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METAL COMPLEXES OF SCHIFF BASE DERIVED FROM 4-(DIETHYLAMINO) SALICYLDEHYDE WITH ANILINE: CHARACTERIZATION, COMPUTATIONAL ANALYSIS, AND ANTIBACTERIAL ACTIVITY STUDY

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ABSTRACT

A biologically active Schiff base derived from 4-(diethylamino)salicylaldehyde with aniline and its Zn(II), Cd(II), Sn(II), and Pb(II) complexes have been synthesized and characterized by various physicochemical techniques. The structure optimization by computational analysis supports the geometry of the metal complexes. The Schiff base existed as a bidentate ligand bonded to the metal ion through the deprotonated phenolic oxygen and the azomethine nitrogen forming neutral ML_2 metal chelates. The synthesized ligand and their metal complexes have been screened at three different concentrations and compared for their antibacterial action against bacterial species *Streptococcus, Staph, Staphylococcus aureus,* and *Escherichia coli.* The result shows that the metal complexes are more bioactive than ligands.

Keywords: Antibacterial Activity, Metal Complexes, Molecular Modeling, Schiff Base, Spectral Studies.

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INTRODUCTION

Schiff bases are considered "exclusive ligands" because they are easily synthesized and form stable complexes with almost all metal ions. The activity is usually increased by complexation to understand the properties of both Schiff base and metal can lead to the synthesis of highly active compounds.[1] Schiff base ligands are derived from an amino compound and carbonyl compound under specific conditions and have their synthetic flexibility, selectivity, and sensitivity towards the metal ions. The influence of different metals on the bioactivity of these compounds and their intrinsic chemical interest as multidentate Schiff base ligands has prompted a considerable increase in their complexation behavior. Its metal complexes have been extensively investigated due to a wide range of applications as catalysts, medicine (especially as chemotherapeutic agents), and anti-corrosion and also they have many biochemical, clinical, and pharmacological properties.[2] The improved biological properties of Schiff base complexes over their precursor ligands, and the chelation effect improves the lipophilicity of the compound and also lead to the formation of a more stable metal-organic framework.[3,4] Many Schiff base complexes show high catalytic activity and have a significant role to enhance their yield and product selectivity. The convenient route of synthesis of Schiff base complexes and their thermal stability have contributed to their possible applications in catalysis.[5] The chelating property of Schiff base also plays a significant role in its antioxidant activity and this could be useful in the design and development of compounds with anticancer activity.[6]

This manuscript presents the synthesis, characterization, molecular modeling, and biological activities of complexes of Schiff base derived from 4-(diethylamino)salicylaldehyde and aniline with Zinc(II), Cadmium(II), Tin(II), and Lead(II) ions. Computational analysis has become a useful tool for theoretical calculation to predict stereochemical structures. The newly synthesized Schiff base ligand and its

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complexes have been tested *in vitro* against *Streptococcus, Staph, Staphylococcus aureus,* and *Escherchia coli* bacteria with different concentrations in order to assess their antimicrobial potential.

EXPERIMENTAL

General and Instrumentation

All the reagents, starting materials as well as solvents used were of analytical grade, purchased commercially, and used without any further purification. The melting point of the synthesized compounds was recorded on an OMEGA melting point apparatus. Elemental C, H, and, N analysis were carried out on an Elementar Vario EL III model. Shimadzu flame atomic absorption spectrophotometer was used to estimate metal content by decomposing the complex in hot concentrated nitric acid. Bruker Advance 400MHz instrument was used for recording ^{1}H NMR spectra. The solid-state Fourier transform infrared (FTIR) spectra were recorded on Perkin Elmer FTIR spectrophotometer in the range of 4000-400 cm^{-1} and 400-100 cm^{-1} in potassium bromide and polyethylene pellets respectively. The Ultraviolet-Visible spectra were recorded using Shimadzu 160A Ultraviolet spectrometer in the range of 1100-100 nm. Mass spectra (TOF-MS) were recorded on the Waters KC-455 model with ES^+ mode. Computational analysis of the proposed structure of the complexes was performed using *HyperChem* professional version 7.51 program package. *In vitro* antibacterial activity of the synthesized compounds against *Streptococcus, Staph, Staphylococcus aureus,* and *Escherchia coli* bacteria was carried out using the paper disc method.[7] The solution of all compounds was prepared in double distilled water and chloramphenicol was used as a reference.

Synthesis of 4-(Diethylamino) Salicyldehyde Aniline Schiff Base Ligand

4-(diethylamino) salicylaldehyde (0.01 moles) and aniline (0.01 moles) with a few drops of anhydrous $ZnCl_2$ was transferred to a round bottom flask containing 20 ml ethanol. The reaction mixture was refluxed at 100°C for 3h. The hot reaction mixture was cooled, and a dark yellow solid mass separated out. The resulting solid mass was filtered, washed first with distilled water and then with cold ethanol, and finally dried in vacuum desiccators. The dried mass was recrystallized from ethanol to obtain the pure product (Fig.-1) proposed structure of the ligand)**.**

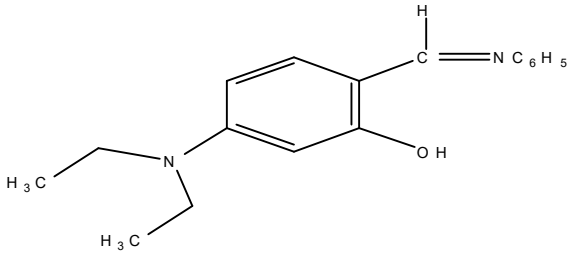

Fig.-1: Proposed structure of the ligand : 4-(diethylamino)salicyldehyde aniline)

Synthesis of Metal Complexes

The newly synthesized ligand 4-(diethylamino) salicylaldehyde aniline Schiff base (5 m mol) in 20 ml of absolute ethanol was added to a solution containing metal salt (Zinc(II) Acetate, Cadmium(II) Acetate, Tin(II) Chloride, and Lead(II) Chloride) (2.5 m mol) in 20ml absolute ethanol with constant stirring. Stirring was continued with heating at 60^0C for 4h, after which the volume was reduced on a water bath. On adding a few drops of dilute Sodium hydroxide, the precipitate was obtained. After cooling at room temperature the precipitate was filtered, washed with cold ethanol, and dried over P_4O_{10} in *vacuo*. The dried mass was recrystallized from ethanol to obtain the pure product (Fig.-2: Proposed structure of complexes).

RESULTS AND DISCUSSION

The analytical data for the Schiff base and its complexes together with some physical properties are summarized in Table-1. The analytical data of the complexes correspond well with the general formula ML_2 where M= Zn(II), Cd(II), Sn(II), and Pb(II) and HL = $C_{17}H_{20}N_2O$ [4-(diethylamino) salicylaldehyde aniline Schiff base]. The complexes were obtained in powder form and sufficiently soluble in Acetone and DMSO.

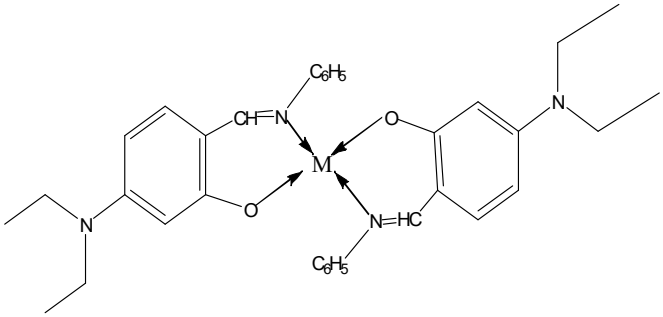

Fig. -2: Proposed structure of the complexes, M= Zn(II), Cd(II), Sn(II) and Pb(II)

Table -1: Analytical and electronic spectral data of the ligand and their metal complexes

S. No.	Compound/complex (Empirical formula)	Color	MP (^{0}C)	Yield %	Analysis Found (Calculated) (%)					Electronic spectra(nm)
					C	H	O	N	M	
1	Ligand ($C_{17}H_{20}ON$)	Dark yellow	159	85	76.08 (76.13)	7.50 (7.55)	5.96 (5.92)	10.43 (10.50	- -	325,386
2	Complex I [Zn($C_{17}H_{18}ON_2$)$_2$]	Pale yellow	217	87	68.31 (68.29)	6.02 (6.08)	5.35 (5.39)	9.37 (9.43)	10.94 (10.98)	340.392
3	Complex II [Cd ($C_{17}H_{18}ON_2$)$_2$]	Dull green	298	86	63.10 (63.18)	5.58 (5.50)	4.96 (4.99)	8.69 (8.72)	17.44 (17.46)	335,395
4	Complex III [Sn ($C_{17}H_{18}ON_2$)$_2$]	Grey	287	82	62.70 (62.68)	5.53 (5.55)	4.91 (4.960	8.60 (8.57)	18.24 (18.29)	337,391
5	Complex IV [Pb ($C_{17}H_{18}ON_2$)$_2$]	White	373	80	55.20 (55.26)	4.87 (4.91)	4.33 (4.40)	7.57 (7.60)	28.02 (27.99)	343,394

Spectroscopic Studies

The structural features of the synthesized Schiff base ligand and metal complexes were studied by ^{1}H NMR spectroscopic investigations. The ^{1}H NMR signal associated with the OH group was observed at 13.12 ppm in ligand but on complexation, no signal of the phenolic hydrogen indicates deprotonation of the ortho-hydroxyl group (Fig.-3: ^{1}H NMR spectrum of the complex I).

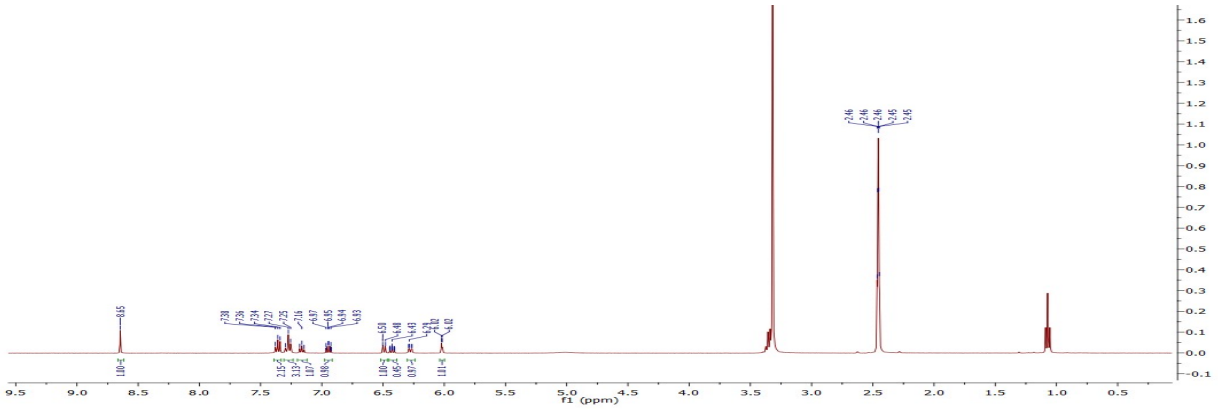

Fig- 3: ^{1}H NMR of complex I

A characteristic sharp signal was observed at 8.3-8.7 ppm, due to C(H)=N proton in complexes, indicating the equivalent magnetic environment for all such protons. This observation suggests the presence of a planar ligand in the synthesized Schiff base complexes.[1] A multiplet peaks were observed within the range of 6.3-7.6 ppm, assigned chemical shifts for the hydrogen of the symmetrical aromatic ring. Protons on the methylene group attached to a nitrogen atom N-CH_2- with resonances in the region of 2.30-2.60 ppm as a singlet pattern. Furthermore, the aliphatic protons are unaffected upon complexation. The infrared spectrum of the ligand (Fig.-4a), shows a broad band between 3200-3600 cm^{-1}, which can be

attributed to the phenolic OH group.[8] This band is either disappears or shifted to a lower frequency in complexes, which can be attributed to the involvement of the phenolic OH group in coordination. The coordination of deprotonated phenolic group in complexes is confirmed by the shift of ν(C-O) stretching band observed at 1390 cm^{-1} in the free ligand to a lower frequency to the extent of 10-20 cm^{-1}, suggests the weakening of ν (Ph-C-O) and formation of stronger M-O bond.[9] The free Schiff base ligand exhibited a characteristic strong band at1660 cm^{-1}, attributed to the azomethine(-HC=N) group, which were shifted to lower frequencies(1650-1630 cm^{-1}) in the complexes due to the chelation of the imine nitrogen to the metal ions. Coordination of the Schiff base to the metal through the nitrogen atom is expected to decrease electron density in the azomethine link and lower the ν(C=N) absorption frequency.[10] (Fig.-4b-e: Infrared spectrum of complexes).The appearance of new bands in the spectra of all metal complexes in the low-frequency regions ν (M-N) 420-408cm^{-1} and ν(M-O) 530-520cm^{-1}, were not observed in the spectra of free Schiff base ligand. The M–O stretching frequencies for the metal ions show good agreement with Irving–William's stability order.[11]

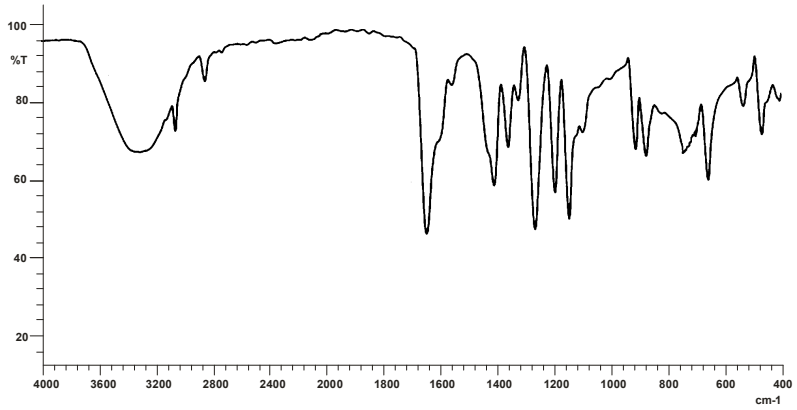

Fig.- 4a: Infrared Spectrum of the Ligand

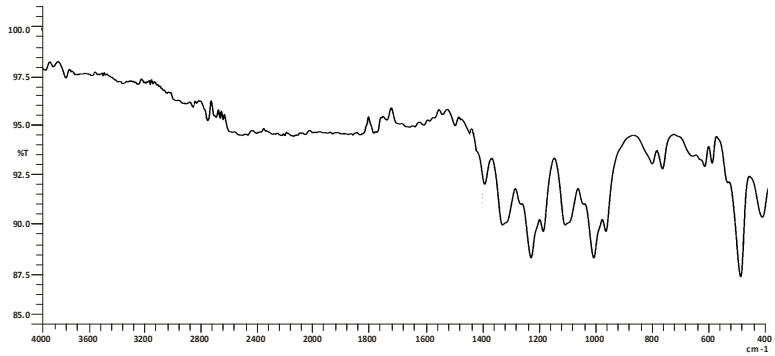

Fig.- 4b: Infrared spectrum of Complex I

Fig.-4c: Infrared spectrum of the complex II

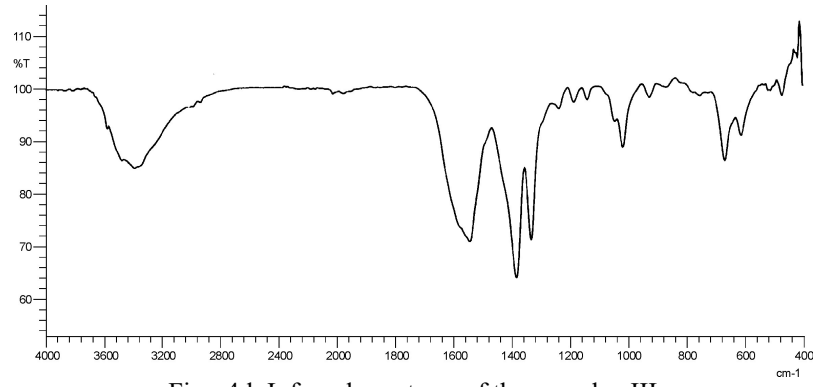

Fig.- 4d: Infrared spectrum of the complex III

Fig.- 4e: Infrared spectrum of the complex IV

The ultraviolet-visible spectra of the ligand exhibited two bands observed at 325 and 386nm, attributed to benzene π →π* transition and azomethine n→π* transition respectively. In complexes, the two bands due to π →π* and n→π* transitions were observed but the bands due to azomethine(C=N) n→π* has shifted to the lower wavelength, due to donation of the lone pairs of the nitrogen atoms to metal ions[12] (Table-1: Electronic spectral data). The mass spectrum of the Schiff base ligand shows a molecular ion peak at m/z 269 confirming the purity of the ligand. The molecular formulas calculated from microanalytical data for complexes have been supported by the TOF-mass studies. The metal complexes' initial fragmentation pattern is similar, a binuclear nature for these complexes $[M(L_2)]^+$can be deduced(Fig.-5a-d: TOF Mass spectrum of the complexes). The mass spectrum of the complexes has a molecular ion peak at m/z 600/601 (complex I), m/z 647/648 (complex II), m/z 653/654(complex III), and m/z 742/743(complex IV) respectively, further confirming the purity of the complexes. The prominent peak at m/z 123 in all the complexes is the degradation of $[C_7H_8NO]^+$ molecule which is the result of demetallation and subsequently a partial intramolecular hydrogen bonding.[13]

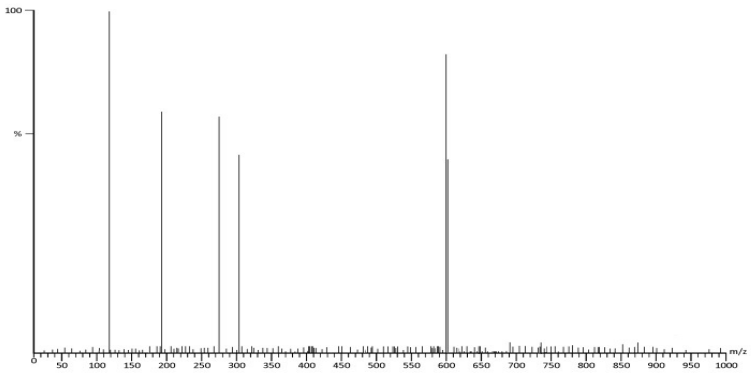

Fig.- 5a: TOF mass spectra of complex I

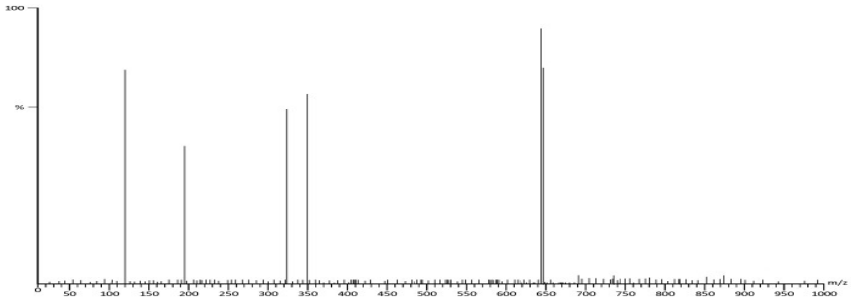

Fig.-5b: TOF mass spectra of complex II

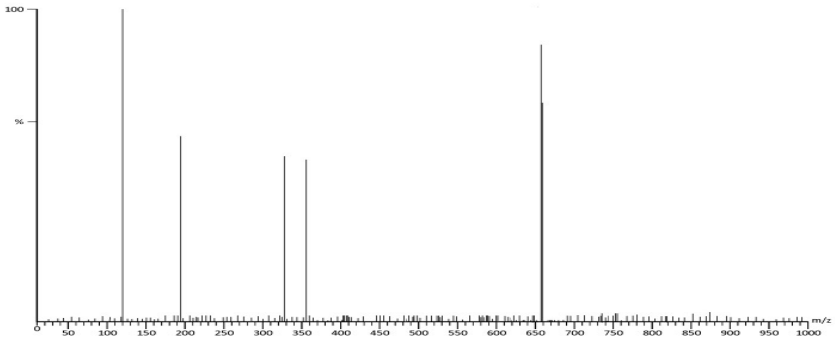

Fig.- 5c: TOF mass spectra of complex III

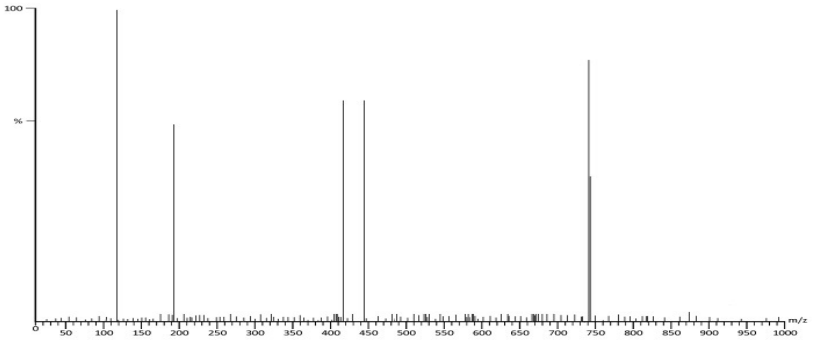

Fig.-5d: TOF mass spectra of complex IV

Molecular Modeling

The minimized energy values for the metal complexes, with and without restricting the structure are almost the same as shown in (Fig.-6a-d: Optimized structure of complexes along with bond length(Å)).

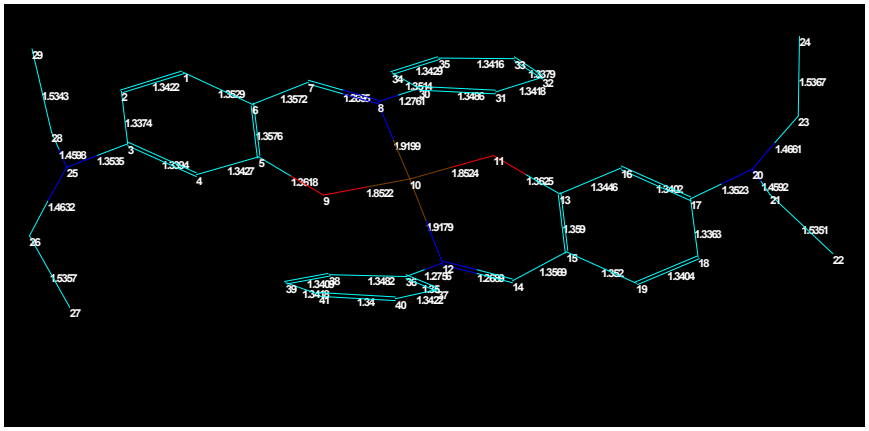

Fig.-6a: Optimized structure of complex I

Complex I have greater binding energy than complex II followed by complex III followed by IV and also indicates a similar trend of the heat of formation. The energy minimization value for square planar and without restricting the structure for the Zn(II), Cd(II), Sn(II) and Pb(II) complexes are 44.07kcal/mol with gradient 0.9990, 50.1691kcal/mol with gradient 0.9896, 64.3762kcal/mol with gradient 0.9585 and 100.6085kcal/mol with gradient 0.9985 respectively. The energy minimization values for the Zinc complex have a minimum of Cadmium complex and then tin complex than a Lead complex which has maximum energy. It indicates Zinc complex has maximum stability than other metal complexes.

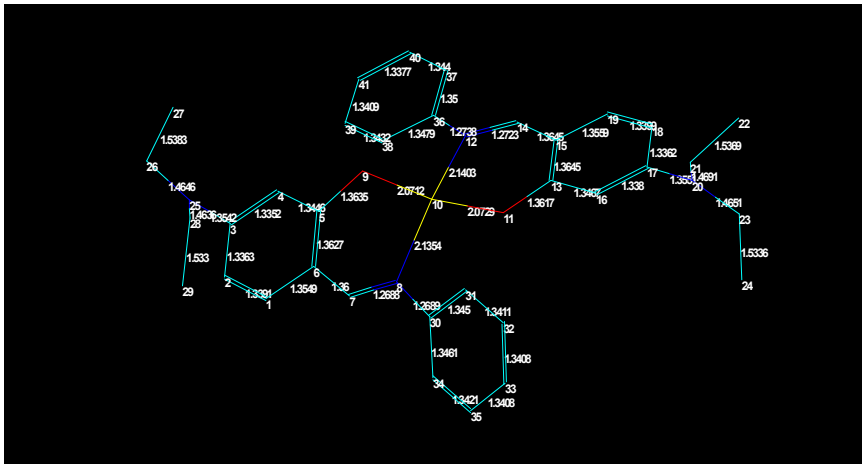

Fig.-6b: Optimized structure of complex II

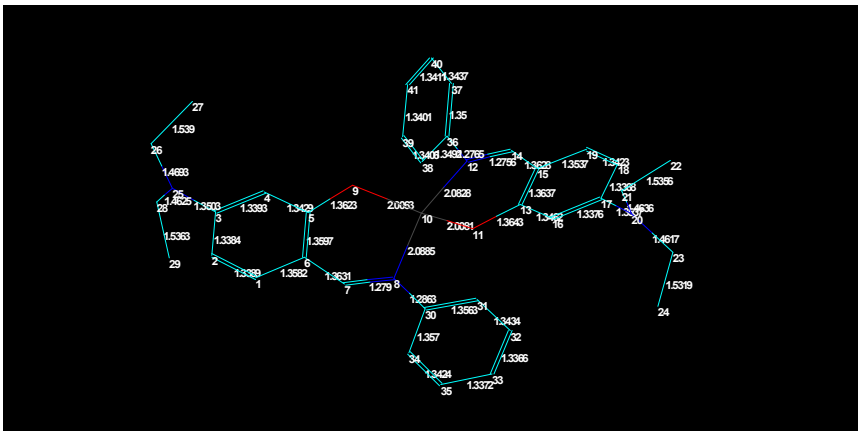

Fig.-6c: Optimizrd structure of complex III

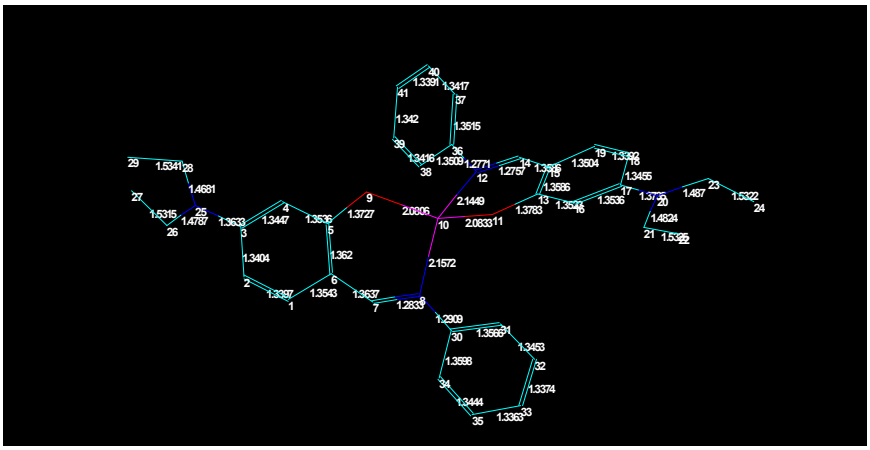

Fig.-6d: Optimizrd structure of complex IV

Antibacterial Screening

In vitro antibacterial activity of the synthesized compounds against *Streptococcus, Staph, Staphylococcus aureus* and *Eschrchia coli* were carried out. The ligand bears activity even better than reference chlorophinacol. Three different concentrations of the synthesized compound have been selected for antibacterial studies. The metal complexes deliver better antibacterial activity at their higher concentration. The ligand and complexes I and III exhibits high activity against *Escherichia coli* and others show very effectiveness against *Staphylococcus aureus* bacteria. The activity was the least against the staph bacteria (Fig.-7a-b).

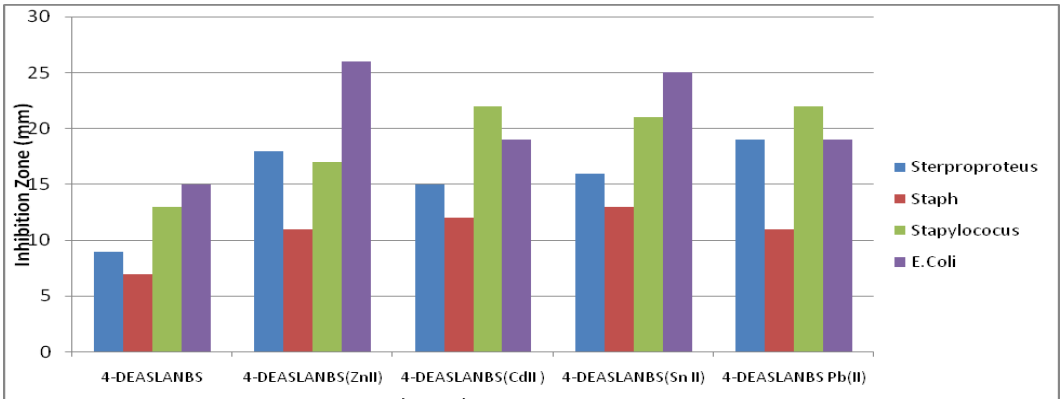

Fig.-7a: Antibacterial activities of synthesized compounds

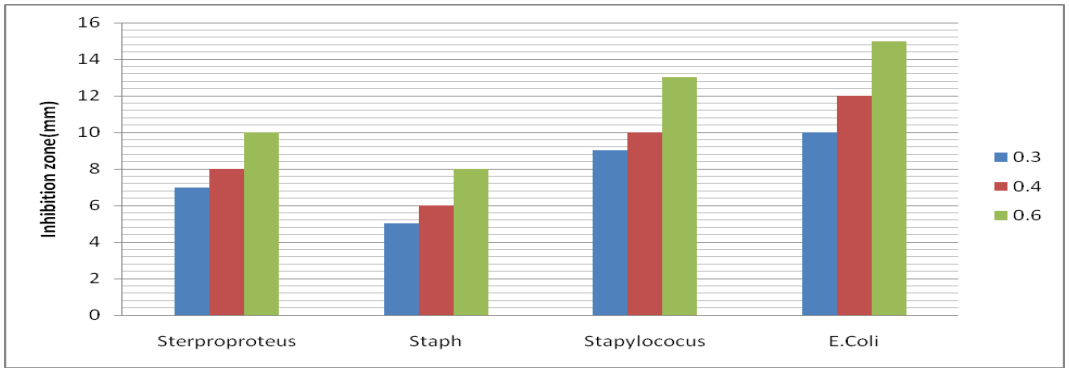

Fig.-7b: Effect of complex III on its antibacterial potential with varying concentration

The zinc complex showed better activity than other metal complexes for microorganisms. All the metal complexes are more toxic than the ligand. The enhanced activity of the complexes may provide stability and more susceptibility to bacteria. The Schiff base having (C=N) bond with nitrogen and oxygen donor system inhibit enzyme activity due to their deactivation by metal complexes. It permits their efficient permeation through the lipid layer of organisms and destroys their bioactivity.[14]

CONCLUSION

The new Salicylaldehyde Schiff base ligand and its metal complexes were synthesized and characterized by spectral studies and the geometries of the newly synthesized compounds have been proposed. The infrared spectral data displayed the chelation sites of the Schiff base ligand towards the metal ions and electronic absorption spectroscopy exhibited the existence of phenyl ring $\pi \rightarrow \pi^*$ transition and azomethine $n \rightarrow \pi^*$ transitions in the complexes. DFT calculation helps to determine the bond angle and bond length of optimized structures. The ligand and metal complexes were screened *in vitro* for antibacterial studies. The Zn(II) complex was found to be most active against the growth of bacteria.

REFERENCES

1. B.Iftikhar, K. Javed, M.S.U. Khan, Z. Akhtar, B. Mirza, V. Mckee, *Journal of*

*MolecularStructure,***1155**,337(2018), http://doi.org/ 10.1016/j.molstruc.2017.11.022
2. (a)W. Al Zoubi, *International Journal of Organic Chem*istry, **3**, 73(2013), http://doi.org/10.4236/ijoc.2013.33A008 (b) L.J. Li, C.Wang, C. Tian, X.Y.Yang, X.X.Hua, J.L. Du, *Research on Chemical Intermed*iates, **39(2)**,733(2013) (c) S. Arulmurugan, H. P. Kavitha, B. R. Venkatraman, *Rasayan Journal of Chem*istry **3(3)**, 385(2010).
3. (a) A. M. Abu-Dief, I. M. A. Mohamed, *Journal of Basic and Applied Sciences* **4(2)**,119(2015), https://doi.org/10.1016/j.bjbas.2015.05.004
4. C. Festus, S. N. Okafor, A. C. Rkennia, *Journal of Organic Chemistry Forntiers*, **7**, 862(2019), http://doi.org/10.3389/fchem.2019.00962
5. K.C.Gupta, A.K.Sutar, *Coordination Chemistry Rev*iews, **252(12)**, 1420(2008), http://doi.org/ 10.1016/j.ccr.2007.09.005
6. D. Ghosh, S.T. Choudhury, S. Ghosh, A.K. Mandal, S. Sarkar, A Ghosh, K.D. Shaha, N. Das, *Chemistry Biolgical Interact,* **195(3)**, 206(2012), http://doi.org/ 10.1016/j.cbi.2011.12.004
7. A. A. Khandar, S. A. Hosseini-Yazdi,S. A. Zarei , *Inorganic Chimica Acta,* **358**, 3211(2005), https://doi.org/10.1016/j.ica.2005.04.028
8. M. Jafari, M. Salehi, M. Kubicki, A. Arab, A. Khaleghian, *Inorgnica Chimca Acta* **462**, 329(2017), http://doi.org/ 10.1016/j.ica.2017.04.007
9. T.H. Sanatkar, A. Khorshidi, J. Janczak, *Applied Organometallic Chemistry,* **34(4)**, e5493 (2020), http://doi.org/10.1002/aoc.5493
10. K. Sirumalar, M. P. Johnpeter, R. Manikandan, A.P.M.S. Archana, A. Paulraj, *Rasayan Journal of Chemistry*,**14(2)**,1316(2021), http://dx.doi.org/10.31788/RJC.2021.1426283
11. (a) T. T. Eugene-Osoikhia, I. O. Akinpelu, T. I. Odiaka, *Nigerian Journal of Chemical Res*earch **24(1)**, 46(2019).(b) K. Nakamoto Infrared Spectra of Inorganic and Coordination Compunds, 2nd ed., Wiley Interscience, New York(1970).
12. (a)A B P Lever Inorganic Electronic Spectroscopy, 2nd ed. Elsevier, Amsterdam(1984). (b)B. K. Singh, A. Prakash, H. K. Rajour, N. Bhojak, D. Adhikari*, Spectro. Chim Acta,* **76**, 376(2010), http://doi.org/ 10.1016/j.saa.2010.03.031
13. (a) B. K. Singh, P. Mishra, A. Prakash, N. Bhojak, *Arabian journal of Chemistry*,**10**, S472(2017), http://doi.org/ 10.1016/j.arabjc.2012.10.007 (b)B. K. Singh, H. Rajour, A.Prakash, *Spectrochimica Acta,* **94**, 143(2012), http://doi.org/ 10.1016/j.saa.2012.03.077
14. G.B. Bagihalli, P.G. Avaji, S.A. Patil, P. S. Badami, *European Journal of Medicinal Chemistry* **43(12)**, 2639(2008), http://doi.org/ 10.1016/j.ejmech.2008.02.013

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