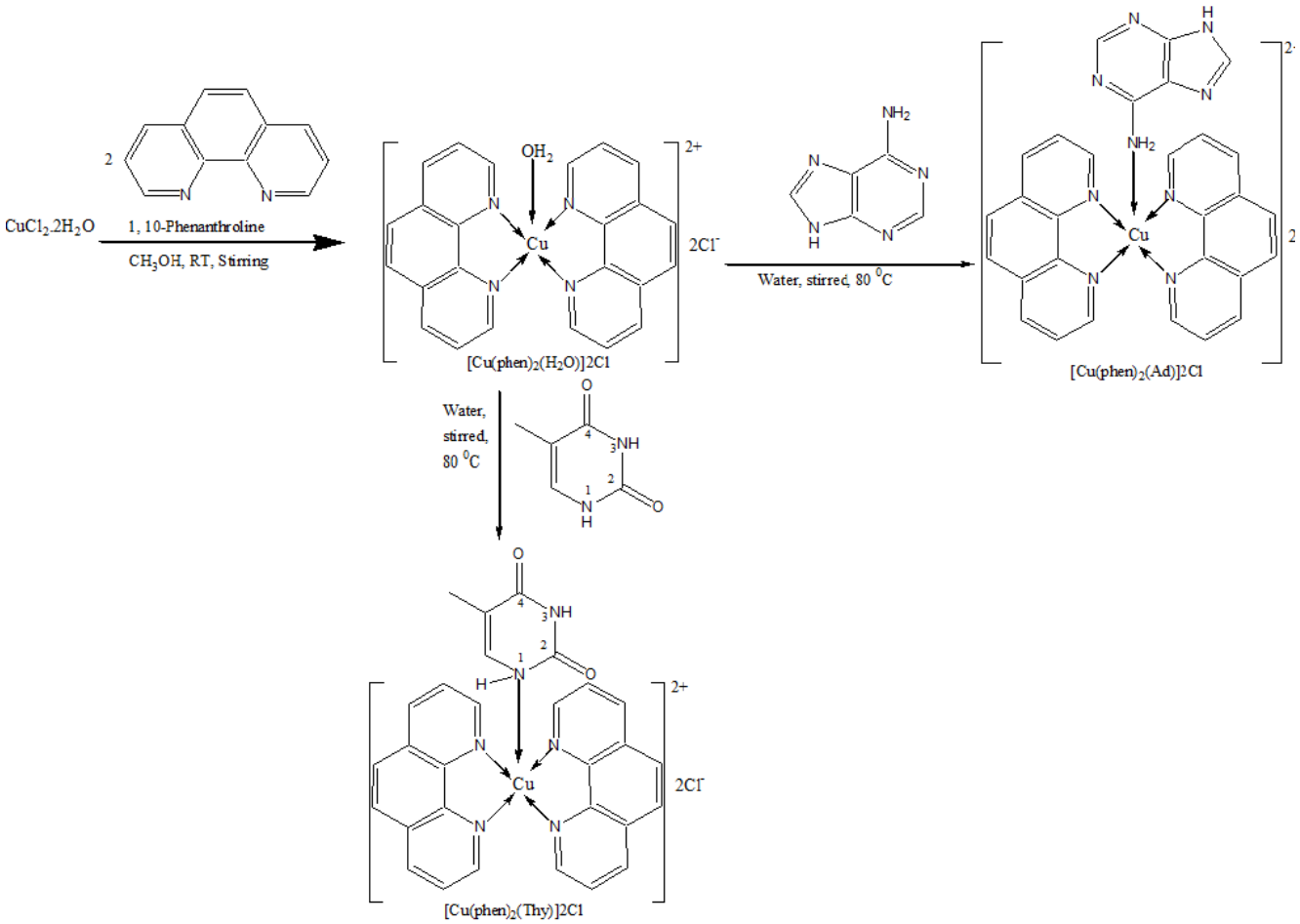
All the chemicals used were either of analytical grade or chemically pure grade. The electronic absorption spectra were measured using Sanyo SP65 UV/VIS Spectrophotometer in the 200-800 nm regions. IR data were obtained using AVATAR 330 FT-IR, Thermo Nicolet spectrophotometer in the range of 4000-400 cm^{-1}. Quantitative analysis of copper ion content of the sample complex was determined using Analytik Jena nov AA300 model atomic absorption spectrophotometer. The melting point of each complex was determined by STONE, STAFFORDSHIRE, ST15 OSA, UK digital melting point apparatus. The conductance of each complex was measured by JENWAY 4200 conductivity meter at room temperature.

Synthesis of the metal complexes

Synthesis of $[Cu(Phen)_2(H_2O)]2Cl$: $[Cu(Phen)_2(H_2O)]2Cl$ was prepared by adding dropwise a solution of 1,10-phenanthroline monohydrate (2 gm, 10 mmol) in 30 mL of methanol to a solution of $CuCl_2 .2H_2O$ (0.87 gm, 5 mmol) in 30 mL of methanol while stirring magnetically at room temperature. A greenish blue homogeneous solution was obtained (Yield: 2.08 gm (80.3%)).

Synthesis of $[Cu(Phen)_2(Ad)]2Cl$ and $[Cu(Phen)_2(Thy)]2Cl$: $[Cu(phen)_2(H_2O)]2Cl$ (0.624 gm,1mmol) was dissolved in 50 mL distilled water. Being magnetacally stirred in an oil bath a hot solution of adenine (1 mmol) in 50 mL distilled water was slowly added. The mixture was refluxed for 6 hours at 80˚C. Green homogeneous solution was obtained. The solvent was removed in vacuum and medium see green powder was collected. Finally, the complex was washed with methanol three times and dried in vacuum desiccator over anhydrous $CaCl_2$. The purity of the metal complexes was checked by TLC (Yield: 0.573 gm, 74.7%).

Synthesis of $[Cu(Phen)_2(H_2O)(Thy)]_2Cl$: To a solution of $[Cu(phen)_2(H_2O)2]Cl_2$ (0.624 gm,1mmol) in 50 mL distilled water in 250 mL double necked round bottomed flask magnetically stirred in oil bath a hot solution of thymine (0.148 gm, 1 mmol) in 50 mL distilled water was slowly added drop wise from burette and the reaction mxture was refluxed for 5 hours at 80 ^{0}C. A green homogeneous solution was formed. The solvent was removed using rotary evaporator and spring green fine powder was collected and



Scheme 1: Synthesis path of the complexes

washed. The complexes kept in desiccators until use. Yield: 0.589 gm (83.1%). The strategy of the synthesis is indicated in Scheme 1.

Antibacterial activity testing

The *in vitro* antibacterial activity of the salt, ligands and complexes were tested using Agar diffusion method. Microorganisms used in this study were two strains of gram-positive: (*Staphylococcus aureous* and Methicillin Resistant *Staphylococcus aureous* (clinical isolate)) and two strains of gram-negative (*Escherichia coli* (ATCC255922), and *Klebsiela pneumoniae* (ATCC986605)). These bacterial strains were maintained in the appropriate blood agar base at 4 ^{0}C until use. Antibiotic discs (Ciprofloxacin 5 µg, Chloramphenicol 30 µg) were used as reference. The minimum inhibitory concentration against each bacterium was determined by preparing aqueous solutions of different concentrations of the complexes (200 µg/ml, 300 µg/ml, 400 µg/ml, 500 µg/ml, 600 µg/ml, 800 µg/ml and 1 mg/ml). The antibacterial tests were carried out at the Amhara Regional Health Research Laboratory Center, Bahir Dar, Ethiopia.

RESULTS AND DISCUSSION

Characterization of the metal complexes

The complexes are colored and stable in air. They are insoluble in common organic solvents but soluble in ethanol, methanol and DMSO. Also highly soluble in water. The appearance, melting poins, elemental estimation, yield and molar conductivity data of all the complexes are shown in Table 1.

Molar conductance of the metal complexes

The conductance measurements, recorded for 10^{-3}M solutions of the metal complexes in water listed in Table 1 provides information about the presence of two chloride ions per copper ion which supports the chloride estimation expirment result. The data shows that all the complexes are 1:2 electrolytes (Bard et al., 1980). However, the molar conductance shows a slight decreasing order as the molar mass of the cation is increasing as the mobility decreases. This is because the speed of the mobility of the cations as the result of the kinetic energy imparted by the electric field from measurement instrument changes in a

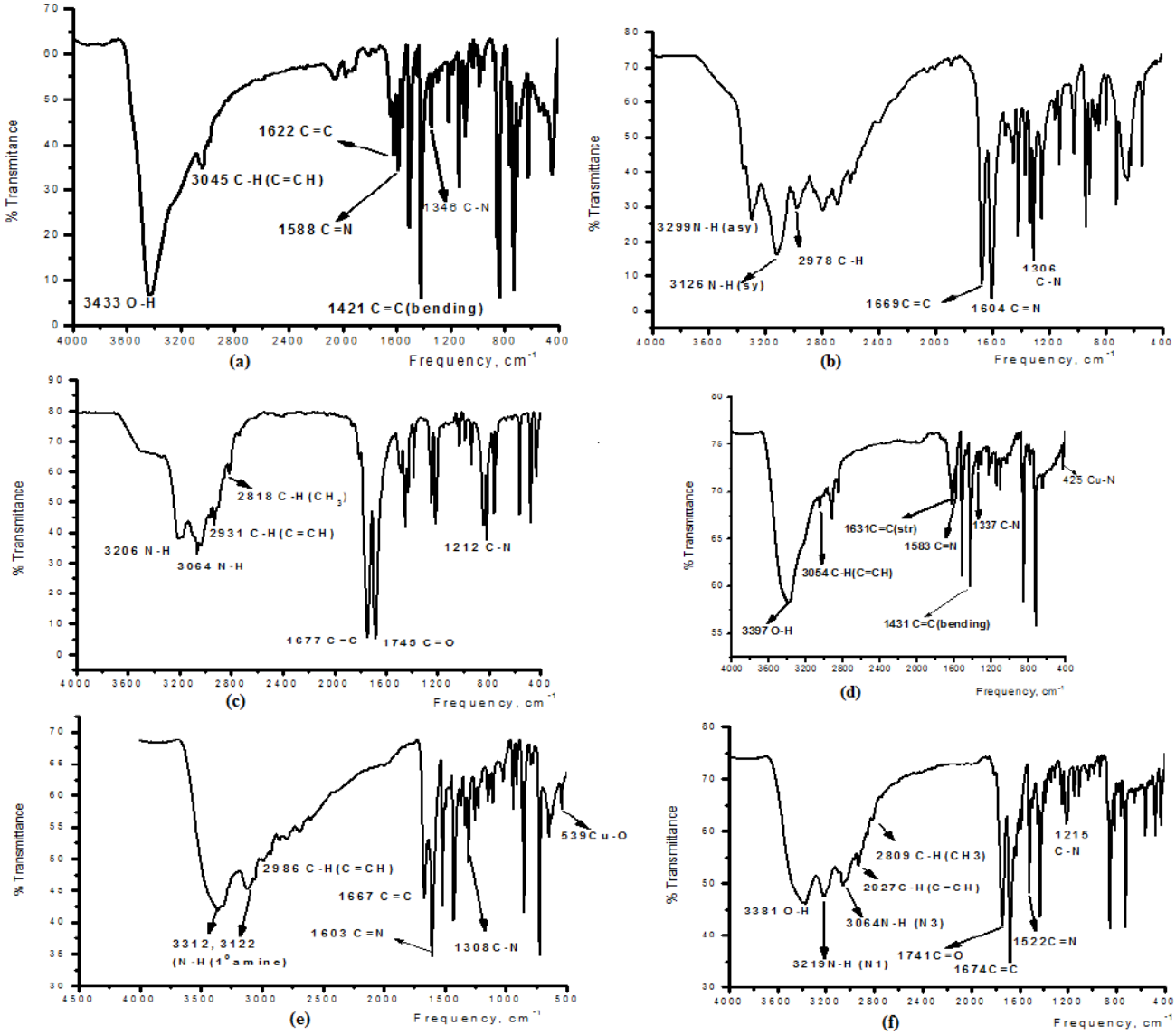


Fig. 1: IR spectra of a) 1, 10-Phenanthroline, b) Adenine, c) Thymine, d) $[Cu(phen)_2(H_2O)]2Cl$, e) $[Cu(phen)_2(Ad)]2Cl$ and f)$[Cu(phen)_2(Thy)]2Cl$

decreasing order $[Cu(phen)_2(H_2O)]2Cl$, $[Cu(phen)_2(Ad)]2Cl$, $[Cu(phen)_2(Thy)]2Cl$, follwoing the increasing molecular mass(Atkins, 1994). This phenomenon is a strong evidence for the coordination of the ligands to the metal.

Infrared spectra of the complexes

Important characteristic IR bands of the ligands and all Cu (II) Complexes are given in Table 2. The IR spectra of the complexes (Figure 1) demonstrate that all the ligands are coordinated to the metal. The characteristic $\nu_{(C=C)}$ (1627 cm^{-1}) of free phenanthroline remains unchanged in $[Cu(phen)_2(H_2O)]Cl_2$ and down shifted in $[Cu(phen)_2(Ad)]2Cl$ to 1600 cm^{-1}, in $[Cu(phen)_2(Thy)]2Cl$ to 1623 cm^{-1} indicating electron cloud is expanded to the nucleobases (adenine and thymine). However, its characteristic $\nu_{(C=N)}$ (1588 cm^{-1}) in its free form is down shifted (to 1582 cm^{-1}, 1569 and 1520 cm^{-1}) indicating the decrease in the bond order of C=N when coordinated to Cu(II).

The characteristic doublate $\nu(NH_2)$ (3297 cm^{-1} and 3120 cm^{-1}) of adenine are also observed in $[Cu(phen)_2(Ad)]Cl$ being up shifted to 3310 cm^{-1} and 3122 cm^{-1} indicating adenine is coordinated through the primary amine ($-NH_2$) rather than through its ring (NH). This fact is supported by the nearly unchanged frequency appearance of its characteristic ring ν(NH) at 3356 cm^{-1}.

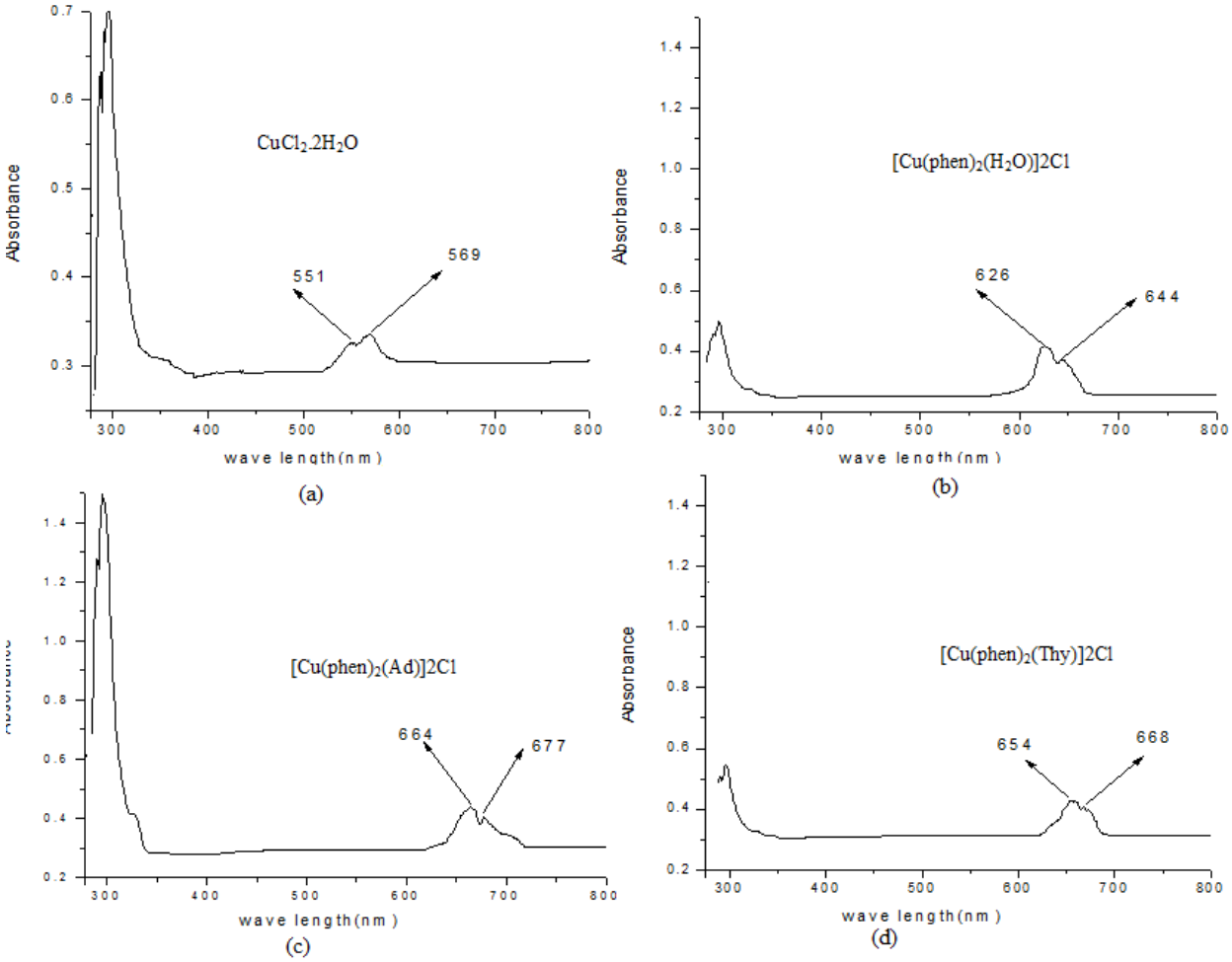
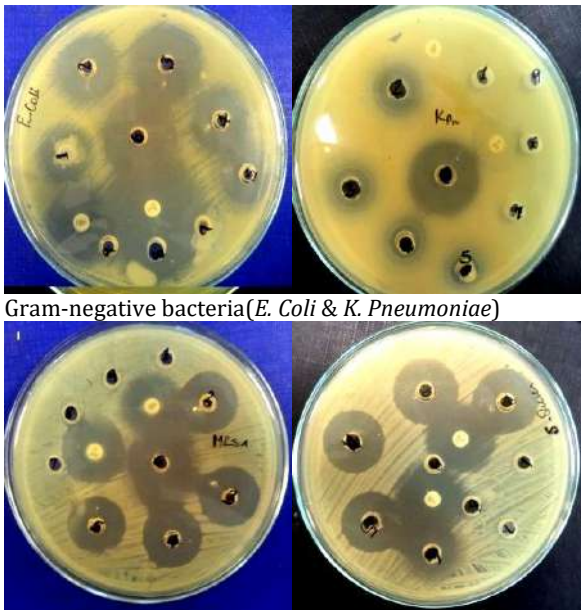


Fig. 2: UV spectra of a) $CuCl_2.2H_2O$, b)$[Cu(phen)_2(H_2O)]2Cl$, c)$[Cu(phen)_2(Ad)]2Cl$ and d) $[Cu(phen)_2(Thy)]2Cl$

The existence of thymine in the complexes is also bestowed by its two characteristic ring $\nu_{(N3H)}$ (3356 cm^{-1}) signaled being obsecured with $\nu_{(OH)}$ of coordinated water and $\nu_{(N1H)}$ (3198 cm^{-1}) up shifted to 3209 cm^{-1}. This confirms that thymine is coordinated to Cu(II) through its N1H(Scheme 1). In addition to this, the coordination of thymine is confirmed by its other characteristic ν(CH)(CH_3) (2933 cm^{-1}) and $\nu_{(C=O)}$ (1735 cm^{-1}) which appeared at 2932 cm^{-1} in $[Cu(phen)_2(Thy)]2Cl$ and 1739 cm^{-1} in both complexes, respectively.

Electronic spectra of the complexes

The electronic spectra of the ligands and complexes are displayed in Table 3. The coordination of the ligands to the metal is demonstrated by the shifts in the maximum absorption wave lengths corresponding to ligand centered π→π*(C=C), π→π*(C=N), n→π*(C=N) as well as metal centered energy states $^2B_{1g} \rightarrow {}^2A_{1g}$ and $^2B_{1g} \rightarrow {}^2B_{2g}$ transitions.



Gram-negative bacteria(*E. Coli* & *K. Pneumoniae*)

Gram-positive bacteria(MRSA & *S. Aureus*)

Fig. 3: Biological Activity of copper salt, Ligands, Cu(II)

Table 1: Appearance, melting point, elemental estimation, molar conductivity data of the metal complexes

Complex (color)	Melting point (^{0}C)	Yield (%)	Elemental estimation (%) Cu	Cl	Λ_M (S cm^2 mol^{-1})
$[Cu(phen)_2(H_2O)]2Cl$ (Medium spring green)	325-327	80.3	12.84 (12.57)	14.36(14.24)	138.46
$[Cu(phen)_2(Ad)]2Cl$ (Medium see green)	246	74.3.	10.09 (9.98)	11.28(11.18)	126.08
$[Cu(phen)_2(Thy)]2Cl$ (Spring green)	253	83.1	10.23(9.98)	11.14(10.96)	124.23

Table 2: Characteristic infra-red frequencies of the ligands and their complexes with Cu(II) (cm^{-1})

Ligands/ complexes	$\nu_{(OH)}(H_2O)$ cm^{-1}	$\nu_{(NH2)}$ cm^{-1}	$\nu_{(NH)}$ cm^{-1} (ring)	$\nu_{(CH)}(CH_3)$ cm^{-1}	$\nu_{(CH)}$ (C-=C) cm^{-1}	$\nu_{(C=C)}$ cm^{-1}	$\nu_{(C=N)}$ cm^{-1}	$\nu_{(C-N)}$ cm^{-1}	$\nu_{(C=O)}$ cm^{-1}
1, 10-phenanthroline hydrate	3424				3041	1627	1588	-	
Adenine		3297, 3120	3356		2972	1667	1511	1254, 1331	
Thymine		-	3356, 3198	2933	3070	1677		1214	1735
$[Cu(phen)_2(H_2O)]2Cl$	3355	-			3050	1627	1582	1306	
$[Cu(phen)_2(Ad)]2Cl$	3362	3310, 3122	3352	-	3048, 2976	1600, 1673	1569, 1520	1303, 1252	
$[Cu(phen)_2(Thy)]Cl$	3376	-	3209	2932	3056	1623 1681	-	1237	1739

Table 3: Electronic spectra of the ligands and the complexes

Complexes	Band position, λ_{max} (nm)	Assignments
$CuCl_2.2H_2O$	292, 569 , 551	LMCT* , $^2B_{1g} \rightarrow {}^2A_{1g}$, and $^2B_{1g} \rightarrow {}^2B_{2g}$
$[Cu(Phen)_2(H_2O)]2Cl$	294, 644, 626	($\pi \rightarrow \pi^*$(C=N), $^2B_{1g} \rightarrow {}^2A_{1g}$, and $^2B_{1g} \rightarrow {}^2B_{2g}$
$[Cu(Phen)_2(Ad)]2Cl$	297, 677, 664	($\pi \rightarrow \pi^*$(C=N), $^2B_{1g} \rightarrow {}^2A_{1g}$, and $^2B_{1g} \rightarrow {}^2B_{2g}$
$[Cu(Phen)_2(Thy)]2Cl$	296, 668, 654	$\pi \rightarrow \pi^*$(C=O), $^2B_{1g} \rightarrow {}^2A_{1g}$, and $^2B_{1g} \rightarrow {}^2B_{2g}$

*LMCT=Ligand to metal charge transfer

In $[Cu(Phen)_2(H_2O)_2]Cl_2$, the absorptions occurred at 294 nm, 644 nm and 626 nm are assigned for $\pi \rightarrow \pi^*$(C=N), $^2B_{1g} \rightarrow {}^2A_{1g}$, and $^2B_{1g} \rightarrow {}^2B_{2g}$ transitions, respectively. This increase in the absorption wave length compared to the salt may be due to the increase in the axial Cu-OH_2 bond length following the formation of shorter and stronger equatorial Cu-N bonds with the strong field phenanthroline. Consequently, the energy gap between d_z^2 and d_{xy} orbitals is decreased which narrows the gap between $^2B_{2g}$ and $^2A_{1g}$ energy states (Housecroft and Sharpe, 2005; Missler and Tarr, 2004). Up on coordination of adenine, $[Cu(phen)_2(Ad)]2Cl$, the absorptions are shifted to 297 nm, 677 nm and 664 nm, respectively. This further increase in the maximum absorption wave lenthes is due to the further increase in the axial Cu-N bond with adenine due to steric reasons (Scheme 1) further decreases the gap between d_z^2 and d_{xy} that decreases the energy gap between $^2B_{2g}$ and $^2A_{1g}$ energy states more than the case of $[Cu(Phen)_2(H_2O)]2Cl$. In $[Cu(phen)_2(Thy)]2Cl$, the absorption wave lengthes are blue shifted by 9 and 10 nm to 296 nm, 668 nm and 654 nm

compared with $[Cu(phen)_2(Ad)]2Cl$. This is because of the formation of axial shorter and stronger Cu-N with thymine where N is in the ring which is influenced by the π-system which gives it π-acidity. On the basis of the data, square pyramidal geometries have been proposed for all complexes.

Screening for antibacterial activity of the ligands and their copper complexes

Antimicrobial acitivity of the ligands and their complexes were investigated against two gram positive (Methicilin resistant *S. aureus* and *S. aureus*) and two gram negative bacteria (*E. coli* and *K. pneumoniae*) on Mueller-Hinton agar, by well-diffusion method using water and methanol as solvents.

Water and methanol exhibited no activity against all of the bacteria tested. The free 1,10-phenanthroline showed the highest antibacterial activities among the freee ligands. Due to its planarity and extended conjugation, 1, 10-phenanthroline is able to intercalate with double strands of the DNA and forming π-π interactions with base pairs of DNA (Table 4, Figure 3). However, thymine and adenine showed no antibacterial activity againest the tested bacteria. The metal salt, $CuCl_2.2H_2O$, showed no effect with the exception of *E. coli* with (20 ± 0.82 mm inhibition zone (Figure 3).

In general, the complexes are all active against the tested bacteria showing a range of inhibition zone 18-30 mm (Table 4). $[Cu(phen)_2(Ad)]2Cl$ demonstrated higher activity than chloramphenicol against Methicilin resistant *S. aureus*, *E.coli* and *K. pneumoniae*. $[Cu(phen)_2(Thy)]2Cl$ showed higher activity than chloramphenicol against Methicilin resistant *S. aureus* and *E. coli* and greater than chloramphenicol and ciprofloxacin against *K. pneumoniae*. The percent activity indexes of the compounds against the reference antibiotics demonstrated significant comparative activity (Table 5). It can be obsereved that these compounds are potential candidates in inhibiting *K.pneumoniae* compared to ciprofloxacine (Table 5a). Moreover, they inhibited MRSA, *E. Coli* and *K.pneumoniae* much better than chloramphenicol (Table 5b).

Minimum inhibitory concentration (MIC)

Table 4: Antibacterial activity of metal salt, ligands, metal complexes and reference antibiotics

Compound tested	Antimicrobial activity (mean IZ diameter(mm) ± SD)			
	S. aureus	MRSA	*E. coli*	*K. pneumoniae*
1	0 ± 0	0 ± 0	20.00 ± 0.82	0 ± 0
2	24.33±0.47	23.67 ± 0.47	23.00 ± 0.82	18.33 ± 0.94
3	22.00 ± 0	26.00 ± 0.82	27.00 ± 0.47	18.33 ± 0.47
4	21.00 ± 0.82	26.67 ± 0.47	32.67± 0.47	22.00 ± 0.82
5	20.00 ± 0.82	28.67 ± 0.47	29.67 ± 0.47	28.33 ±0.94
6	0 ± 0	0 ± 0	0 ± 0	0 ± 0
7	0 ± 0	0 ± 0	0 ± 0	0 ± 0
8	0 ± 0	0 ± 0	0 ± 0	0 ± 0
9	0 ± 0	0 ± 0	0 ± 0	0 ± 0
S1	26.67 ± 0.94	26.00 ± 0.82	34.67 ± 0.94	19.33 ± 0.47
S2	25.67 ± 1.25	23.67 ± 0.47	26.33 ± 0.94	16.67 ± 0.47

MRSA= Methicilin resistant S. *Aureus,* IZ = inhibition zone. SD = Standard deviation, 1 = $CuCl_2.2H_2O$, 2 = $[Cu(phen)_2(H_2O)]2Cl$, 3 = $[Cu(phen)_2(Ad)]2Cl$, 4 = $[Cu(phen)_2(Thy)]2Cl$, 5 = 1,10-phenantroline, 6= adenine, 7 = thymine, 8 = methanol, 9 = distilled water, S_1 = Ciprofloxacin, S_2 = Chloramphenicol.

Table 5: The activity (%) index data of the complexes against the tested microbes compared to: a) ciprofloxacine, b) chloramphenicol

Compounds	*S. aureus*	MRSA	*E. coli*	*K.pneumoniae*
		(A)		
$[Cu(phen)_2(Thy)]2Cl$	78.74	102.57	94.23	113.81
$[Cu(phen)_2(Ad)]2Cl$	82.49	100	77.88	94.83
		(B)		
$[Cu(phen)_2(Thy)]2Cl$	81.81	112.67	124.08	131.97
$[Cu(phen)_2(Ad)]2Cl$	87.7	109.84	102.54	109.96

Table 6: Minimum inhibitory concentration assay of [Cu(Phen)$_2$(Ad)]2Cl against bacterial pathogens

Microbes	Growth observation for each Conc. (µg/mL)						
	100	200	300	400	600	800	1000
E. coli	●	X	X	X	X	X	X
MRSA	●	●	X	X	X	X	X
S. aurous	●	X	X	X	X	X	X
K. pneumonia	●	●	●	X	X	X	X

Note: ● = Bacterial Growth, X = No Bacterial Growth

Table 7: Minimum inhibitory concentration assay of [Cu(Phen)$_2$(Thy)]2Cl against bacterial pathogens

Microbes	Growth observation for each Conc. (µg/mL)						
	100	200	300	400	600	800	1000
E. coli	●	●	X	X	X	X	X
MRSA	●	X	X	X	X	X	X
S. aurous	●	X	X	X	X	X	X
K. pneumonia	●	●	●	●	●	X	X

Explanation as given in Table 6

[Cu(Phen)$_2$(Ad)]2Cl shows high antibacterial activity on the tested bacterial strains except for *K. pneumoniae* with a MIC value of 300 µg/mL to 1 mg/mL . When diluted to 200 µg/mL it shows activity against *E. coli* and *S. aureus*. Below 100 µg/mL bacterial strains it showed no observable growth (Table 6).

[Cu(Phen)$_2$(Thy)]2Cl showed significant antibacterial activity on tested bacterial pathogens except for *K. pneumoniae* with a MIC value of 200 µg/mL to 1 mg/mL. When diluted to 200 µg/mL it showed activity against Methicilin resistant *S. aureus* and *S. aureus*. However, below 100 µg/mL [Cu(Phen)$_2$(Thy)]2Cl bacterial growth was observed (Table 7).

CONCLUSIONS

Two new Copper-mixed ligand complexes of copper(II) containing 1,10-phenanthroline, adenine and thymine as ligands have been synthesized and characterized by elemental analysis using atomic absorption spectroscopy and chloride estimation to determine the amount of copper and chlorine, respectively. IR and visible spectroscopy analyses were employed to confirm the coordination. Conductance measurements were also used to determine the iconicity of the complexes. All of these investigations showed that two 1, 10-phenantroline and one adenine molecules are coordinated to the first complex. In the second complex, two 1, 10-phenanthroline and one thymine molecules are coordinated. In all cases, two chloride ions are found as counter anions. Antimicrobial studies of these complexes against four bacteria show that there is increased activity of the metal ions upon coordination to these ligands. It is speculated that, after in vivo experiments, these complexes could be considered as potential drugs to prevent the multiplication of all of the four bacteria.

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