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Synthesis, Spectroscopic Characterization, Antibacterial and Short term *in vitro* cytotoxicity studies of copper(II)complexes of a tridentate N,N,S donor ligand 2-benzoylpyridinen(4),N(4)-(N,N-diethyln-Phenylamine-2,2'-diyl), Hbptsc^2.

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ABSTRACT

A tridentate N,N,S donor ligand, 2-Benzoylpyridine–N(4),N(4)-(N,N-diethylN-Phenylamine-2,2'-diyl) thiosemicarbazone (Hbptsc^2) was synthesised and characterized by elemental C,H,N and various spectral methods viz. UV-Vis, FT-IR, and ^{1}H NMR spectroscopy. Five Copper (II) complexes were synthesised and characterized by elemental CHN and spectral methods. All the complexes exist as non electrolytes evident from the low molar conductance values at room temperature and have the stoichiometry, [CuLX] where X= Cl^- (1), NO_3^- (2), SO_4^{2-} (3), N_3^- (4), SCN^- (5). The EPR spectra of the complexes in frozen DMF at 77K, show two g-values, $g_\parallel$ & $g_\perp$ indicating an axial spectra leading to four coordinated planar geometry. The antimicrobial studies of the copper (II) complexes were done following the agar-well diffusion method using streptomycin as positive control. The in *vitro* cytotoxicity studies of the complexes following the trypan blue exclusion method against the Dalton's Lymphoma Ascites (DLA) tumour cells extruded from the peritoneal cavity of mice show commendable activity against the tumor cells.

KEYWORDS: Thiosemicarbazone; 2-Benzoylpyridine; Copper (II) complexes; EPR; Antibacterial activity; Antitumour activity.

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INTRODUCTIO

Thiosemicarbazones, of heterocyclic ketones and their metal complexes have attracted a number of researchers due to their wide range of biological properties. These have the ability to undergo chelation with the first row transition metals bonding through sulphur and azomethine nitrogen atoms[1,2,3.] A variety of biological properties such as antitumor, antibacterial, anticancerogenic, antifungal, antioxidant and insulin mimetic activities have been reported[.4-12.] The presence of a third donor atom, like a nitrogen atom of a pyridine ring in the case of a heterocyclic ketone adds to the biological activity by creating a tridentate NNS system.[13,14] . The presence of a metal ion increases the activity and makes a significant contribution in overcoming the side effects of the organic parent compounds .[15.] Thiosemicarbazone is a polar ligand and its interaction with a charged metal ion results in a structure in which hydrophobic part of the molecule gets exposed outside making the entry of the complex inside a cell membrane feasible.

Thiosemicarbazone compounds are being developed extensively as their use against cancer. Their antitumor activity is very much dependent on the typology of tumour cells. The anti-leukemic effect of 2-formylpyridine thiosemicarbazone was first reported by Brockman *et al*[. 16] in 1956. The activity is found to be highly pronounced when the thiosemicarbazone gets attached through the 2-position of the heterocyclic system and the activity diminishes when the point of attachment is shifted further .to positions 3 or 4 presumably due to lower coordination ability.[17]

In this paper, we report the synthesis and characterisation, of an N,N,S-tridentate ligand **Hbptsc**[2] and its copper(II) complexes. The antimicrobial and cytotoxicity studies of these complexes have also been worked upon.

2. MATERIALS AND METHODS

2-Benzoyl pyridine(Aldrich), N-Phenyl Piperazine (Aldrich), copper (II) chloride, Copper(II) sulphate, Copper (II) Nitrate, NaN_3, and KSCN (E.Merck) were used as received. All the solvents were distilled before use.

Elemental C, H, N studies were carried out using Elementar Vario EL III analyzer. Infrared spectra were recorded on a Thermo Nicolet Avatar FTIR spectrometer as KBr pellets in the range 4000-400cm^{-1}. Electronic spectra were recorded in the 900-250nm range in a solution mode on a Varian Carry 5000 UV–VIS-NIR spectrophotometer. ^{1}H-NMR spectrum were obtained on a Bruker 400 Avance III FT NMR spectrometer using CDCl3 as the solvent and TMS as internal reference. The EPR spectra (X-Band) were recorded at Liquid Nitrogen Temperature, LNT (77K) in DMF using ESR-JEOL JAPAN operating at 9.52 GHz equipped with a liquid nitrogen cryostat. The spectrum was recorded with modulation amplitude of 0.05(0.1) mT and 100 kHz modulation frequency and the

field was calibrated using Mn marker. Magnetic susceptibility measurements were made at varying field strengths at room temperature using vibrating sample magnetometer. The PXRD diffraction studies were done using Bruker AXS D8 Advance diffractometer and the SEM studies done using Jeol 6390LV.

2.1. Synthesis of ligand, 2-Benzoylpyridine–N(4),N(4)-(N,N-diethyl N-Phenylamine-2,2'-diyl) thiosemicarbazone (Hbptsc^2)

The ligand, ***Hbptsc^2*** was prepared by the already reported method of J.Scovill et al [18]. Equimolar solutions of N(4)- Disubstituted thiosemicarbazide **(1g,** 5.52 mmol) dissolved in 10 ml hot methanol was treated with N-Phenylpiperazine (0.84ml, 5.52mmol) and 2-BenzoylPyridine (1.011g,5.52mmol) dissolved in 5 ml methanol and the resulting solution heated under reflux for 45 minutes at ~50°C. The solution was allowed to cool and left overnight forslow evaporation. Deep yellow micro crystals of ***Hbptsc^2***separated out in 65%yield. The compound was filtered, recrystallized from methanol, and dried over P_4O_{10} *in vacuo.*

^{1}H NMR ($CDCl_3$–TMS) δ (ppm): N (3) H, 13.794 s; C (1) H, 8.819 d; C(2) H, 8.807 d; C(3) H, 7.824 d; C(4) H, 7.820 d; C(8-12) 5 H, 7.27-7.80m, ; C(14-17)H, 4.286-3.296,d, C (18-23) H, 7.27-7.40m.

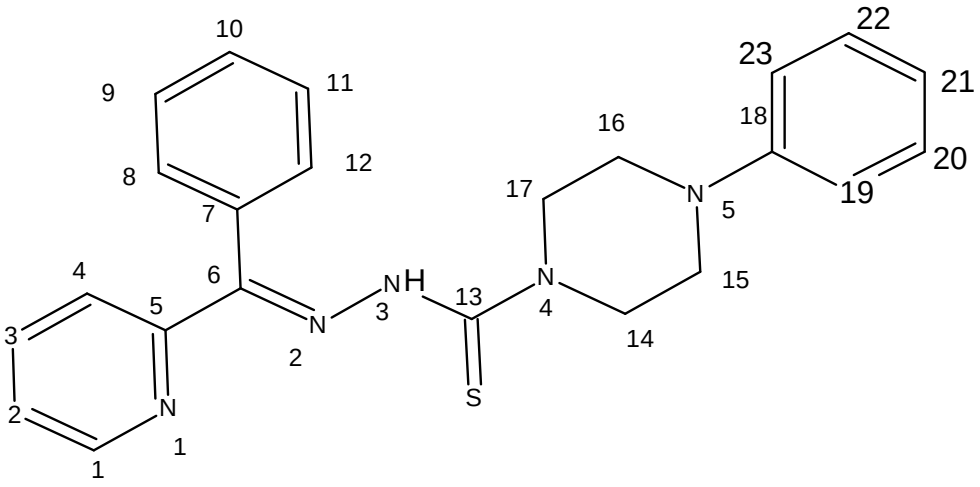


Fig.1, Structure of the ligand, Hbptsc^2

2.2 Synthesis of copper (II) complexes

Copper (II) complexes were prepared by refluxing an equimolar solution of the ligand **(Hbptsc^2)** (0.5 mmol, 0.200 gm) and the hydrated copper (II) salts in methanol for three hours. Azido and thiocyanato complexes were prepared by refluxing an equimolar mixture of ligand,**Hbptsc^2** and copper (II) acetate in hot methanol. To the refluxing solution was added sodium azide and Potassium thiocyanate respectively in the same molar proportions and refluxing

continued. The mixture was let for slow evaporation at room temperature. Dark green microcrystals of complexes ***1-5*** separated out, were collected, washed with ether and dried over P_4O_{10} in vacuo.

3. RESULTS AND DISCUSSION

The colours, elemental analyses, stoichiometries of **Hbptsc^2** and its complexes are presented in **Table.1**. Elemental analyses data shows a 1:1:1 coordination between metal ion, thiosemicarbazone, and heterocyclic base for all the complexes. The complexes show the stoichiometry **[Cu (bptsc^2)X]** for non electrolytes and are insoluble in common polar and non-polar solvents. The low molar conductance values at room temperature further confirm their non – electrolytic nature [19]. The room temperature magnetic susceptibility measurements are in the range 1.80-2.00B.M., very close to spin only values of 1.73 B.M. for a (d^9), configuration.

Table 1, Colors, partial elemental analyses data and magnetic moment of HL^2 and its copper(II)complexes

Compound	Formulae	Color	Composition%(Found/Calcd)			Magnetc Succeptibility (BM)
			Carbon (%)	Hydrogen (%)	Nitrogen (%)	
H bptsc^2	$C_{23}H_{22}N_5S$	Yellow	68.85) (69.00)	5.47 (5.50)	17.14 (17.50)	-
[Cu (bptsc^2)Cl] ***(1)***	$C_{23}H_{21}N_5SCuCl$	Green	55.23 (55.41)	4.14 (4.21)	13.90 (14.05)	1.86
[Cu (bptsc^2)NO3)] **(2)**	$C_{23}H_{21}N_7SCuO_3$	Green	51.44 (51.24)	4.01(3.89)	18.24 (18.19)	1.74
$[Cu_2(bptsc^2)_2(SO_4)].H_2O$ **(3)**	C46H44$N_{10}S_3$Cu2O	Green	53.01 (53.11)	4.40 (4.23)	13.39 (13.47)	1.82
[Cu bptsc2(N_3)] ***(4)***	$C_{23}H_{21}N_8SCu$	Green	54.90 (54.69)	4.51(4.16)	22.01(22.19)	1.94
[Cu bptsc^2(NCS)] ***(5)***	$C_{24}H_{21}N_6S_2Cu$	Green	55..70 (55.32)	4.40 (4.03)	16.42(16.10)	1.96

The ^{1}H-NMR spectra of **Hbptsc^2** in CDCl3 **is** shown in **Fig 2**. The spectrum reveals four signals for the pyridyl (δ, 8.8-7.8 ppm), a multiplet for the phenyl (δ,7.27-7.80 ppm) and a pair of doublets for the piperazine moieties (δ,4.2-3.2 ppm) while a multiplet for the phenyl substitution in the piperazine (δ, 7.4-7.2 ppm) moiety. The ^{3}NH proton shows a signal at *δ*, 13.79 ppm , due to the electronegative nitrogen atom attached to the proton. The phenyl group appears as a multiplet at about 7.45 ppm [19,20,21]. The multiplet due to the phenyl substituent attached to the piperazine moiety also appears at about the same position.

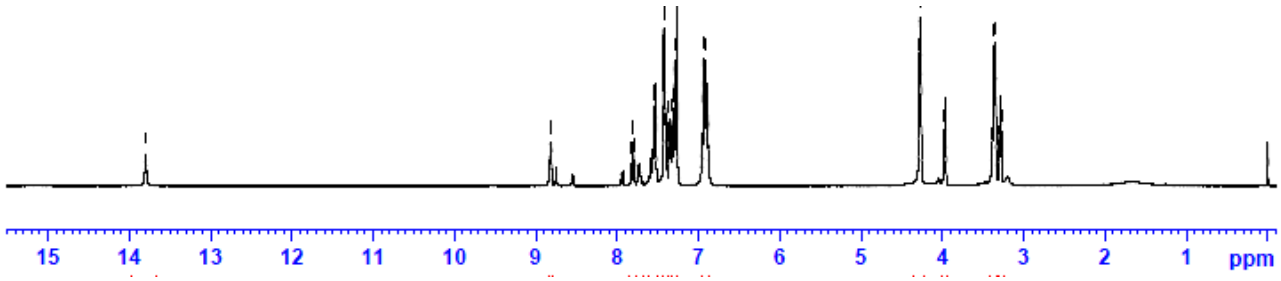


Fig.2, ^{1}H-NMR spectrum of the Hbptsc^{2} in $CDCl_3$

3.1 IR Spectra

The selected IR bands of ligand, Hbptsc^{2} as well as the copper (II) complexes are given in **Table 2.**

The **Hbptsc^{2}** shows a medium band at ~3050 cm^{-1}, due to the ν(^{3}NH) vibration and this vanishes in the spectra of complexes indicating ligand coordination with the metal ion in its deprotonated form. The band at 1593cm^{-1} due to ν(^{6}C=^{2}N) of **Hbptsc^{2}** undergoes subsequent shift to a greater wavenumber in complexes as a consequence of coordination through the azomethine nitrogen[22,23.] The bands at 1338 cm-1 due to ν(C=S_{str}) and bands at 870 cm-1 due to ν(C=$S_{,bend}$) in the free ligand **Hbptsc^{2}** shifts to lower energies in complexes, due to the coordination via the thiolate sulphur [24.]

The bands at 791 and 640 cm^{-1} as part of pyridine ring in-plane and out of plane bending vibrations in the ligand shifts to higher on complex formation due to the coordination via. Pyridine nitrogen. [25-27]. These spectral evidences, suggest a tridentate mode of coordination *via* the azomethine nitrogen, pyridyl nitrogen and thiolate sulphur.

Compound ***(1)*** shows a strong band at 326 cm^{-1} due to ν(Cu-Cl) bond vibrations and are consistent with the terminal chloro ligands. Compound (***2***) shows two strong bands appearing at 1297cm^{-1} & 1427 cm^{-1}(ν_5, ν1) with a separation of 130cm-1 characteristic of the terminally bonded monodentate nitrato group in the complex.

The sulfato complex Compound ***(3)*** may be characterised by four fundamental vibrations. Of these ν_1 appears with medium intensity at 923 cm^{-1} and medium band at 468, cm^{-1} due to ν_2. Weak split bands at 1190 and 1112 cm^{-1} corresponding to ν_3, and ν_4 does not appear in the spectra. Thus sulfato group in the complex is concluded to be a bridging bidentate ligand [27.] .

The azido compound **(*4*)** shows very strong bands at 2043 cm^{-1} due to the ν_a vibration of the azido group. Strong bands at 1386 cm-1, may be attributed due to the ν_s of the azido group. Medium bands at 648 cm^{-1}, corresponds to δ (N-N-N) vibrations of the azido complex of the ligand, while weak bands at 450,449 and 445 cm^{-1} is assignable to ν(Cu-N) of coordinating azide.[27].

The compound (***5) shows a*** strong band at 2083cm^{-1} corresponding to vibrations of ν(C=N) bond of the thiocyanato complex. The band at 787cm-^{1}, cm-1 applies to the ν(C=S), and the band at 481, may be assigned to δ(NCS) vibrations.

Table 2. IR spectroscopic assignments of *Hbptsc*^{2} and complexes

Compound	ν(NH)	ν (C=N)+ν (N=C)	ν (N─N)	ν (C=S)	δ(C=S)	δ(o.p)
Hbptsc^{2}	3050w	1593 m	1127 w	1339 m	870w	694w
[Cu(bptsc^{2})Cl] ***(1)***	-	1595 m	1123 w	1305 m	871w	699w
[Cu(bptsc^{2})(NO$_3$)] ***(2)***	-	1594 m	1122 w	1297 m	896w	696w
[Cu$_2$(bptsc^{2})$_2$(SO$_4$)].H$_2$O ***(3)***	-	1538 m	1112 w	1307 m	861m	685m
[Cu(bptsc^{2})N$_3$ ***(4)***	-	1597 m	1132 w	1305 m	876w	699w
[Cu(bptsc^{2})(NCS)] ***(5)***	-	1598 m	1155 w	1300 m	873w	690w

These facts suggest that the thiocyanate group is N-coordinated to the copper(II) complexes of ligand **Hbptsc^{2}**, [27].

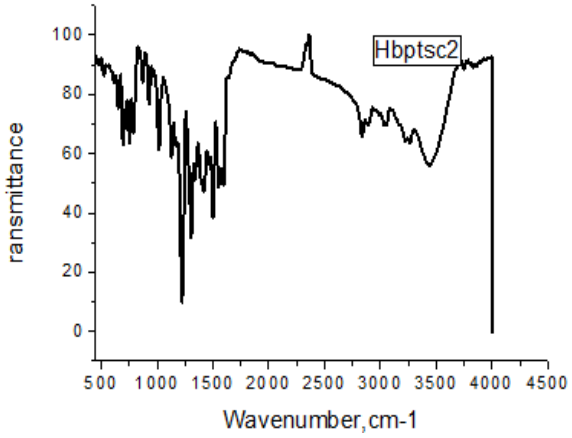


Fig 3. FTIR spectrum of the ligand,Hbptsc^{2}

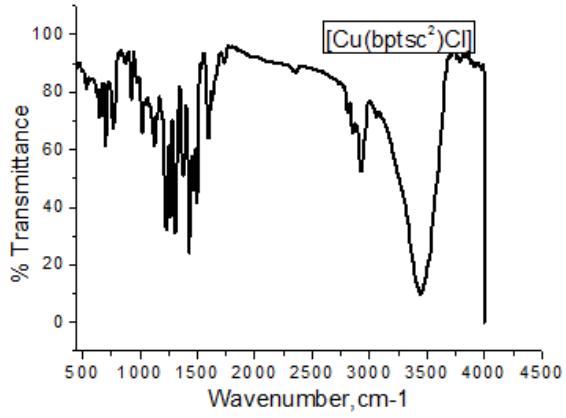
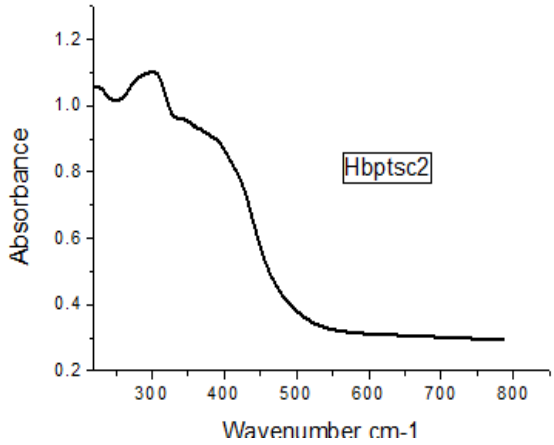


Fig 4. FTIR spectrum of the [Cu(bptsc^{2})Cl] *(1)*

3.2. Electronic spectra

Table 3. Shows the electronic spectral details of the **Hbptsc ^{2}** and complexes in DMF.

The π→ π* transitions of the pyridyl ring and the thiosemicarbazone imine function of the ligand,**Hbptsc^{2}** appears at 35460 cm-1 and shifts to lower energies due to C=S bond weakening and conjugation system being enhanced after complexation. The band at 341nm (29325 cm-1) due to n→π* of the pyridine ring in the ligand diminishes in intensity in complexes suggesting coordination via. pyridyl nitrogen. The complexes show two charge transfer bands due to the S→Cu(II) LMCT transition at around 26,000cm^{-1} and a band due to a combination of S→Cu(II) and N(pyridyl)→Cu(II) LMCT transitions at 23,000cm^{-1} [28]. The complexes exhibit d-d transitions at around 625nm(16000cm-1) as a broad band charactreistic of square planar complexes. [29,30].



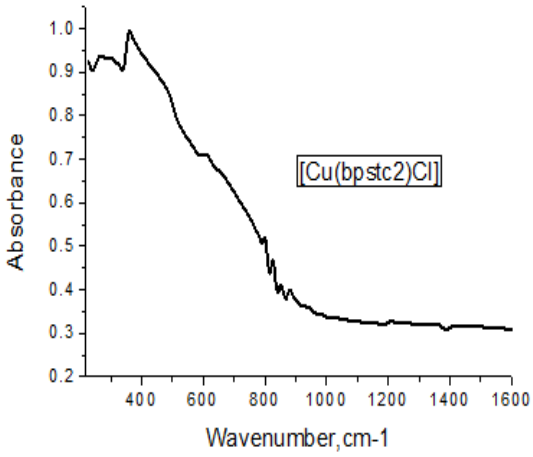


Fig.5. Electronic spectra of ligand,Hbptsc^2

Fig 6.Electronic spectra of [Cu(bptsc^2)Cl]

Table 3. Electronic spectral (cm^{-1}) assignments of *Hbptsc^2* and its complexes.

Compound	Solvent	d-d	C-T	n- π*	π-π*
Hbptsc^2	DMF	-	25641	29325, 23003	35460
[Cu(bptsc2)Cl] ***(1)***	DMF	16286	26109 sh, 23148 sh	28011	36231, 33222
[Cu(bptsc)^{2}NO3)] ***(2)***	DMF	16420	26666 sh 23148 sh	27624	38610
[Cu$_2$(bptsc^2)$_2$(SO$_4$)].H$_2$O ***(3)***	DMF	16556	26509 sh 23727 sh	28409	38022
[Cu(bptsc)^{2}N$_3$] ***(4)***	DMF	18416(sh),16420(sh)	26449 sh 23148 sh	27624	38022
[Cu(bptsc)^2(NCS)] ***(5)***	DMF	16420,15037	26584 sh 23271 sh	27624	39215

3.3. EPR Spectra

3.3.1. Solution phase

Table 4. Shows the spin Hamiltonian and bonding parameters of the copper (II) complexes of **Hbptsc^2**. The EPR spectra of complexes were recorded in frozen DMF at 77K, Liquid Nitrogen Temperature in X- band with a 100-kHz frequency modulation and *g* factors quoted relative to the standard Mn marker with six lines.

. The *epr* spectra of complexes, ***1-5 in*** , frozen DMF (77 K) shows typical axial spectra with two distinct g⊥ and g∥values > 2.0023 and well resolved hyperfine lines. The four well resolved copper hyperfine lines indicates the coupling of the Cu nuclei with (*I*=3/2) with the odd electron. The geometric parameter, G-value for all the compounds is in the 3.5- 4 range, indicating a $d_{x^2-y^2}$ ground state characteristic of square planar complexes[31].

The covalent bonding parameters of the complexes viz. α^2, β^2 and γ^2 have been calculated using $g_{\|}$, $g_{\perp}$, g_{av}, $A_{\|}(Cu)$ and $A_{\perp}(Cu)$ and the energy values of the d-d transitions.

The value of in-plane σ bonding parameters α^2 was estimated from the expression [31,32] $\alpha^2 = -A_{\|}/0.036 + (g_{\|} - 2.0023) + 3/7\ (g_{\perp} - 2.0023) + 0.04$

The parameters calculated are consistent with both strong in plane σ and in plane π bonding. For all the complexes.

The EPR spectra of the complexes have been simulated to get the accurate values of spin Hamiltonian and bonding parameters.

The X-band EPR simulated spectra of compounds **2, 4** and **5** are presented in the figure 7,8 and 9.

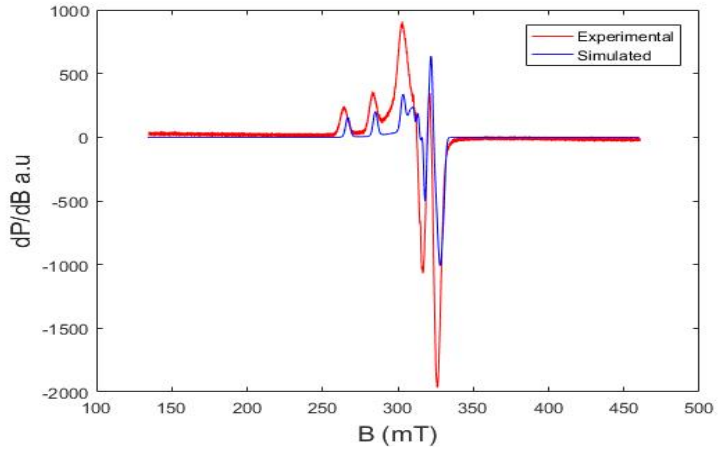


Fig 7. Simulated EPR spectra of [Cu(bptsc^2)NO_3] in DMF at 77K, LNT

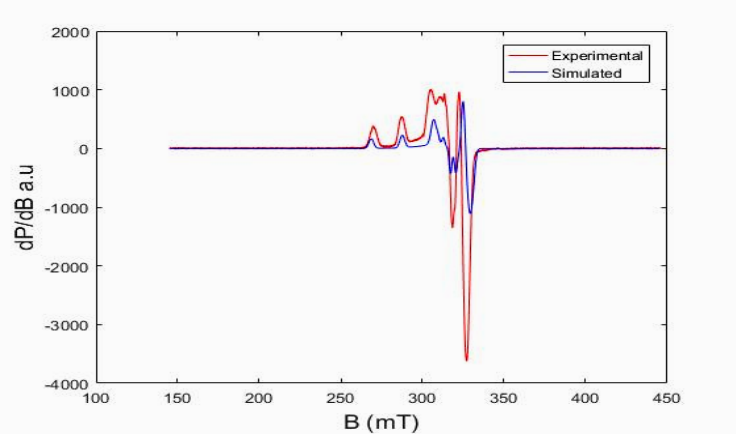


Fig 8. Simulated EPR spectra of [Cu(bptsc^2)N_3] in DMF at 77K, LNT

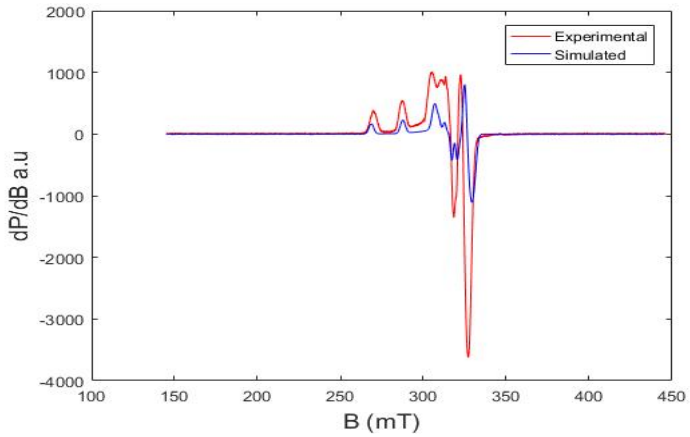
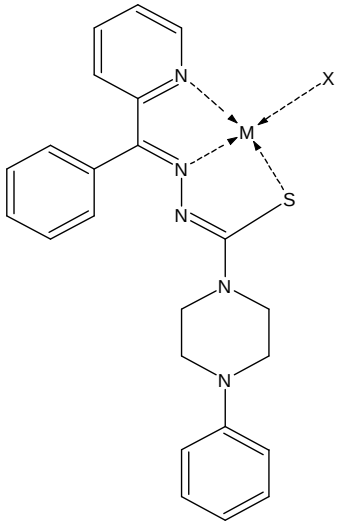


Fig 9. Simulated EPR spectra of [Cu(bptsc^2)NCS] in DMF at 77K, LNT

Table 4. The Spin Hamiltonian and bonding parameters of copper (II) complexes of *Hbptsc^2*.

DMF Soln(77K)	[Cu(bptsc^2)Cl]‥	[Cu(bptsc^2)NO$_3$]‥	[Cu$_2$(bptsc^2)$_2$(SO$_4$)] H$_2$O	[Cu(bptsc^2)N$_3$]‥	[Cu(bptsc^2)NCS]
$g_{\parallel}$	2.034	2.056	2.047	2.031	2.030
$g_{\perp}$	2.124	2.199	2.170	2.115	2.110
g_{av}	2.0783	2.1267	2.093	2.074	2.083
$A_{\parallel}$ (mT)	20.3	13.6	16.2	19.0	18.8
$A_{\perp}$ (mT)	2.88	2.67	2.50	2.69	2.62
G	3.8391	3.6629	3.7517	3.9268	3.8881
α^2	0.7338	0.6469	0.6821	0.6855	0.6733
β^2	0.7454	1.0795	0.9491	0.7711	0.7674
γ^2	0.761	1.128	0.9801	0.7783	0.7784
$K_{\parallel}$	0.547	0.6983	0.6474	0.5286	0.5167
$K_{\perp}$	0.5584	0.7297	0.6685	0.5335	0.5241

The following tentative structures may be proposed for the complexes;



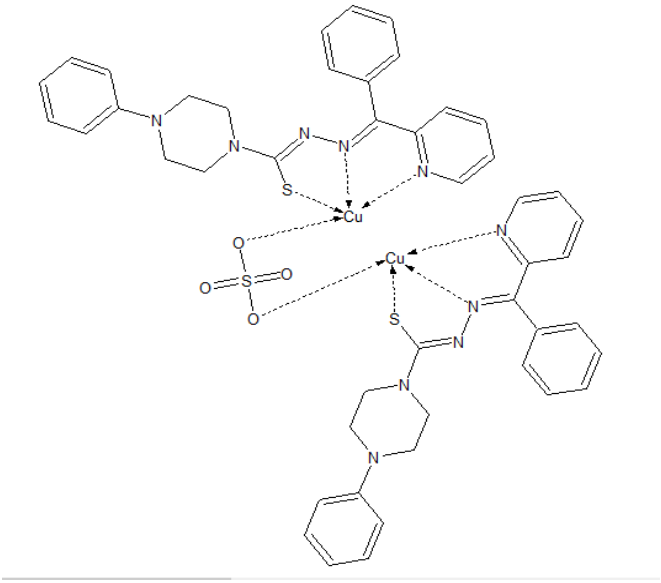


Fig 10.[Cu(bptsc^2)X], where X=Cl$^-$,NO$_3^-$, N$_3^-$,SCN$^-$] **Fig 11. [Cu(bptsc^2)X], where X= SO4^{2-}].**

3.4. ANTIMICROBIAL ASSAY

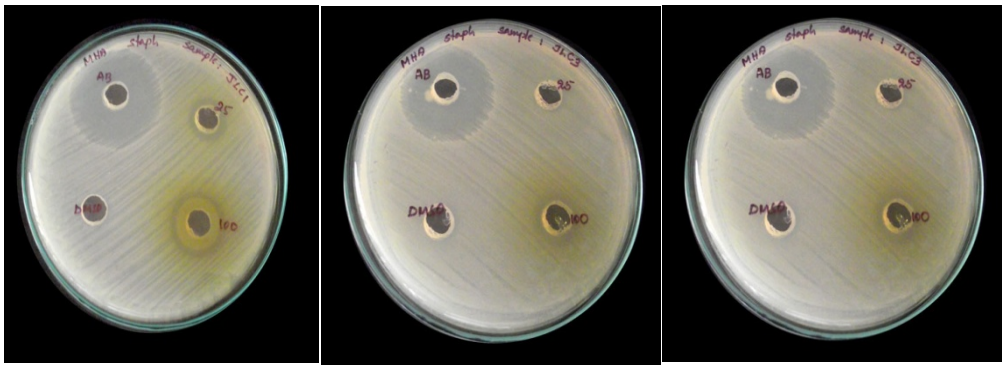
The antibacterial assay of the copper (II) complexes of **Hbptsc^2** was carried out following the Agar-well diffusion method. ***Table 5***. shows the results of the antibacterial activities of **Hbptsc^2** copper(II) complexes.

The petriplates were inoculated with bacteriae (two Gram positive and two Gram negative) cultured in 20 ml Muller Hinton Agar Medium (growth of culture adjusted according to Mc Fards Standard, 0.5%) in the form of discs (10mm) bored using well cutter. The test samples in concentrations of 250 and 1000 µg/ml concentrations in DMSO were added and the petriplates incubated at 37°C for 24 hours. The growth of the organisms around the area of the discs impregnated with the sample was inhibited and could be seen as inhibition zones. The antibacterial potency of the samples was assayed by measuring the zones of inhibition to the nearest cm's [33] in the culture plates using streptomycin as the positive control.

The complexes show commendable antibacterial potency against the organisms chosen and the order of activity is as follows;

[Cu(bptsc^2)N$_3$]> [Cu$_2$ (bptsc^2)$_2$SO$_4$.].H2O = [Cu(bptsc^2)NO$_3$] > [Cu(bptsc^2)Cl] > [Cu(bptsc^2)NCS]

The activity could be well explained on the basis of chelation theory, according to which the polarity of the metal ion decreases due to partial sharing of its positive charge with the donor group which in turn favours the permeability of the test samples into the bacterial lipid cell wall.



(a) **(b)** **(c)**

Fig 12. Petriplates showing inhibition zones produced by control as well as S.aureus for the complexes

a) [Cu(bptsc^2)Cl] **b) [Cu(bptsc^2)NO_3]** **C) [Cu_2(bptsc^2)SO_4..H_2O]**

Table.5: The antibacterial activities of the copper (II) complexes of ligand,Hbptsc^2 using the Agar-well diffusion method.

Bacterial culture	[Cu(bptsc^2)Cl]..		[Cu(bptsc^2)(NO_3)]		[Cu_2(bptsc^2)$_2$(SO_4)].H_2O		[Cu(bptsc^2)N_3]		[Cu(bptsc^2)(NCS)]	
Gram positive	25µg/ml	100µg/ml	25 µg/ml	100 µg/ml	25 µg/ml	100 µg/ml	25µg/ml	100 µg/ml	25 µg/ml	100 µg/ml
Staphylococcus aureus	1.1	1.4	1.7	2.0	1.7	2.1	1.9	2.2	1.2	1.5
Streptococcus mutans	1.6	2.1	1.7	2.1	1.3	1.9	1.4	2.0	1.4	2.2
Gram negative										
Pseudomonas aeruginosa	-	1.3	1.0	1.4	-	1.8	-	1.1	-	1.0
Escheria.coli	-	1.3	-	1.6	-	1.4	-	1.7	-	1.1

Stock concentration 10mg/mL DMSO

3.5. In vitro CYTOTOXICITY STUDIES

The cytotoxicity studies of the copper (II) complexes were carried following the trypan blue exclusion method and the results shown in the ***Table 6***.

The viable cells suspension (1×10^6 tumour cells/ 0.1ml PBS) of the tumour cells aspirated from the peritoneal cavity of tumour bearing mice were incubated in clean sterile tubes with the test compounds (25, 50, 100, 200 µg/ml in dimethyl sulfoxide (DMSO)) for 3h at37°C, keeping the final volume at 1.0 ml. The control tube was to contain only cell suspension. The cell suspension was then mixed with 0.1ml of 1%trypan blue and kept for 2-3 minutes and loaded on a haemocytometer. The live cells (without stain) and dead cells (with blue stain) were counted using haemocytometer and percent cell death was calculated.

% Cytotoxicity = (No. of dead cells/No. of live cell+ No. of dead cell) ×10.

The results show a very interesting trend of the cytotoxicity by the complexes in the following order **[Cu(bpstc)NCS] = [Cu(bptsc)Cl] < [Cu(bptsc)N3] < [Cu(bptsc)SO_4 < [Cu(bptsc)NO_3]**. The complex ***5*** showed maximum cytotoxicity of 75% at a concentration of 50µg/ml.

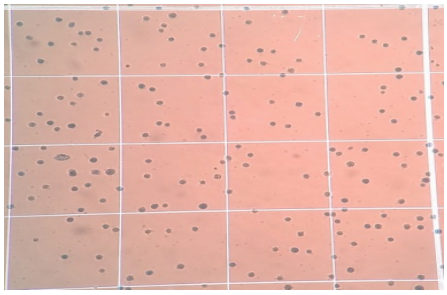


Fig.13. 100% dead control

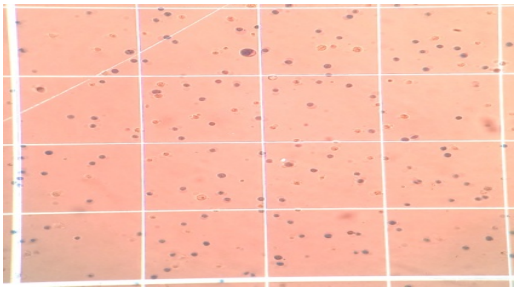


Fig14. 70%cytotoxic activity shown by Cu(bptsc)SO4] at 50µg/ml conc.

Table.6: The short term in vitro cytotoxicity results of the copper (II) complexes of Hbptsc^2

Concentration	% cytotoxicity of complexes				
µg/ml	[Cu(bptsc2) Cl]	[Cu(bptsc)NO_3]	[Cu_2(bptsc)$^2SO_4$].H_2O	[Cu(bptsc)N_3]	[Cu(bptsc)NCS]
10	20	6	15	20	40
20	48	12	20	38	52
50	58	22	26	50	75
100	70	36	35	63	88
200	82	58	46	84	100

4. CONCLUSIONS

An N(4)-disubstituted Heterocyclic Schiff base ligand**, Hbptsc^2** and its metal complexes have been synthesised and characterized on the basis of various physico-chemical and spectral studies. The ligand behaves as a neutral tridentate chelating agent coordinating through the azomethine nitrogen, nitrogen atom of the pyridine ring and sulphur atom in the thiosemicarbazone moiety. The spectral and EPR studies invariably confirm the four coordinated planar geometry for the complexes. Antibacterial and short term in vitro cytotoxicity studies further confirms a planar geometry for all the copper (II) complexes.

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