*Available online at* **www.joac.info**

ISSN: 2278-1862

*Journal of Applicable Chemistry*

2019, 8 (4): 1568-1577

(International Peer Reviewed Journal)

# Synthesis, Characterization and *in vitro* Studies of Metal Complexes Derived from Isoxazole Schiff base

**Karunakar Dasa[1]*, Bhaskar Saggella[2], Anil Kumar Marapaka[3], Karunakar Rao Kudle[4], Ramchander Merugu[3] and P. Muralidhar Reddy[2]**

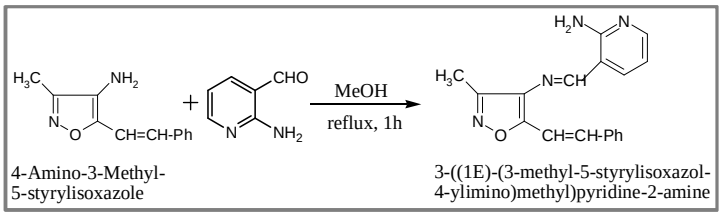
1. Govt Degree College, Sadashivpet, Telangana, **INDIA**
2. Department of Chemistry, Nizam College, Osmania University, Hyderabad, Telangana, **INDIA**
3. University College of Science and Informatics, Mahatma Gandhi University, Nalgonda, Telangana-508254, **INDIA**

Email: karunakardasa76@gmail.com

## ABSTRACT

*In the present study some new isoaxazole based Shciff base binary metal complexes were synthesized from Schiff base ligand* ***3-((1E)-(3-methyl-5-styrylisoxazol-4-ylimino)methyl)pyridine-2-amine(L)*** *derived by condensation of 4-amino-3-methyl-5-styrylisoxazole with 2-aminepyridine-3-carbaldehyde. All the synthesized Schiff base ligand and metal complexes were well characterized by different physico and spectral techniques such as Elemental Analysis, Magnetic susceptibility, Thermo-gravimetric Analysis (TGA), Mass spectra,* $^{1}H$ *and* $^{13}C$*NMR, IR, UV-Vis, EPR spectroscopy. The spectral studies revealed that* ***Co(II)*** *and* ***Cu(II)*** *complexes have octahedral geometry;* ***Zn(II)*** *complex has Tetrahedral structure where as* ***Pd(II)*** *complex shown square planar geometry. The Schiff base ligand and its corresponding metal complexes were further screened for their DNA binding activity and antimicrobial evaluation studies and in vitro cytotoxic activity.*

## Graphical Abstract




Synthesis of Schiff base Ligand

**Keywords:** Isoxazole scaffold, Schiff base, Metal complexes, *in vitro* biological studies.

## INTRODUCTION

Heterocycles are abundant in nature and are of great significance to life hence they have been attracting many chemists attention towards the design of biologically active molecules and advanced organic materials. Isoxazoles were significant heterocyclic structural scaffolds present in biologically active natural compounds and pharmaceutical agents and they can be acts as key intermediates in

many organic compounds. Isoxazoles were used widely and efficiently in medicinal chemistry due to their extensive range of biological activities and its derivatives showed potent antibacterial activity against Gram-positive and Gram-negative bacteria. Isoxazoles have been regarded as isostere of pyrazole or triazole and constitutes an important group due to wide variety of biological activity such as analgesic, anti-tuberculosis, anti-inflammatory, antibacterial, CNS-active [**1**], antitumor [**2**], chemotherapeutic agents [**3**] and anti-HIV found to be exhibit vasodilating effect [**4**] similar to that of nifedipine. Isoxazole ring is an electron- deficient fragment. It represents a five membered heterocycle and is an adequate acceptor, which can be applied as conjugative pi-linker in donor-pi-acceptor organic sensitizers.

Schiff's bases and their amine analogues have been found to possess fungicidal [**5**] bactericidal [**6**], antiviral [**7**], antioxidant [**8**] and antimicrobial activity [**9**]. Due to diverse structural aspects of Schiff bases and their analogues, there are many reports on the synthesis of Schiff bases compounds. Keeping the diverse therapeutic activities of Schiff's base analogues, it was contemplated to synthesize a series of isoxazolyl Schiff's base derivatives. Isoxazole Schiff base and their analogues have been found to exhibit significant therapeutic and pharmacological activities including antifungal, antibacterial, antiviral and antitumour activity. Isoxazolyl Schiff's base metal complexes have been extensively studied. All the isoxazolyl Schiff base metal complexes were screened for their in vitro antibacterial and in vitro anti-tumour activity.

In the present investigation, herewith we report the synthesis and characterization of isoxozolyl Schiff base ligand and its corresponding bivalent **$[CoL_2(H_2O)]$**, **$[Cu(OAc)_2L_2]$**, [**$ZnL_2$**] and **$[PdL_2]$** metal complexes by non-template method. The Schiff base ligand and its metal complexes were screened for their in vitro antimicrobial and cytotoxic activity.

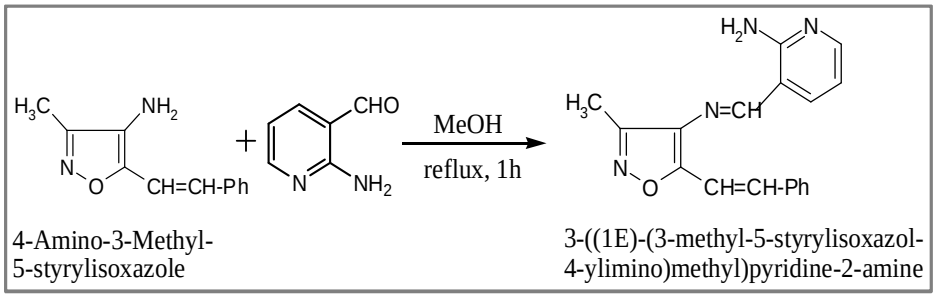
## MATERIALS AND METHODS

All the Chemicals and solvents of an Analar reagent grade were commercially purchased from Sigma-Aldrich (USA), Alfa Aeser (USA) and used as received without further purification.

**Physical Measurements:** The $^{1}$H- NMR spectra of the Schiff base ligand was recorded at 200 MHz and 300 MHz on Varian Gemini Unity Spectrometer using TMS as internal standard and $^{13}$C-NMR spectra was recorded at 100.6MHz on Varian Gemini Spectrometer. The EI-Mass spectra were recorded on a VG micro mass 7070–H Instrument and ESI-MS spectra were recorded on VG AUTOSPEC mass spectrometer. IR spectra of the Schiff base ligand and metal complexes were recorded using KBr pellets in the range (4000-250 $cm^{-1}$) on Perkin-Elmer Infrared model 337. Electronic spectra of metal complexes in DMSO were recorded on Schimadzu UV-Vis 1601 spectrophotometer. Magnetic susceptibilities of the complexes were determined on Gouy balance model 7550 using $Hg[Co(NCS)_4]$ as standard. The diamagnetic correction of the complexes was computed using Pascal's constants. The percentage composition of C, H, N for the ligand and complexes were determined by using micro analytical techniques on Perkin Elmer 240C (USA) elemental analyzer. The percent composition of metal ions in solid metal complexes was determined by EDTA titration procedure.

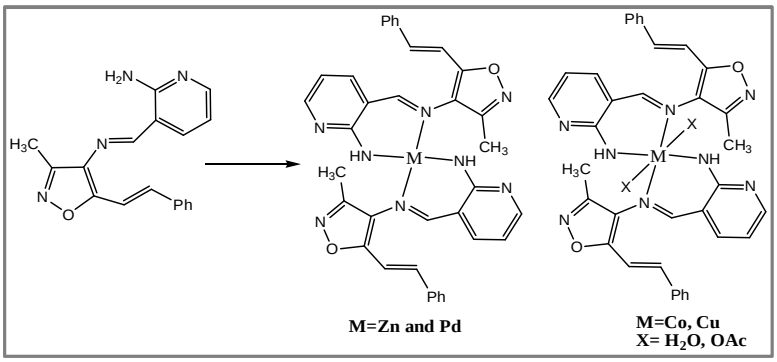
**General Procedure for the Synthesis of Schiff base Ligand:** The precursor 4-amino-3-methyl-5-styrylisoxazole was synthesized according to previously reported procedure with slight modification [**14, 15**]. About 2 gm (0.01mol) of 4-amino-3-methyl-5-styrylisoxazole was dissolved in 100 mL of methanol in a 250 ml round bottomed flask. To this, 1.22g (0.01mol) of 2-aminopyridine-3-carbaldehyde was added and the resultant contents were refluxed on a water bath for 1 h. The solution on cooling gave the yellow colored product which was filtered and crystallized from $CH_2Cl_2$: Methanol (8:2 v/v). M.P of Schiff base ligand is 165$^{o}$C.

**General Procedure for the synthesis of Metal complexes:** To a hot methanolic solution of Isoxazole derived Schiff base ligand (MSIPA) (0.02 mol) add methanolic solution of corresponding




**Scheme 1.** Synthesis of Schiff base Ligand

metal salts($Cu(OAc)_2.2H_2O$, $Zn(OAc)_2$ and $PdCl_2$) (0.01 mol in 2:1 eq) drop wise under stirring and the resultant mixture was refluxed on a hot water bath for 4 hrs. The solution was allowed to cool to room temperature and the precipitate was collected through filtration, followed by washing with water, ether and ethanol and dried in vacuum desiccators over fused $CaCl_2$ which was crystallized in aqueous methanol. Schematic representation of preparation of metal complexes was presented in scheme 2.




**Scheme 2.** Synthesis of Metal complexes.

**Antimicrobial Screening:** The antibacterial activity of all the metal complexes was tested by the agar diffusion method. For the determination of antibacterial activity, the antibiotic resistant bacteria namely, *Bacillus subtilis, Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae* were examined. Luria Bertani media was prepared and poured into sterilized petriplates and then plates were spreaded with bacteria. Then sterile discs were kept and the samples were added to the disc and the plates were incubated at 37°C overnight. The plates are examined for the presence of growth inhibition which is indicated by a clear zone surrounding each disc.

**Cytotoxicity Assay (MTT Assay):** Cellular viability in the presence of test compounds was determined by MTT-microcultured tetrazolium assay following the reported protocol [**10**]. All the experiments were carried out in triplicates. One human breast cancer cell line (MCF-7) and prostate cancer cell lines (DU145) were employed in the current study. Cell lines were seeded to flat bottom 96 (10,000 cells 100 $\mu L^{-1}$) well plates and cultured in the medium containing 10% serum followed by incubated for 24 h in a 5% $CO_2$ humid chamber so that the cells adhere to the surface. The MTT [3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyl tetrazolium bromide] was dissolved in PBS at 5 mg $mL^{-1}$ and sterile filtered. Different concentrations of the compounds were added to the adhered cells. After 48 h, MTT solution (10 µL per well) was added to the culture plate. Cells were further incubated in the $CO_2$ chamber for 2 h. Following this, media was removed and 100 µL of DMSO was added. Absorbance was measured at 562 nm in a multimode microplate reader (Tecan GENios). The results were represented as percentage of cytotoxicity/viability. All the experiments were carried out in triplicates. From the percentage of cytotoxicity the $IC_{50}$ values were calculated and presented in the table.

## RESULTS AND DISCUSSION

**NMR Spectroscopy:** The $^1$H-NMR spectra of Schiff base Ligand(**L**) shows a singlet at δ 8.20 ppm assigned to azomethine (-HC=N) proton strongly supports the formation of Schiff base. A singlet is appeared at δ 2.5 ppm due to substituted methyl protons on isoxazole ring and broad peak at δ 3.3 ppm corresponding to amine group (Figure 1a and 1b). All the aromatic protons corresponding signals were appeared as multiplets in the range of δ 6.7-8.8 ppm. In the $^1$H-NMR spectra of **ZnL$_2$** complex, the azomethine signal was observed slightly downfield in the range of δ 8.17 ppm confirms the coordination of imine nitrogen to metal atom in metal complexes [**11-14**] (Figure 2).

$^1$H-NMR (**L**, DMSO-d$_6$, ppm): δ2.5(s, 3H, -CH$_3$), 3.3(s, 2H, -NH(broad)), 6.7(d, 1H), 7.2-7.5(m, 5H), 7.8(s, 2H), 7.9-8.0(d, 3H), 8.2(s, 1H), 8.8(s, 1H) .

$^1$H-NMR (**ZnL$_2$**, CDCl$_3$, ppm): δ 2.40 (s, 3H, -CH$_3$), 6.91(s, 1H), 6.95(s, 1H), 7.27(s, 1H), 7.32-7.47(m, 5H), 7.51(d, 2H), 7.62(s, 1H), 8.17 (d, 1H), 8.53(s, 1H).

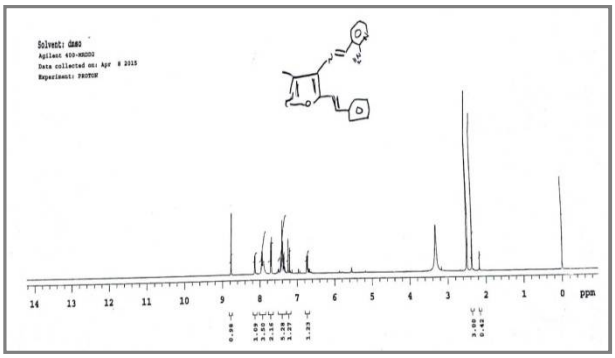


**Figure 1a.** $^1$H-NMR Spectra of Schiff base Ligand(L).

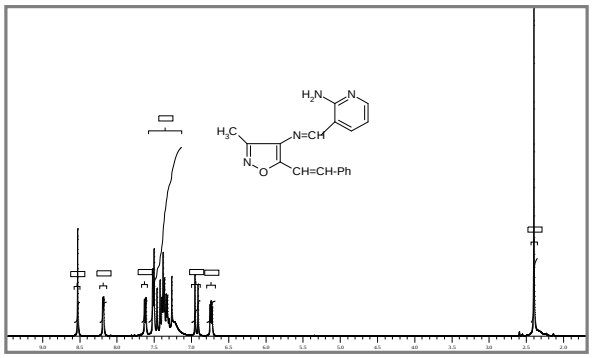



**Figure 1b.** $^1$H-NMR Spectra of Schiff base Ligand(L).

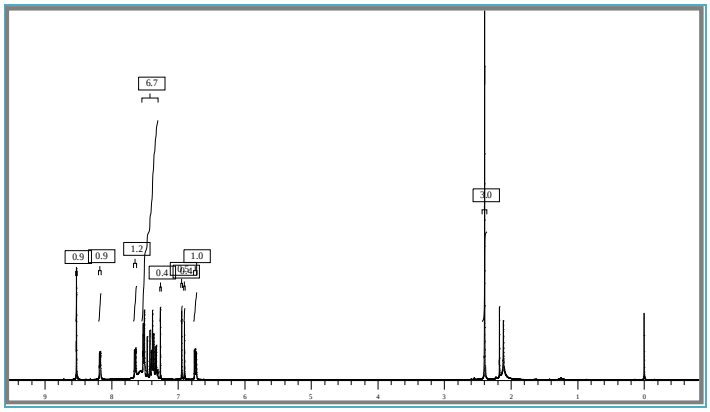



**Figure 2.** $^1$H-NMR Spectra of ZnL$_2$Complex.

**IR Spectroscopy:** The Infrared spectra of Schiff base ligand was compared to metal complexes in order to elucidate the binding modes of ligand to metal ion in all the metal complexes[**15-21**]. IR spectra of Schiff base ligand gives a high intensity characteristic band at around 1636 cm$^{-1}$ assigned to azomethine (-HC=N) stretching frequency (Table 1). This was shifted to lower side about 4-22 cm$^{-1}$ in Schiff base metal complexes indicates the coordination of imino nitrogen (-HC=N) to the metal ion [**22**]. In the IR spectrum of metal complexes coordination of nitrogen to metal (M-N) is further supported by the presence of weak intensity band in the region 520-583 cm$^{-1}$ and in addition a weak intensity band appeared at 624-647cm$^{-1}$ supports the (M-O)stretching frequency [**23, 24**]. A broad band is observed in the region 3268–3432 cm$^{-1}$ due to coordinated water in the complexes (Figure 3).

**Table 1.** Significant IR stretching frequencies of Metal complexes

| Compd. | υ(-NH) | υ(-HC=N) | υ(M-O) | υ(M-N) | υ(M-$H_2O$) | υ(M-Cl) |
|---|---|---|---|---|---|---|
| L | 3261-3342 | 1636 | - | - | - | - |
| [$Cu(OAc)_2L_2$] | 3268 | 1620 | 624 | 571 | 3136-3632 | - |
| [$PdL_2$] | 3350-3432 | 1632 | - | 583 | - | 349 |
| [$ZnL_2$] | 3261-3351 | 1636 | - | 547 | - | 355 |
| [$CoL_2(H_2O)$] | - | 1614 | 647 | 520 | 3050-3640 | - |

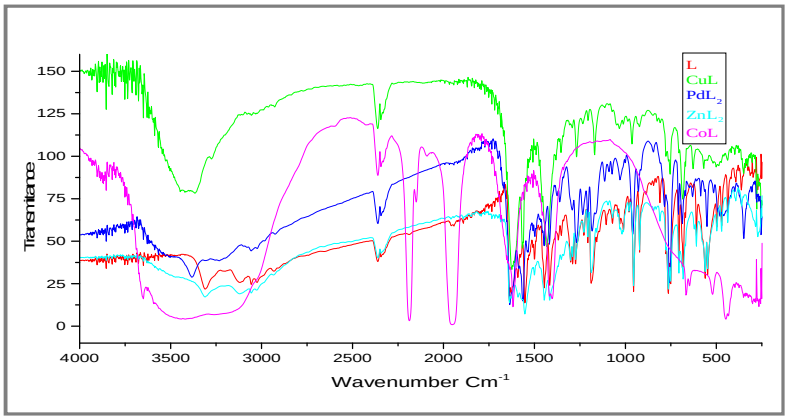



**Figure 3.** IR Spectra of Ligand(A) and Metal complexes.

**UV-Vis Spectroscopy:** Electronic absorption spectra of all the Metal complexes were recorded in DMSO solvent in the range of 200-800 nm [25-27]. The electronic absorption spectra of Schiff base ligand shows strong absorption bands at 330 and 384 nm which are attributed to π→π* and n→ π* transitions respectively (Figure 4). Electronic absorption spectra of Co(II) complex gives two absorption bands corresponding to $^4T_1g$ (F)→$^4T_2g$ (F) and $^4T_1g$ (F)→$^4T_1g$(P) transitions, respectively indicates an octahedral geometry around Co(II) ion[16]. The Cu(II) complex shows a low intense broad band at 650 nm which might be attributed to $^2T_2g$→$^2$ Eg transition, which is characteristic of distorted octahedral structure [20]. The UV-Vis spectra of Pd(II) complex shows three absorption bands attributed to $^1A_1g$→$^1A_2g$ , $^1A_1g$→$^1B_1g$ , and $^1A_1g$→$^1$Eg transitions suggests square planar geometry [15].

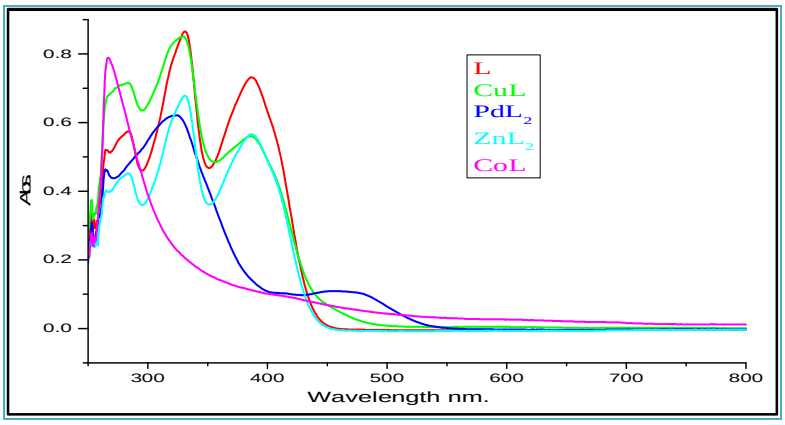



**Figure 4.** UV-Visible Spectroscopy of Schiff base Metal Complexes.

**Mass Spectra:** The LC-MS spectrum of ligand further confirms the formation of Schiff base by showing a molecular ion peak at m/z 305 (M+H) and other peaks at 101, 114 and 214 m/z contributed to various fragments. ESI-Mass spectra of complexes give strong evidence for the formation of metal

complexes by showing corresponding molecular ion peaks. The molecular ion peaks of metal complexes Cu(II)(**B**), Pd(II)(**C**), Zn(II)(**D**) and Co(II)(**E**) were observed at m/z 705, 480, 451 and 670 respectively (Figure 5).

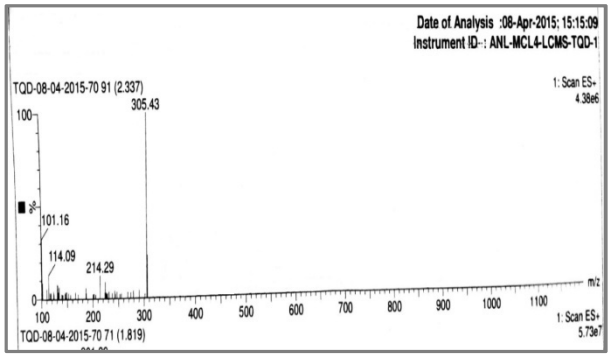



**Figure 5.** ESI-MS Spectra of Schiff base Ligand(L).

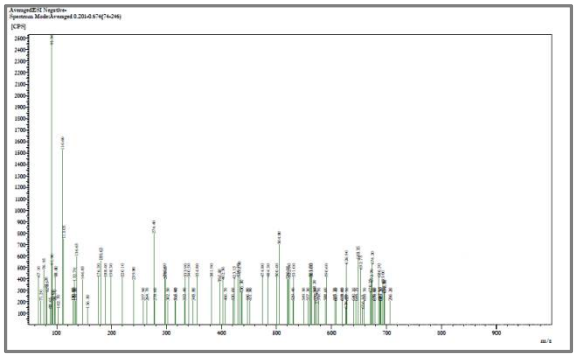


**Figure 5a.** ESI-MS spectra of Cu(II)Complex(m/z-706).

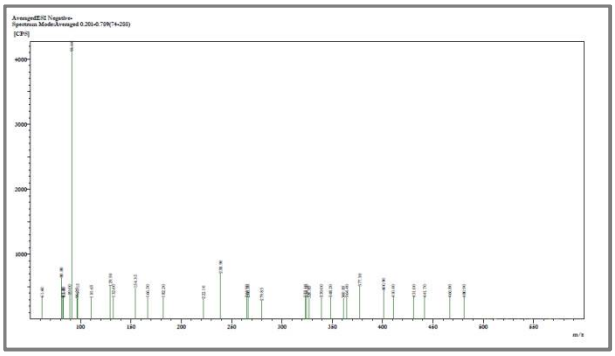


**Figure 5b.** ESI-MS spectra of Pd(II) Complex(480).

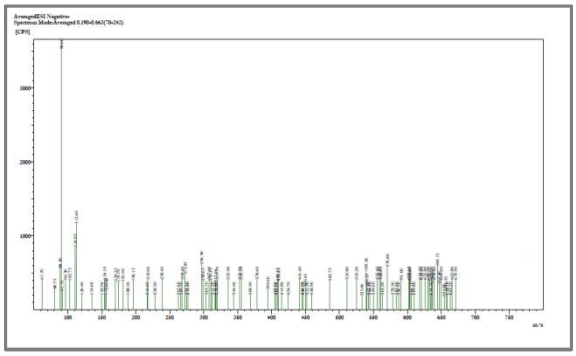


**Figure 5c.** ESI-MS Spectra of Zn(II) Complex(670).

**Thermal Analysis:** Thermal stability and thermal behavior of all the metal complexes was carried out at 10$^{o}$C min$^{-1}$ under dynamic nitrogen atmosphere up to 800°C. TGA thermogams of metal complexes conclude that initial mass loss occurring in the temperature range of 100-110°C due to loss of moisture and non-coordinated water molecules. The next weight loss above 150°C due to loss of coordinated water molecules in metal complexes and finally the organic ligand starts gradual decomposition to corresponding metal oxides at higher temperature.

**EPR Spectra:** The X-band EPR spectrum of a powdered sample at room temperature was shown in figure 6. EPR spectra of Cu(II) complex gives a pseudo-isotropic signal with $\mathbf{g}_{\|}$=2.24, $\mathbf{g}\perp$ =2.07 with hyperfine splitting. This type of typical EPR spectra is assigning to distorted octahedral Cu(II) complexes[**20**].

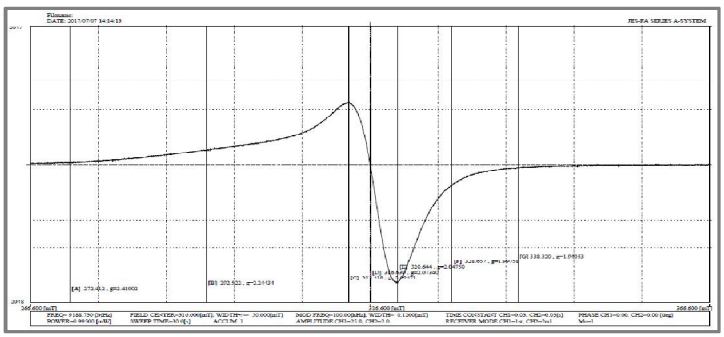
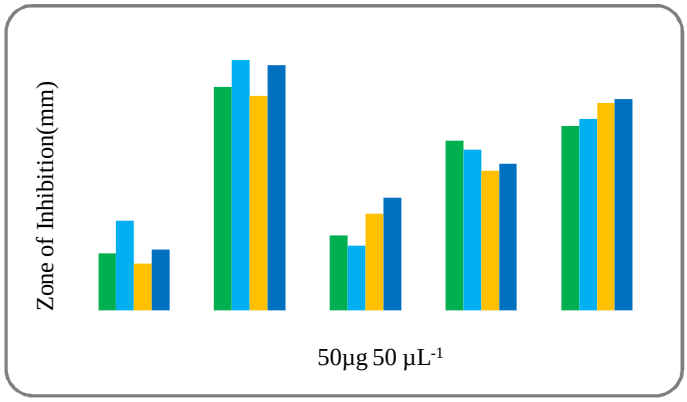


**Figure 6.** EPR Spectra of Cu(II) Complex.

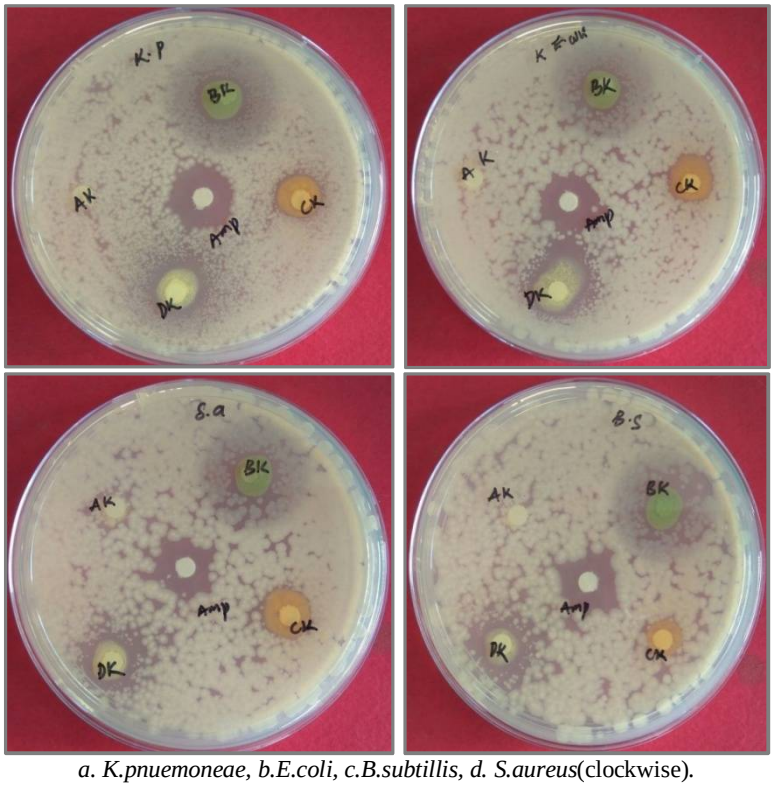
## APPLICATION

**Antimicrobial studies:** Against all the tested bacterial strains, Cu(II) complex was most active against both gram positive and negative microorganisms and exhibits highest activity against *Bacillus subtilis* followed by other bacteria (Figure 7 and 8). The Cu(II) complex was also shown to be effective against all bacteria which were investigated. Isozolyl Schiff base ligand (A) was found to be shown least antibacterial activity among all the tested complexes [**14, 15, 28-34**].




*E.coli*-green, *Bacillus subtilis*- light blue, *K.pneuomniae*- yellow, *Staph.aerues*- dark blue

**Figure 7.** Antimicrobial activity of Schiff base Ligand(L) and Metal complexes.



*a. K.pnuemoneae, b.E.coli, c.B.subtillis, d. S.aureus*(clockwise).

**Figure 8.** Zone of Inhibition of Schiff base Metal complexes

**In vitro antitumor studies:** Studies on antitumor activity clearly show that the complexes synthesized had significant antitumor activity. The Co(II) and Pd(II) complexes showed more activity than other compounds against DU145 (prostate cancer cell line).The Schiff base ligand and

Zn(II)complexes showed similar inhibition on the cancer cell line DU145 (prostate cancer cell line). Antitumor activity of the all the metal complexes against MCF-7 (Breast cancer cell line) clearly shows that the compounds synthesized had significant antitumor activity (Figure 9). The complexes Co(II) and Pd(II) showed more activity than other compounds against MCF-7 (Breast cancer cell line).Zn(II) complex showed the least inhibition of MCF-7 (Breast cancer cell line).

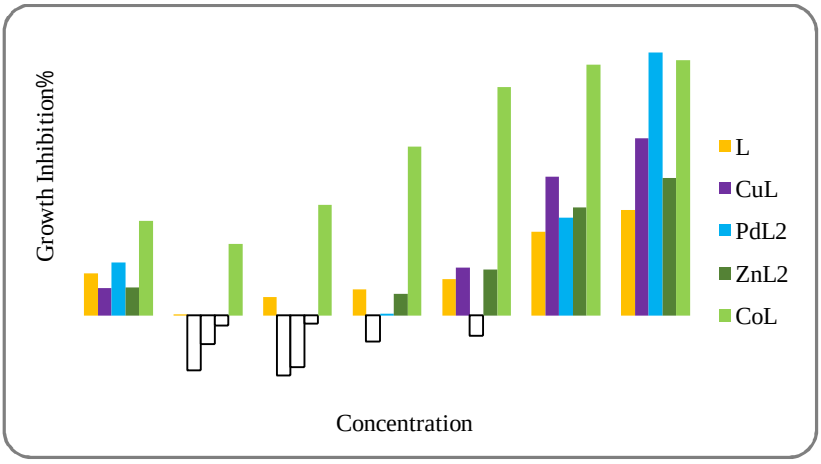



**Figure 9.** Antitumour activity of Schiff baseLigand(L) and Metal complexes.

## CONCLUSION

In the present investigation, herewith we report the synthesis of bivalent **Cu(II), Pd(II), Zn(II)** and **Co(II)**metal complexes from isoxazole derived Schiff base ligand(**L**). The geometries of the newly synthesized metal complexes have been proposed tentatively based on the UV-Vis spectra, IR, NMR, ESR, ESI-Mass, elemental analysis and thermal studies data. Electronic data reveals that an octahedral structure was assigned to the metal complexes **Cu(II)** and **Co(II)**.Square planar and Tetrahedral structures were proposed to the complexes **Pd(II)** and **Zn(II)** respectively.

All the metal complexes were tested for their anti-microbial studies against *Bacillus subtilis, Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae*. The obtained results conclude that, among these the **Cu(II)**Complex was most active against both gram positive and negative microorganisms. In vitro anti-tumor screening of all the metal complexes was carried out against DU145 (prostate cancer cell line) and MCF-7 (Breast cancer cell line) tumour cell lines. The results revealed that the Schiff base ligand (**L**) and **Zn(II)** complex have shown similar inhibition on the cancer cell line DU145 (prostate cancer cell line). The **Pd(II)** and **Co(II)**metal complexes showed more activity than other compounds against MCF-7 (Breast cancer cell line).

## ACKNOWLEDGEMENTS

We the authors thank Head, Department of Chemistry and Central facilities and Research Development (CFRD), Osmania University, Hyderabad for providing facilities.

## REFERENCES

[1]. H. Kan o, I. Adachi, R. Kido, K. Hirose, Isoxazoles. XVIII. Synthesis and pharmacological properties of 5-aminoalkyl-and 3-aminoalkylisoxazoles and related derivatives, *Journal of Medicinal Chemistry*, **1967**, 10, 411-418.

[2]. D. Martin, C. Chidester, S. Mizsak, D. Duchamp, L. Baczynskyj, W. Krueger, R. Wnuk, P. Meulman, The Isolation, Structure, and Absolute Configuration of U-43.795, A New Antitumor Agent, *The Journal of antibiotics*, **1975**, 28, 91-93.

[3]. E. Rajanarendar, M. N. Reddy, K. R. Murthy, K. G. Reddy, S. Raju, M. Srinivas, B. Praveen, M.S. Rao, Synthesis, antimicrobial, and mosquito larvicidal activity of 1-aryl-4-methyl-3, 6-bis-(5-methylisoxazol-3-yl)-2-thioxo-2, 3, 6, 10b-tetrahydro-1H-pyrimido [5, 4-c] quinolin-5-ones, *Bioorganic and Medicinal Chemistry Letters*, **2010**, 20, 6052-6055.
[4]. J. I. McKenna, L. Schlicksupp, N. R. Natale, R. D. Willett, B. E. Maryanoff, S. F. Flaim, Cardioactivity and solid-state structure of two 4-isoxazolyldihydropyridines related to the 4-aryldihydropyridine calcium-channel blockers, *Journal of Medicinal Chemistry*, **1988**, 31, 473-476.
[5]. A. M. Isloor, B. Kalluraya, P. Shetty, Regioselective reaction: synthesis, characterization and pharmacological studies of some new Mannich bases derived from 1, 2, 4-triazoles, *European Journal of Medicinal Chemistry*, **2009**, 44, 3784-3787.
[6]. L. Shi, H.-M. Ge, S.-H. Tan, H.-Q. Li, Y.-C. Song, H.-L. Zhu, R.-X. Tan, Synthesis and antimicrobial activities of Schiff bases derived from 5-chloro-salicylaldehyde, *European Journal of Medicinal Chemistry*, **2007**, 42, 558-564.
[7]. D. Sriram, P. Yogeeswari, N.S. Myneedu, V. Saraswat, Abacavir prodrugs: Microwave-assisted synthesis and their evaluation of anti-HIV activities, *Bioorganic & medicinal chemistry letters*, **2006**, 16, 2127-2129.
[8]. A. D. Yılmaz, T. Coban, S. Suzen, Synthesis and antioxidant activity evaluations of melatonin-based analogue indole-hydrazide/hydrazone derivatives, *Journal of Enzyme Inhibition and Medicinal Chemistry*, **2012**, 27, 428-436.
[9]. A. M. Vijesh, A. M. Isloor, P. Shetty, S. Sundershan, H.K. Fun, New pyrazole derivatives containing 1,2,4-triazoles and benzoxazoles as potent antimicrobial and analgesic agents, *European Journal of Medicinal Chemistry*, **2013**, 62, 410-415.
[10]. C.-Y. Huang, D.-T. Ju, C.-F. Chang, P. Muralidhar Reddy, B. K. Velmurugan, A review on the effects of current chemotherapy drugs and natural agents in treating non-small cell lung cancer, *BioMedicine*, **2017**, 7, 23-23.
[11]. P. M. Reddy, K. Shanker, R. Rohini, M. Sarangapani, V. Ravinder, Substituted tertiary phosphine Ru(II) organometallics: Catalytic utility on the hydrolysis of etofibrate in pharmaceuticals, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2008**, 70, 1231-1237.
[12]. B. Geeta, K. Shravankumar, P. M. Reddy, E. Ravikrishna, M. Sarangapani, K. K. Reddy, V. Ravinder, Binuclear cobalt(II), nickel(II), copper(II) and palladium(II) complexes of a new Schiff-base as ligand: Synthesis, structural characterization, and antibacterial activity, *Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy*, **2010**, 77, 911-915.
[13]. E. R. Krishna, P. M. Reddy, M. Sarangapani, G. Hanmanthu, B. Geeta, K. S. Rani, V. Ravinder, Synthesis of N-4 donor macrocyclic Schiff base ligands and their Ru (II), Pd (II), Pt (II) metal complexes for biological studies and catalytic oxidation of didanosine in pharmaceuticals, *Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy*, **2012**, 97, 189-196.
[14]. K. Shanker, R. Rohini, V. Ravinder, R. M. Reddy, Y. P. Ho, Ru(II) complexes of N-4 and $N_2O_2$ macrocyclic Schiff base ligands: Their antibacterial and antifungal studies, *Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy*, **2009**, 73, 205-211.
[15]. K. Shanker, P. M. Reddy, R. Rohini, Y. P. Ho, V. Ravinder, Encapsulation of Pd(II) by $N_4$ and $N_2O_2$ macrocyclic ligands: their use in catalysis and biology, *Journal of Coordination Chemistry*, **2009**, 62, 3040-3049.
[16]. P. M. Reddy, A.V.S.S. Prasad, K. Shanker, V. Ravinder, Synthesis, spectral studies and antibacterial activity of novel macrocyclic Co(II) compounds, *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, **2007**, 68, 1000-1006.
[17]. M. Ashok, A.V.S.S. Prasad, P. M. Reddy, V. Ravinder, Ru(III)-catalyzed oxidation of pyridoxine and albuterol in pharmaceuticals, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2009**, 72, 204-208.

[18]. P. M. Reddy, A.V.S.S. Prasad, R. Rohini, V. Ravinder, Catalytic reduction of pralidoxime in pharmaceuticals by macrocyclic Ni(II) compounds derived from orthophthalaldehyde, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2008**, 70, 704-712.
[19]. P. U. Rani, P. M. Reddy, K. Shanker, V. Ravinder, Synthesis, characterization and catalytic applications of rhodium(I) organometallics with substituted tertiary phosphines, *Transition Metal Chemistry*, **2008**, 33, 153-160.
[20]. P. M. Reddy, A.V.S.S. Prasad, V. Ravinder, Synthesis, spectral characterization, catalytic and antibacterial activity of macrocyclic CuII compounds, *Transition Metal Chemistry*, **2007**, 32, 507-513.
[21]. P. M. Reddy, A.V.S.S. Prasad, C. K. Reddy, V. Ravinder, Synthesis of new macrocyclic rhodium(III) compounds and their utility as catalysts for the oxidation of ascorbic acid, *Transition Metal Chemistry*, **2008**, 33, 251-258.
[22]. P.M. Reddy, A.V. Prasad, K. Shanker, V. Ravinder, Synthesis, spectral studies and antibacterial activity of novel macrocyclic Co (II) compounds, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2007**, 68, 1000-1006.
[23]. A. Kumar, V. K. Vashistha, P. Tevatia, R. Singh, Electrochemical studies of DNA interaction and antimicrobial activities of Mn II, Fe III, Co II and Ni II Schiff base tetraazamacrocyclic complexes, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2017**.
[24]. M. Tyagi, S. Chandra, P. Tyagi, Mn (II) and Cu (II) complexes of a bidentate Schiff's base ligand: spectral, thermal, molecular modelling and mycological studies, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2014**, 117, 1-8.
[25]. G. Budige, M. R. Puchakayala, S. R. Kongara, A. Hu, R. Vadde, Synthesis, characterization and biological evaluation of mononuclear Co(II), Ni(II), Cu(II) and Pd(II) complexes with new N2O2 Schiff base ligands, *Chem Pharm Bull (Tokyo)*, **2011**, 59, 166-171.
[26]. P. M. Reddy, R. Rohini, E. R. Krishna, A. R. Hu, V. Ravinder, Synthesis, Spectral and Antibacterial Studies of Copper(II) Tetraaza Macrocyclic Complexes, *International Journal of Molecular Sciences*, **2012**, 13, 4982-4992.
[27]. M. Ashok, A.V.S.S. Prasad, P. M. Reddy, V. Ravinder, Synthesis, Spectral studies, Catalytic and Antibacterial activity of Ru(II) Complexes with Coordinated amides, *Journal of Applied Spectroscopy*, **2008**, 75, 872-879.
[28]. R. Rohini, P. M. Reddy, K. Shanker, A. R. Hu, V. Ravinder, Antimicrobial study of newly synthesized 6-substituted indolo[1,2-c]quinazolines, *European Journal of Medicinal Chemistry*, **2010**, 45, 1200-1205.
[29]. R. Rohini, P. M. Reddy, K. Shanker, A. R. Hu, V. Ravinder, Synthesis of Some New Mono, Bis-Indolo[1, 2-c]quinazolines: Evaluation of their Antimicrobial Studies, *Journal of the Brazilian Chemical Society*, **2010**, 21, 897-904.
[30]. R. Rohini, P. M. Reddy, K. Shanker, K. Kanthaiah, V. Ravinder, A. Hu, Synthesis of mono, bis-2-(2-arylideneaminophenyl) indole azomethines as potential antimicrobial agents, *Archives of Pharmacal Research*, **2011**, 34, 1077-1084.
[31]. R. Rohini, P. M. Reddy, K. Shanker, V. Ravinder, New Mono, Bis-2,2-(arylidineaminophenyl) benzimidazoles: Synthesis and Antimicrobial Investigation, *Acta Chimica Slovenica*, **2009**, 56, 900-907.
[32]. R. Rohini, K. Shanker, P. M. Reddy, Y.-P. Ho, V. Ravinder, Mono and bis-6-arylbenzimidazo [1,2-c]quinazolines: A new class of antimicrobial agents, *European Journal of Medicinal Chemistry*, **2009**, 44, 3330–3339.
[33]. R. Rohini, K. Shanker, P. M. Reddy, V. Ravinder, Synthesis and Antimicrobial Activities of a New Class of 6-Arylbenzimidazo[1,2-c]quinazolines, *Journal of the Brazilian Chemical Society*, **2010**, 21, 49-U36.
[34]. R. Rohini, K. Shanker, P. M. Reddy, V. C. Sekhar, V. Ravinder, 6-Substituted Indolo[1,2-c] quinazolines as New Antimicrobial Agents, *Archiv Der Pharmazie*, **2009**, 342, 533-540.
[35]. A. A. S. Al-Hamdani, W. Al Zoubi, New metal complexes of $N_3$ tridentate ligand: Synthesis, spectral studies and biological activity, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **2015**, 137, 75-89.