JOURNAL OF DYNAMICS AND CONTROL

VOLUME 8 ISSUE 9

SYNTHESIS, CHARACTERIZATION AND BIOLOGICAL INVESTIGATION OF NI[II], CU[II] CO[II], ZN[II], MN[II] METAL COMPLEXES OF TETRADENTATE SCHIFF BASE LIGAND

Sanjeevan A. Survase[1], Mahadeo A. Sakhare[1], Yogesh N. Bharate[1], C. S. Patil[2]

[1]Department of Chemistry, Balbhim Arts, Science & Commerce College, Beed - 431122

[2]Department of Chemistry, Shri. Muktanand College, Gangapur, Dist: Chhatrpati Sambhajinagar – 431109

SYNTHESIS, CHARACTERIZATION AND BIOLOGICAL INVESTIGATION OF Ni[II], Cu[II] Co[II], Zn[II], Mn[II] METAL COMPLEXES OF TETRADENTATE SCHIFF BASE LIGAND

*Sanjeevan A. Survase[1], Mahadeo A. Sakhare[1], Yogesh N. Bharate[1], C. S. Patil[*2]*

[1]Department of Chemistry, Balbhim Arts, Science & Commerce College, Beed - 431122

[2] Department of Chemistry, Shri. Muktanand College, Gangapur, Dist: Chhatrpati Sambhajinagar – 431109

***Corresponding Author: Email: ssurvase70@gmail.com**

ABSTRACT: Biological active Schiff base (HPMBP) was prepared from 2,4-Diamino-6-hydroxypyrimidine and 5-bromo-2-hydroxybenzaldehyde by condensation method. A series of novel Ni[II], Cu[II] Co(II), Zn(II) and Mn(II) complexes have been synthesized from Schiff base ligand (HPMBP). The structural features and physical properties of Schiff base ligand (HPMBP) and their metal complexes were explored from spectral characterization techniques such as ^{1}H NMR, ^{13}C NMR, Mass, FT-IR spectra, P-XRD and TGA. The spectral analysis data shows that the metal complexes have composition of ML(1:1) type. The P-XRD data propose monoclinic crystal system for Ni(II), Co(II), Zn(II), Mn(II) complexes and orthorombhic crystal system for Cu(II) complex. The bio-efficiency of ligand and its transition metal complexes have been tested against three gram +ve /gram -ve bacteria (*Staphylococcus aureus, Pseudomonas aeruginosa and Klebsiella pneumonia*) and four fungi (*Penicillium chrysogenum, Trichoderma viride, Aspergillus niger and Candida albicans*) in vitro to examine their microbial activity. The bioactivity data reveals that the metal complexes showed good antifungal and antibacterial activity than the Schiff base ligand (HPMBP).

KEYWORDS: 2,4-Diamino-6-hydroxypyrimidine, Schiff base, Metal complexes. Bio-efficiency

INTRODUCTION:

Schiff bases are organic compounds having azometine (-CH=N-) group which is derived from aromatic amine and aromatic aldehyde or ketone by elimination of water molecule [1]. The coordination chemistry of Schiff base ligand and its transition metal complexes has come to be interesting area for researcher due to their significant impact on

environment as well as human life [2]. Schiff bases ligands are identified as acceptable antibacterial agents [3]. The tetradentate Schiff base ligands with O, N donor atoms are an interesting class of compound because of their wide range of use in synthesis of biochemical, agrochemicals and medicine [4]. on the other hand transition metal complexes have remarkable range of applications such as antimicrobial, antitubercular, antioxidant, antimalarial activity, antiviral, anticancer, antifungal, antianalgesic, anti-inflammatory, sedative, antipyretic, antiproliferative, use in organic battery, photostabilizer, electrode, photodetector, opto-electronic, solar filter, electrochromic device is due to the presence of the (HC=N) azomethine group [5-12]. The Schiff base ligands and their transition metal complexes are very acceptablel as catalysts in various biological systems. The pyrimidine ring containg shiff base have a exclusive medicinal applications [13]. The bioefficiency of these Schiff base molecules in biological aspects encouraging the research scolars to synthesis of new Schiff base compound and to examine the bio-activity in vivo and in vitro analysis [14].

In view of miscellaneous function of Schiff base ligand and their metal complexes, the metal complexes of Ni[II], Cu[II], Co(II), Zn(II) and Mn(II) with Schiff base ligand derived from 2,4-Diamino-6-hydroxypyrimidine and 5-bromo-2-hydroxybenzaldehyde have been synthesized and investigated by ^{1}H NMR, ^{13}C NMR, Mass, FT-IR spectra, P-XRD and TGA. The Schiff base ligand and its metal complexes have been screened for their antibacterial and antifungal activities by using the agar disk diffusion method against preferred bacteria and fungi.

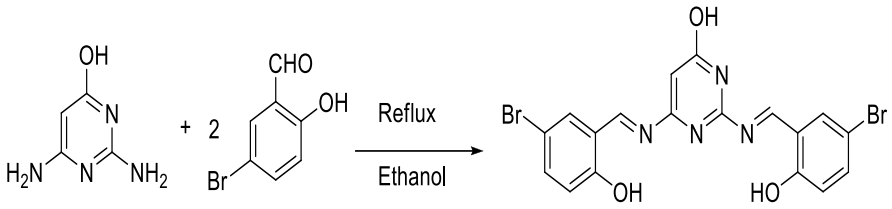
EXPERIMENTAL:

All chemicals used for the synthesis of Schiff base ligand and its complexes were pure and AR grade. FT-IR spectra was recorded on Bruker AlphaT FT-IR spectrophotometer using KBr disc. ^{1}H and ^{13}C NMR spectra was recorded on Bruker 500MHz NMR instrument in $CDCl_3$. A mass spectrum was recorded on Bruker Esquire 3000 mass spectrometry. The thermo gravimetric analysis was performed on Perkin Elmer TA/SDT-2960 and P-XRD were recorded on Philips 3701.

Preparation of Schiff base:

2,2’-(1E,1’E)-(6-hydroxypyrimidine-2,4-diyl)bis(azan-1-yl-1-ylidene)bis(methan-1-yl-1-ylidine) bis(4-bromo phenol) (HPMBP) was prepared by gradualy mixing hot alcoholic solution (20ml) of 2,4-Diamino-6-hydroxypyrimidine (0.005 mol) with hot alcoholic solution (20ml) of 5-bromo-2-hydroxybenzaldehyde (0.01 mol) along with adding 2-3 drops

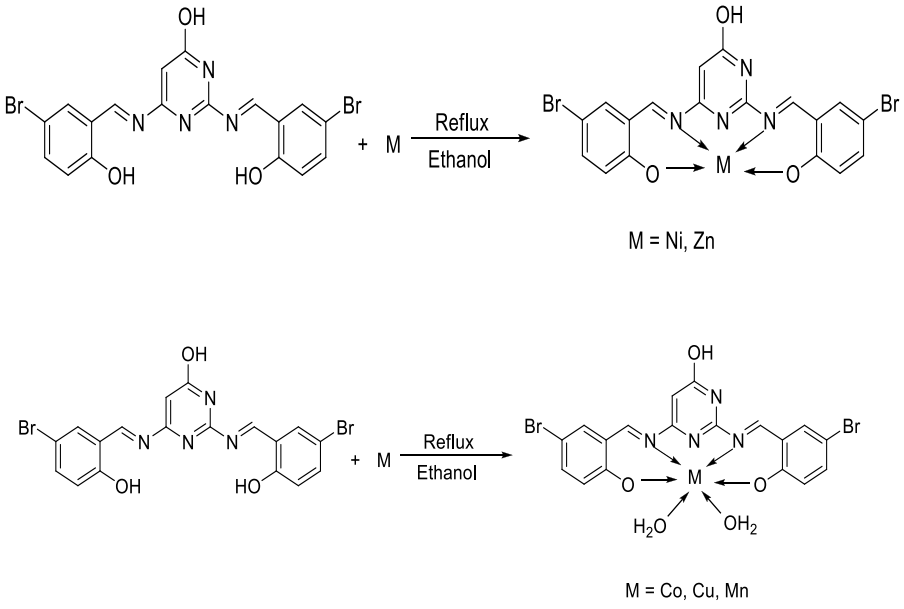
of HCl with constant stirring. The above reaction mixture was refluxed at 80-85ºC for about 4 hrs. On cooling, the solid yellow color product was formed, which was filtered and washed thoroughly with cold ethanol and dried under vaccume. (Yield =71 %.)



Scheme 1. Synthesis of Schiff base ligand (HPMBP)

Preparation of metal complexes:

The ethanolic solution (25 ml) of the Schiff base ligand (0.001 mol) and ethanolic solution (25 ml) of the corosponding metal acetate salt (0.001 mol) was mixed together with stirring. The pH of reaction mixture was maintained in between 7-8 by adding few drops of 10% alcoholic solution of ammonia. The reaction mixture was refluxed about 3-4 hrs at 80-90 ºC. On cooling, solid colored products obtained. The ppt. was filtered, washed with ethanol and dried under vacuum. (Yield 51-65%.)



Scheme 2. Synthesis of Ni[II], Cu[II], Co(II), Zn(II) and Mn(II) complexes

RESULTS AND DISCUSSION:

All metal complexes having different colours, insoluble in ethanol and methanol.

Table 1: Physical and analytical data of ligand (HPMBP) and its metal complexes

Sr. No	Ligand/Metal Complexes	Colour	Yield (%)	Elemental Analysis Found % [Calc. %]				
				C	H	N	Br	M
1	HPMBP	Yellow	71	43.84 [43.93]	2.38 [2.46]	11.33 [11.38]	32.39 [32.47]	-- --
2	[Ni(II) L]	Wine	65	39.39 [39.36]	1.84 [1.82]	1.21 [10.20]	29.12 [29.16]	10.69 [10.69]
3	[Cu(II) $L(H_2O)_2$]	Green	64	36.66 [36.60]	2.39 [2.37]	9.50 [9.49]	27.10 [27.09]	10.78 [10.75]
4	[Co (II) $L(H_2O)_2$]	Brown	60	36.95 [36.90]	2.41 [2.40]	9.58 [9.55]	27.31 [27.30]	10.07 [10.6]
5	[Zn(L)]. $2H_2O$	Mustard	53	38.92 [38.90	1.81 [1.80]	10.09 [10.8]	28.77 [28.75]	11.77 [10.75]
6	[Mn (II) $L(H_2O)_2$]	Yellow	51	37.21 [37.20]	2.43 [2.41]	9.64 [9.60]	27.50 [27.48]	9.45 [9.43]

^{1}H NMR spectra of Schiff base:

The ^{1}H NMR Spectrum of ligand shows singlet for 1H at δ=10.93 ppm (pyridine ring cotaining -OH), singlet for 2H of phenolic -OH at δ=5.35 ppm, singlet for 2H (azomethinic proton) at δ=9.85 ppm[15]. The signals of seven aromatic protons observed in the range of δ=7.26 -7.68 ppm [16,17].

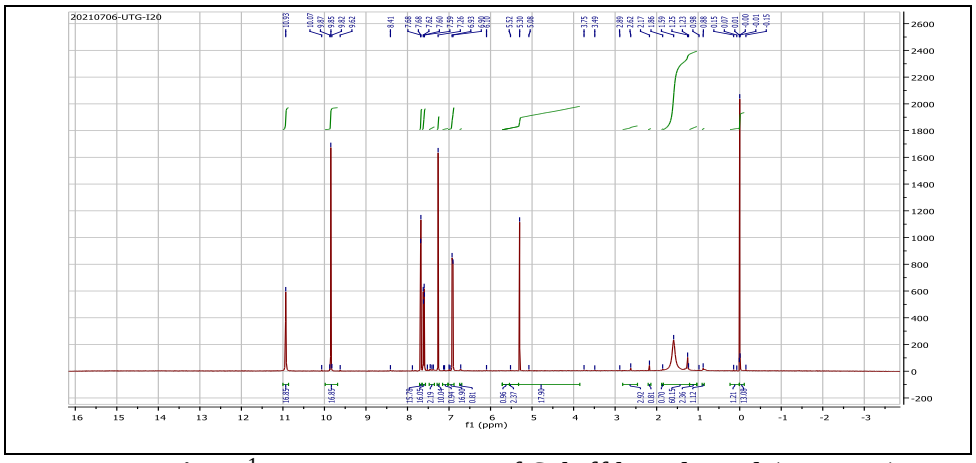


Fig.1. ^{1}H NMR spectrum of Schiff base ligand (HPMBP).

^{13}C NMR spectra of Schiff base:

The ^{13}C NMR of the Schiff base ligand i.e. 2,2'-(1E,1'E)-(6-hydroxypyrimidine-2,4-diyl)bis(azan-1-yl-1-ylidene) bis(methan-1-yl-1-ylidine)bis(4-bromophenol) was determined in $CDCl_3$. Seven signals were observed in ^{13}C NMR Spectra in the range of δ =195.32–111.24 ppm. The peak observed at δ = 160.44 ppm is due to azomethine (-CH=N-) carbon. The peaks observed at δ = 111.24 – 139.58 ppm belong to the aromatic carbons of two phenyl ring. Peak observed at δ = 195 ppm is of desheilded pyrimidine ring carbon due to conjugation effect of the electronegative nitrogen atom present in Schiff base [18]. The Peak observed at δ = 135.51 ppm may be attributed to pyrimidine ring aromatic carbons.

Mass spectrum of Schiff base:

Mass spectra is a important tools to ensure the purity of prepared Schiff base ligand (HPMBP) as well as depict their characteristic fragmentation and expected molecular weight. The mass spectrum of ligand (HPMBP) shows a peak at m/z = 491.95 (M^+ Peak) which confirms the formation of Schiff base (HPMBP).

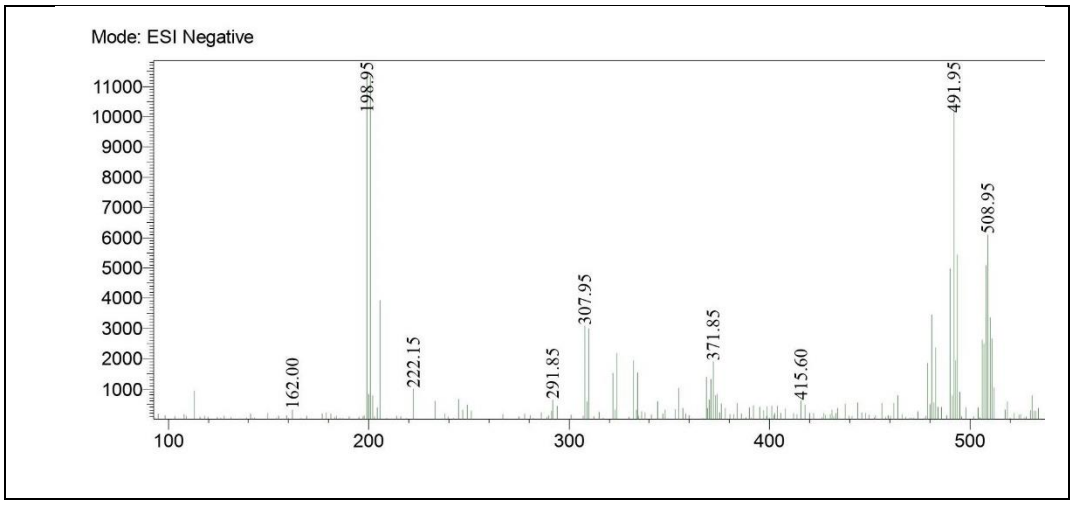


Fig.2. Mass spectrum of Schiff base ligand (HPMBP).

FT-IR analysis

The FT-IR spectral data of ligand (HPMBP) and their metal complexes were recorded and summarized in table no.2. The FT-IR spectra of the metal complexes were analysed and compaired with Schiff base ligand for elucidate the involvement of the coordination sites in chelation. The characteristics peaks in the FT-IR spectra of the Schiff base ligand and its metal complexes were considered and compared. The FT-IR spectral data of ligand (HPMBP) and its metal complexes were compared to confirm the changes during formation of complexes. Spectra of Schiff base ligand exhibited the characteristics band at 3475 cm^{-1} is due to phenolic -OH of ligand and in metal complexes the band at 3475 cm^{-1} is missing, it indicates that -OH is engaged in bonding with metal [19]. In complexation, the -HC=N-

band shifts to lower wave numbers compared to the ligand, indicating that the nitrogen atom of the azomethine group is coordinated to the metal ion. The band of week intensity observed in metal complexes in the region 506-527 cm^{-1} is assigned to M-O bond stretching frequency and in the region of 456-512 cm^{-1} is assigned to the M-N bond stretching frequency [20]. From above confirmative FT-IR spectral data it is clear that two azomethine nitrogen -HC=N- and two phenolic hydroxyl -OH group take part in the coordination with metal ion [21,22].

Table 2: FTIR spectral data of the ligand (HPMBP).and its metal complexes (cm^{-1}).

Ligand/Metal Complexes	υ(2-OH) phenilic -OH	υ(-OH) pyrimidine ring -OH	υ(C=N)	υ(M-O)	υ(M-N)
HPMBP	3545	3413	1659	--	--
[Ni(II)L]	--	3414	1616	506	488
[Cu(II) $L(H_2O)_2$]	--	3414	1625	564	478
[Co (II) $L(H_2O)_2$]	--	3415	1648	527	456
[Zn(II) L]. $2H_2O$	--	3412	1634	524	455
Mn(II) $L(H_2O)_2$]	--	3413	1637	482	451

Powder X-ray diffraction

The P-XRD of metal complexes were scanned at wave length 1.540 Å in range 2θ = 20-80°.

The strong and broad peaks indicate the formation of the metal complexes, the presence of large, weak peaks suggests a microcrystalline structure [23]. The P-XRD data is useful for determination of lattice parameters, cell parameters, crystal system etc. are given in table no.4. The P-XRD pattern shows the crystalline nature of transition metal complexes [24].

Table 3: XRD spectral data of Metal complexes.

Complexes	[Ni(II) L[	[Cu(II)$L(H_2O)_2$]	[Co(II)$L(H_2O)_2$]	[Zn(II)L].$2H_2O$	[Mn(II)$L(H_2O)_2$]
No. of reflection	12	15	17	22	13
maxima(2θ)	19.318 º	17.131º	11.862º	53.165 º	11.710 º
Intensity	16383.02 a.u.	12066.59 a.u.	1937.16 a.u.	1042.36 a.u.	15506.38 a.u.
d value	4.59100 Å	5.17187 Å.	7.45478 Å.	1.72 140 Å.	7.55119 Å.
Lattice constants	a = 14.852 Å, b = 9.121Å,	a= 13.257 Å, b = 11.235Å,	a= 10.659 Å,	a=6.870 Å. B=9.820 Å.	A=16.239Å. b= 8.610 Å.

	c = 8.129 Å	c= 15.942 Å,	b = 9.369 Å, c= 8.283Å	C=12.640 Å.	C= 6.294 Å.
Unit cell volume	947.45Å^3	2370.60 Å^3	800.11 Å^3.	748.79 Å^3.	879.40 Å^3.
Crystal Size	72.36 Å	190.40 Å	107.14 Å	153.45 Å	207.08 Å
Axis and axis angle	a ≠b ≠ c and α = γ =90^0 ≠β	a ≠b ≠ c and α = β = γ =90^0	a ≠b ≠ c and α = γ =90^0 ≠β	a ≠b ≠ c and α = γ =90^0 ≠β	a ≠b ≠ c and α = γ =90^0 ≠ β
Crystal system	Monoclinic	Orthorombic	Monoclinic	Monoclinic	Monoclinic

Thermal analysis

The thermal stability of Schiff base ligand and its complexes have been checked by thermogravimetric analysis in temperature range from 0-1000 ^{0}C under a nitrogen atmosphere. The TGA curve of the Ni(II) complex show no mass loss up to 350 ^{0}C reveals that the absence of lattice and coordinated water. At the temperature range 350-550 ^{0}C mass loss represent the removal of non coordinated part of ligand, At the temperature range 550 to 750 ^{0}C broad endothermic peak was observed may be attributed to mass loss represent the decomposition of coordinated part of ligand. Above 750 ^{0}C temperature stable nickel oxide was obtained [25]. The TGA curve of Zn(II) complex shows loss of lattice water in the temperature range 0- 100^{0}C . The temperature range 100-670 ^{0}C mass loss observed due to decomposition of ligand. In final step stable zinc oxide was formed. The thermograms of Cu[II], Co(II), and Mn(II) metal complexes shows same pattern of decomposition. In first step coordinated mass loss at 200-400 ^{0}C temperature range is attribute to elimination of two coordinated water molecule. After this temperature range 400-700 ^{0}C mass loss is represent the ligand prrolysis [26]. Finaly above 750 ^{0}C temperature residue of stable oxides of Cu[II], Co(II) and Mn(II) was formed [27,28]

Antimicrobial activities:

The Schiff base ligand and its transition metal complexes were screened against antifungal and antibacterial strain. All these synthesized complexes were found bioactive. The observation showed that the transition metal complexes are more bioactive than the Schiff base ligand (HPMBP) [29]. Activity variation of ligand and complexes depends on the permeability of the cell membrane, chelation and type of ligand donor atoms [30,31]

Table 4. Recommended values consider:

R (Resistant)	Intermediate sensitive	Sensitive	Highly Sensitive
Upto 8 mm	> 8 to 12 mm	>12-18 mm	≥ 18 mm

Antibacterial activity:

The bio-eficiency of synthesized Schiff base ligand and its transition metal complexes have been tested against one gram positive bacterial strain i.e *Staphylococcus aureus* and two gram negative bacterial strain i.e *Pseudomonas aeruginosa and Klebsiella pneumonia.* The antibacterial activity of ligand and its complexes screened by using disc diffusion method. The result showed that metal complexes exposed the good and effective inhibitory effect on the growth of bacteria than Schiff base ligand, but some complexes are non effective [32]. Cu(II) complex on *Staphylococcus aureus* (+) and *Pseudomonas aeruginosa* (-) bacterial strain shows good result of antimicrobial activity than Schiff base ligand because of their chelation capability [33]. The antibacterial activity data are summarized in table 5.

Table 5. Antibacterial activity of Schiff base ligands (HPMBP) and metal complexes series

Sample No.	***Staphylococcus aureus* (+)**	***Pseudomonas aeruginosa* (-)**	***Klebsiella pneumonia* (-)**
Control	-ve	-ve	-ve
HPMBP	R	R	R
[Ni(II)L]	R	28.5	R
[Cu(II) $L(H_2O)_2$]	21.5	10	R
[Co (II) $L(H_2O)_2$]	R	R	18.5
[Zn(II) L]. $2H_2O$	R	R	R
Mn(II) $L(H_2O)_2$]	R	R	35

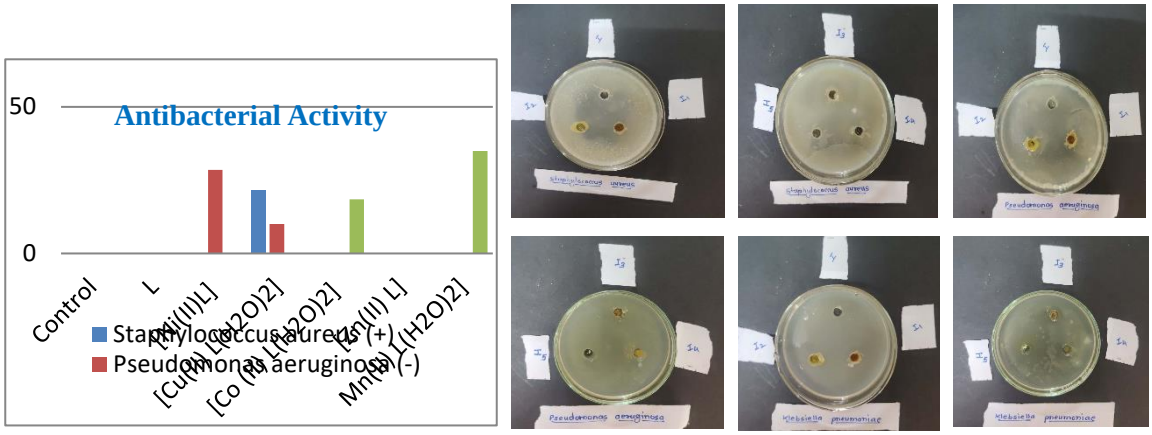


Fig.3 Inhibition zones formed for (a) *S. aureus* (b) *P. aeruginosa* (c) *K. pneumonia*

Antifungal activity:

The antifungal activity of prepared compound was evaluated by disc duffusion method [34]. The Schiff base ligand and their metal complexes were tested against four fungal strains i.e. *Penicillium chrysogenum, Trichoderma viride, Aspergillus niger and Candida albicans* Fungi. The antifungal screening result exposed that Schiff base ligand and its all the metal complexes showed highly sensitive against *Penicillium chrysogenum, Aspergillus niger and Candida albicans*. However, they show inferior fungal activity against *Trichoderma viride*. The superior antifungal activity proved that the presence of azomethine group in ligand and metal complexes for their potential use in the region of medicinal bio-inorganic chemistry [35]. The antifungal activity data is given in table 6.

Table 6. Antifungal activity of Schiff base ligands (HPMBP) and metal complexes series

Sample No.	***Penicillium chrysogenum***	***Trichoderma viride***	***Aspergillus niger***	***Candida albicans***
Control	-ve	-ve	-ve	-ve
HPMBP	30	R	30	40
[Ni(II)L]	30	R	30	40
[Cu(II) $L(H_2O)_2$]	30	R	35	30
[Co (II) $L(H_2O)_2$]	30	R	35	35
[Zn(II) L]. $2H_2O$	30	R	35	23
Mn(II) $L(H_2O)_2$]	30	R	35	40

Fig.4 Inhibition zones formed for (a) *P.chrysogenum*, (b) *A.niger* (c) *C.albicans* (d) *T.viride*

CONCLUSION:

In this article, coordination chemistry of 2,2'-(1E,1'E)-(6-hydroxypyrimidine-2,4-diyl)bis(azan-1-yl-1-ylidene)bis (methan-1-yl-1-ylidine)bis(4-bromo phenol) (HPMBP) Schiff base ligand was described. The characterization confirmed the composition and structure of ligand and its metal complexes. From spectral data it was observed that Ni(II) and Zn(II) complexes having tetrahedral structure while Cu(II), Co(II) and Mn (II) having octahedral structure. The Schiff base ligand coordinates to metal through azomethine nitrogen and phenolic -OH of Schiff base ligand (HPMBP). P-XRD data suggest monoclinic crystal system for Ni[II], Co[II], Zn[II] and Mn[II] metal complexes and orthorhombic crystal system for Cu[II] complex. The biologicl activity screening showed that the transition metal complexes are more bioactive than the Schiff base ligand.

ACKNOWLEDGMENTS:

The authors are thankful to the Director, SAIF Chandigarh for providing the facility of IR, the Director, Scientific Instrumentation Centre, Punyashlok Ahilyadevi Holkar Solapur University, Solapur. for providing XRD analysis, the Director, Scientific Instrumentation Centre, Dr. Babasaheb Ambedkar Marathwada University, Chh.Sambhajinagar for providing TGA analysis and also wish to extend their gratitude to the Principal, Balbhim Arts, Science and Commerce College Beed for providing necessary laboratory facilities.

REFERENCES:

1. *Md. Arifuzzaman, Mohammad R. Karim, Tasneem A. Siddiquee, Aminul H. Mirza and Mohamad A. Ali, "Synthesis and Characterization of New Schiff Bases Formed by Condensation of 2,9-Phenathroline-1,10-dialdehyde with Sulfur-Containing Amine", International Journal of Organic Chemistry., vol. 3,* ***(2013)****, pp. 81-86.*
2. *Bushra Mohan and Naser Shaalan, "Synthesis, Spectroscopic and Biological Activity Study for New Complexes of Some Metal Ions with Schiff Bases Derived From 2-Hydroxy Naphthaldehyde with 2-amino benzaldehyde", Ibn Al-Haitham Journal for Pure and Applied Sciences., vol. 36, no. 1,* ***(2023)****.*
3. *Mohammad Nasir Uddin, Sayeda Samina Ahmed and S. M. Rahatul Alam****, "****Review: Biomedical applications of Schiff Base Metal Complexes", Journal of Coordination Chemistry., vol. 73, no. 23,* ***(2020)****, pp. 3109–3149.*
4. *G.B. Pethe, K.A. Thakare, A.S. Aswar, "Synthesis, Spectral and Thermal Study: Transition Metal Complexes of Hydrazine Ligand", Journal of Research in Chemistry., vol. 4, no. 2,* ***(2023)****, pp. 7-13*
5. *Asnake Lealem Berhanu, Gaurav, Irshad Mohiuddin, Ashok Kumar Malik, Jatinder Singh Aulakh, Vanish Kumar and Ki-Hyun Kim, "A Review of the Applications of Schiff Bases as Optical Chemical Sensors", Trends in Analytical Chemistry., vol. 116,* ***(2019)****, pp. 74-91.*
6. *May Joda Kareem, "Synthesis, Spectroscopic Study and Biological Activity of new Bidentate Schiff Base (4-(Dimethylamino) Benzylidene)-5-(3,4,5-Trimethoxybenzyl)-5 Pyrimidine-2,4-Diamine) and Transition Metal Mn(II), Ni(II) and Cu(II) Complexes", Pakistan Journal of Medical & Health Sciences., vol. 16, no. 05,* ***(2022)****, pp. 655-659.*
7. *J. Zhang, L. Xu and W. Wong, "Energy Materials Based on Metal Schiff Base Complexes", Coordination Chemistry Reviews., vol. 355* ***(2018)****, pp. 180-198.*
8. *R. Jayalakshmi, V. Jayakkumar, D. Dhivya Priya and Dr. R. Rajavel, "Synthesis and Characterization of 4-Amino Antipyrine Based Schiff Base Complexes: Antimicrobial, Cytotoxicity and DNA Cleavage Studies", International Journal of Engineering Research & Technology., vol. 6, no. 08,* ***(2017).***
9. *K. Brodowska and E. Łodyga-Chruścińska, "Schiff Bases-Interesting Range of Applications in Various Fields of Science", Chemik., vol. 68, no. 2,* ***(2014)****, pp. 129-134.*
10. *G. Srıdevı, S. Arul Antony and R. Angayarkanı, "Schiff Base Metal Complexes as Anticancer Agents", Asian Journal of Chemistry., vol. 31, no. 3,* ***(2019)****, pp. 493-504.*
11. *Tuly Paul, Md. Faruk Hossen, Md. Kudrat-E-Zahan, Md. Masuqul Haque, Md. Saddam Hossain, Rausan Zamir and Md. Ali Asraf, "Schiff Base Metal Complexes: Synthesis,*

Characterization, Thermal Analysis and Antibacterial Activity", Asian Journal of Research in Chemistry., vol. 13, no. 4, ***(2020)****.*

12. *M. A. Malik, O. A. Dar, P.Gull,, M. Y. Wani and A. A. Hashmi, "Heterocyclic Schiff Base Transition Metal Complexes in Antimicrobial and Anticancer Chemotherapy", Medicinal Chemistry Communication., vol. 9,* ***(2018)****, pp. 409-436.*
13. *K. Sruthi, M. Sumakanth, C.B. Mahendra Kumar and K. Naresh, "Nitrogen Bridged Imidazo Pyrimidine Acetamides: Synthesis, Molecular Docking, Toxicity Prediction and Anti-proliferative Studies", European Journal of Biomedical and Pharmaceutical Sciences., vol. 4, no. 5,* ***(2017)****, 313-320.*
14. *A. sakthivel, K. Jeyasubramanian, B. Thangagiri and J. Dhaveethu Raja, "Recent Advances in Schiff Base Metal Complexes Derived from 4-Aminoantipyrine Derivatives and Their Potential Application", Journal of Molecular Structure., vol. 1222, no. 128885* ***(2020)****.*
15. *Mehmet Sonmez, Abdulkadir Levent, and Memet S ekerci, "Synthesis and Characterization of Cu(II), Co(II),Ni(II), and Zn(II) Complexes of a Schiff Base Derived from 1-Amino-5-benzoyl-4-phenyl-1Hpyrimidine-2-one and 3-Hydroxysalicylaldehyde", Synthesis And Reactivity In Inorganic And Metal-Organic Chemistry., Vol. 33, no. 10,* ***(2003)****, pp. 1747–1761.*
16. *M. Priyadharsani, P.Tharmaraj, C.D. Sheela and J.Jone Celestina, "Novel Hydroxy Pyrimidine Based Chelating Ligand for Microbial Evaluation Studies", International Journal of Scientific Research and Reviews., vol. 8, no. 2,* ***(2019)****, pp. 4167-4176.*
17. *M. Usharani, E. Akila, S. Ramachandran, G. Velraj and R. Rajavel, "Synthesis, Composition, Geometry and Antibacterial Assay of Binuclear Schiff Base Metal Complexes Derived from Benzene-1,4-Dicarbaldehyde, 2-Hydroxy-Benzaldehyde and Pyridine-2,6-Diamine", International Journal of Pharmacy and Pharmaceutical Science., vol. 5,* ***(2013)****, pp. 639-647.*
18. *R. Mohammed Shafeeulla, G, Krishnamurthy, H. S. Bhojnaik, H. P. Shivarudrappa and Yallappa Shiralgi, "Spectral, Thermal, Cytotoxic and Molecular Docking Studies of N0-2-Hydroxybenzoyl; Pyridine-4-Carbohydrazide its Complexes", Beni-Suef University Journal of Basic and Applied Sciences., vol. 6, no.4,* ***(2017)****.*
19. *N. K. Ocek, S. K. Ocek and F. Kormali, Mono-, Di- and Tri-Nuclear Copper(II) Complexes of a Schiff Base Ligand, 2-{(E)-[(6-{[(1E)-(2-hydroxyphenyl) methylene] amino}pyridin-2-yl)imino]-methyl}phenol, Turkish Journal of Chemistry., vol. 31, no. 3,* ***(2007)****, pp. 271-277.*

20. *Rajendra K. Jain and A.P. Mishra, "Microwave Synthesis, Spectral, Thermal, 3D Molecular Modeling Analysis and Antimicrobial Activities of Some Transition Metal Complexes of Schiff Bases Derived from 5-Bromosalicylaldehyde", Journal of Saudi Chemical Society., vol. 20,* ***(2016)****, pp. 127-137.*
21. *A. Etorki, S, Ben-saber and A. Maihub, "Metal Ions Uptake using Schiff Bases Derived from Salicylaldehyde and Appropriate Amino Compounds", Journal of Chemistry and Chemical Engineering., vol. 7,* ***(2013)****, pp. 193-199.*
22. *A. Z. El-Sonbati and A. A. El-Bindary, "Stereochemistry of New Nitrogen Containing Aldehydes. V. Novel Synthesis and Spectroscopic Studies of Some Quinoline Schiff Bases Complexes", Polish Journal of Chemistry., vol. 74,* ***(2000)****, pp. 621-630.*
23. *Bismi S Prakash, Isac Sobana Raj C and Allen Gana Raj G., Zr(Iv) And Th(Iv) Complexes with Schiff Base Ligands: Synthesis, Characterization, Antimicrobial Studies, International Refereed Journal of Engineering and Science., vol 6, no 10,* ***(2017)****, pp. 43-53.*
24. *Abdulaziz Ali Alomari1 and Mohamed Mustafa Ibrahim, "Synthesis and Thermogravimetric Behavior of Ni(II), Cu(II) and Zn(II) Complexes of Triazine-Salicyldamine Schiff Bases", Asian Journal of Advance and Basic Science., vol. 3, no.2,* ***(2015)****, pp. 20-25.*
25. *Achut S. Munde, Amarnath N. Jagdale, Sarika M. Jadhav and Trimbak K. ChondhekaR, "Synthesis, characterization and thermal study of some transition metal complexes of an asymmetrical tetradentate Schiff base ligand", Journal of Serbian Chemical Society., vol. 75 no. 3* ***(2010)****, pp. 349–359.*
26. *Kuldeep B. Sakhare, Kirti N. Sarwade, Yogesh N. Bharate, Mahadeo A. Sakhare, "Anticancer Acitivity of Schiff Base Ligand(E)-4-((5-chloro-2 hydroxybenzylidene) amino)-1, 5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one and its Co(II), Cu(II) and Zn(II) Metal Complexes", Journal of Serbian Chemical Society., vol. 89 no. 2,* ***(2024)****, pp. 165-175.*
27. *Arvind K. Aghao, Dnyandeo M. Janrao, Siddharth D. Janrao and S. A. Survase, "Synthesis and Characterization of Mn (II),Co(II), Ni(II), Cu(II) and Zn(II) Complexes Derived from 3-[(pyridine-2-ylimino) methyl] quinoxalin-2-ol", Der Chemic Sinica., vol. 6, no, 5,* ***(2015)****, pp. 90-95.*
28. *M. A. Sakhare, S. L. Khillare, M. K. Lande and B. R. Arbad, "Synthesis, Characterization and Antimicrobial Studies on La(III), Ce(III) and Pr(III) Complexes with a Tetraaza Macrocyclic Ligand", Advances in Applied Science Research., vol. 4, no.1,* ***(2013)****, pp. 94-100.*

29. *W. Al Zoubi, A. A. S. Al-Hamdani, S. D. Ahmed, and Y. G. Ko, "Synthesis, Characterization, and Biological Activity of Schiff Bases Metal Complexes," Journal of Physical Organic Chemistry., vol. 31, no. 2,* ***(2018)****, pp. 1-7.*
30. *S. El-Sayed Saeed, Budoor A. Alomari, Ahmed N. Al-Hakimi, M. M. Abd El-Hady, Jawza Sh Alnawmasi, Hussein H. Elganzory, and Wael A. El-Sayed, "Pyrimidine hydrazide Ligand and its Metal Complexes: Synthesis, Characterization and Antimicrobial Activities", Egyptian Journal of Chemistry., vol. 66, no. 5,* ***(2023)****, pp. 315-329.*
31. *Irfan Mushtaq, Maqbool Ahmad, Muhammad Saleem and Adnan Ahmed, "Pharmaceutical Significance of Schiff Bases: An overview", Future Journal of Pharmaceutical Sciences., vol. 10, no. 16* ***(2024)***
32. *Mehmet Gulcan, Mehmet Sonmez andIsmet Berber, "Synthesis, Characterization, and Antimicrobial Activity of a New Pyrimidine Schiff Base and its Cu(II), Ni(II), Co(II), Pt(II), and Pd(II) Complexes", Turkish Journal of Chemistry., vol. 36,* ***(2012)****, pp. 189 – 200.*
33. *Sahul Hameed Sukkur Saleem, Murugesan Sankarganesh, Jeyaraj Dhaveethu Raja, Paul Raj Adwin Jose, Arumugam Sakthivel, Thayalaraj Christopher Jeyakumar and Radhakrishnan Nandini Asha, "Synthesis, Characterization, DFT Calculation, Biological and Molecular Docking of Cu(II) Complex of Pyrimidine Derived Schiff Base Ligand", Journal of Saudi Chemical Society., vol. 25, no. 101225,* ***(2021)****.*
34. *M.L. Sundararajan, T. Jeyakumar, J. Anandakumaran and B. Karpanai Selvan, "Synthesis of Metal Complexes Involving Schiff Base Ligand with Methylenedioxy Moiety: Spectral, Thermal, XRD and Antimicrobial Studies", Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, vol. 131,* ***(2014)****, pp. 82-93.*
35. *Alessia Catalano, Maria Stefania Sinicropi, Domenico Iacopetta, Jessica Ceramella, Annaluisa Mariconda, Camillo Rosano, Elisabetta Scali, Carmela Saturnino and Pasquale Longo,* ***"****A Review on the Advancements in the Field of Metal Complexes with Schiff Bases as Antiproliferative Agents", Applied Sciences., vol. 11, no. 6027,* ***(2021)****.*