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ORIGINAL ARTICLE

Synthesis of new cadmium(II) complexes of Schiff bases as alkaline phosphatase inhibitors and their antimicrobial activity

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Abstract The present investigation deals with the synthesis, characterization and pharmacological evaluation of four cadmium complexes (**1**–**4**) with Schiff bases (^{1}L-^{4}L) derived from the substituted amines and aryl aldehydes. Amantadine is reacted with different aryl aldehydes (salicylaldehyde, 3-ethoxysalicylaldehyde and 4-(diethylamino) salicylaldehyde) to prepare Schiff base ligands ^{1}L-^{3}L, while ^{4}L was prepared using 4-methylaniline. The complexes were characterized by elemental analysis, spectroscopic techniques and thermal analysis, and the structure of one of the ligands, ^{3}L was determined by X-ray crystallography. The spectroscopic data indicate that the ligands coordinate with Cd(II) in a bidentate fashion to give octahedral geometry. Single crystal XRD analysis shows that ^{3}L is orthorhombic with the space group $P2_12_12_1$. The ligands and their Cd(II) complexes were

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evaluated for antimicrobial activities, while the complexes were also investigated for inhibition effects towards an enzyme, alkaline phosphatase. The anti-microbial screening results showed that cadmium complex **1** exhibited significant antibacterial potential, particularly against *Staphylococcus aureus* with respect to the corresponding ligand suggesting that the complexes are more effective than their ligands for antimicrobial activity. In case of alkaline phosphatase inhibition screening, the synthesized cadmium complex **1** was found to maximally inhibit the activity of alkaline phosphatase in comparison to rest of three complexes.

1. Introduction

The Since the discovery of Schiff bases by Hugo Schiff 1864 (Schiff, 1864; Tidwell, 2008); these compounds have been exploited extensively due to their easy preparation, versatile ligation modes, stereogenicity, chirality, thermal stability, medicinal utility, solubility in common solvents and ability to stabilize different oxidation states of metals (Collinson and Thielemans, 2010; Nath et al., 1997; Siddiqui et al., 2006). Schiff bases have been employed as models for biological systems (Corden and Wallbridge, 1999) and for tuning the stereochemistry of *hexa*-coordinated transition metal complexes, which are expected to be potential catalysts for alkene polymerization (Nozaki et al., 1968). For example, Ryoji Noyori has been awarded a share of the 2001 Nobel Prize in chemistry for developing a copper-II Schiff base complexes for the metal-carbenoid cyclopropanation of styrene (Vigato and Tamburini, 2004). Metal complexes of Schiff bases have been found to be potential antimicrobial, antifungal, antitumor, antimalarial, antiviral, and anti-Alzheimer agents (Jones et al., 1979; Kenche and Barnham, 2011). A large number of Schiff bases and their complexes have been studied for their interesting and important properties such as their ability to reversibly bind oxygen, catalytic activity in hydrogenation of olefins, transfer of an amino group and photo-chromic properties (Henrici-Olivé and Olivé, 2012; Dugas and Penney, 2013; Margerum and Miller, 1971; Zuo et al., 2013; Uddin et al., 2020; Abu-Dief and Mohamed, 2015; Miroslaw, 2020; Alagarraj and Natarajan, 2020; Shazia, 2020).

Schiff bases are versatile ligands and ligate *via* azomethine nitrogen atom with a variety of metals such as Ni, Cu, Co, Pb, Bi, Zn, Cd and many other forming metal complexes (Cozzi, 2004; Gupta et al., 2008). Amantadine is a clinically safe compound for humans and has been reported for the treatment of several diseases *i.e.,* Influenza, fitness impairment and Parkinson's disease (Deyde et al., 2007; Vollum et al., 1971). Several Schiff bases of amantadine and their complexes have been reported for biological applications like anti-microbial and inhibitors for carbonic anhydrases II and Schiff bases of amantadine with salicylaldehyde, 5-chlorosalicylaldehyde and *O*-vanillin exhibited anti-viral potential. Furthermore, water soluble synthesized polymers of amantadine have also been reported having antiviral activity (Holt, 1987).

Although cadmium(II) is an environmental pollutant and human carcinogen, which inhibits RNA polymerase activity *in vivo* and reacts readily with proteins and other biological molecules but several stable cadmium complexes with different ligands have been reported (Anacona and Rodriguez, 2005; Drew et al., 1979; Guha et al., 2011; Hakimi, 2013; Naik et al., 2002; Nelson et al., 1977; Saghatforoush et al., 2008; Sultana et al., 2005; Jimmy et al., 2008). It has been revealed that organo-Cd complexes are potent inhibitor of proteasomal chymotrypsin-like (CT-like) activity and are capable of inducing apoptosis in a cancer cell-specific manner. Cd(II) complexes with tridentate Schiff base having HNNS donor sequence have been found to exhibit cytotoxicity with CD_{50} value of 2.30 μg mL^{-1} against the T-lymphoblastic leukemic cells (Tarafder et al., 2001, 2000). The Cd (II) complexes were also effective against colon cancer cells with CD_{50} values of 3.10 μg mL^{-1}. These compounds demonstrated a higher antioxidant activity than the α-tocopherol (vitamin E) and was comparable with butylated hydroxytoluene (BHT), a commercially used synthetic antioxidant (Tarafder et al., 2001). Furthermore, Cd(II) ions showed stronger inhibitory effect for alkaline phosphatase (ALP) than other heavy metals, such as Hg(II), Cu(II), Ni(II), Zn(II), Mn(II) and Pb(II) (Suzuki et al., 1989). Several studies have been reported, which describe the inhibition of ALP using Cd ions in the presence of other metals and additives (Renella et al., 2003; Tan et al., 2018).

Inspired by the interesting biological activities of cadmium complexes, herein we report the synthesis, characterization, antimicrobial properties and ALP inhibition study of four cadmium(II) complexes (**1**–**4**) of Schiff bases derived from amantadine or 4-methylaniline and salicylaldehyde or its derivatives. The structure of one of the ligands, ^{3}L is also presented, while those of other ligands are known in the literature (Fernández-G et al., 2001; Shaheen et al., 2012a, 2012b).

2. Experimental

2.1. Materials and measurements

All the solvents and reagents used *i.e.,* Ethanol, Methanol, *n*-Hexane, Ethyl acetate, Magnesium sulfate, amantadine, salicylaldehyde, 3-ethoxysalicylaldehyde, 4-(diethylamino)salicylal dehyde, 4-methylaniline and cadmium chloride were of analytical grade and purchased from Sigma-Aldrich, Merck and Alpha Aesar Companies. These were used without further purification. The solid-state IR spectra of the ligands and their complexes were measured on Prestige-21, Shimadzu IR Spectrophotometer. NMR spectra were recorded on Bruker 300 MHz UltraShield NMR spectrometer.

2.2. Preparation of ligands

2.2.1. N-adamantylsalicylimine (^{1}L)

The ligand ^{1}L was prepared according to a published procedure with little modification (Fernández-G et al., 2001). To 15 mL of ethanolic solution of amantadine (2 mmol, 0.302 g) was added to equimolar solution of salicylaldehyde (2 mmol, 0.194 mL) drop wise and the reaction mixture was refluxed for 3 h. The resulting solution was concentrated in rotary evaporator and allowed to stand overnight and filtered. Fine fluorescent yellow crystals of ^{1}L were washed with ice cold ethanol and dried. Yield: 75%. M.P.: 91 °C. ^{1}H NMR (300 MHz, CD_3OH): δ = 12.74 (s, 1H), 8.54 (s, 1H), 7.34 (t, 2H), 6.75 (m, 2H), 2.16 (s, 6H), 1.96 (d, 3H), 1.79 (d, 6H) ppm. Elemental analysis (%): Calculated: C: 79.96, H: 8.29, N: 5.49; Found: C: 79.48, H: 8.03, N: 5.31.

2.2.2. N-adamantyl(3-ethoxy)salicylimine (^{2}L)

The equimolar ethanolic (15 mL) solutions of 3-ethoxysalicylaldehyde (2 mmol, 0.332 g) and amantadine (2 mmol, 0.302 g) were added to round bottom flask and refluxed for 3 h. The resultant solution was evaporated to one-third of original. The yellow crystals of the Schiff base were obtained after 36 h. The crystals were washed with cold ethanol and dried in desiccator. Yield: 80%. M.P.: 82 °C. ^{1}H NMR (300 MHz, CD_3OH): δ = 13.12 (s, 1H), 8.54 (s, 1H), 6.96 (d, 2H), 6.71 (t, 1H), 4.46 (dd, 2H), 2.25 (s, 3H), 1.96 (s, 6H), 1.79 (m, 6H), 1.77 (t, 3H) ppm. Elemental analysis (%): Calculated: C: 76.22, H: 8.42, N: 4.68; Found: C: 75.98, H: 8.35, N: 4.51.

2.2.3. N-adamantyl(4-diethylamino)salicylimine (^{3}L)

To 15 mL hot ethanolic solution of 4-(diethylamino)salicylalde hyde (2 mmol, 0.386 g,) was added ethanolic (15 mL) solution of amantadine (2 mmol, 0.302 g) and the reaction mixture was refluxed for 4 h. The resultant solution was concentrated and left for crystallization. Rod like red crystals of *N*-adamantyl(4-diethylamino)salicylimine were obtained after 48 h. Crystals were washed with cold ethanol and dried. Yield: 75%. M.P.: 147 °C. ^{1}H NMR (300 MHz, CD_3OH): δ = 12.96 (s, 1H), 7.94 (s, 1H), 7.11 (d, 1H), 6.15 (d, 1H), 5.92 (s, 1H), 3.51 (m, 4H), 2.21 (s, 3H), 1.85 (d, 6H), 1.66 (m, 6H), 1.23 (t, 6H) ppm. Elemental analysis (%): Calculated: C: 77.26, H: 9.26, N: 8.58; Found: C: 77.56, H: 9.13, N 8.47. CCDC NUMBER 989105.

2.2.4. 3-ethoxy-6-{(E)-[(4-methylphenyl)imino]-methyl} phenol (^{4}L)

To 15 mL ethanolic solution of 4-methylaniline (2 mmol, 0.214 g) was added drop wise to ethanolic solution (15 mL) of 3-ethoxysalicylaldehyde (2 mmol, 0.332 g). Resultant solution was refluxed for 1 h. The needle like crystals was obtained on cooling (Shaheen et al., 2012). The crystals were washed with cold ethanol and dried in air. Yield: 85%. M.P.: 80 °C. ^{1}H NMR (300 MHz, CD_3OH): δ = 12.54 (s, 1H), 8.69 (s, 1H), 7.78 (s, 1H), 7.35 (s, 4H), 7.12 (dd, 1H), 6.75 (t, 1H), 4.21 (m, 2H), 3.34 (s, 3H), 1.51 (t, 3H) ppm. Elemental analysis (%): Calculated: C: 75.27, H: 6.71, N: 5.49; Found: C: 75.43, H: 6.45, N: 5.31.

2.3. Synthesis of Cd(II) complexes

For preparation of complexes, 15 mL ethanolic solution of cadmium chloride (1 mmol, 0.183 g) was added drop wise to 2 mmoles of the ligands (^{1}L-^{4}L) in 15 mL ethanol. The reaction mixture was refluxed for 2 h. The resulting yellow precipitates of the complexes were filtered, washed with ice cold ethanol and dried under vacuum (Mriganka et al., 2017).

2.4. Analytical data of complexes

Complex **1:**

Yield: 65%. M.P.: 285 °C; ^{1}H NMR (300 MHz, CD_3OD): δ = 8.44 (s, 2H), 7.32 (t, 4H), 6.77 (m, 4H), 2.1 (s, 12H), 1.94 (d, 6H), 1.85 (d, 12H) ppm. Elemental analysis (%): Calculated: C: 65.75, H: 6.49, N: 4.51; Found: C: 64.98, H: 6.07, N: 5.11. Conductivity: 2.02 μS.

Complex **2:**

Yield: 70%. M.P.: >300 °C; ^{1}H NMR (300 MHz, CD_3OD): δ = 8.44 (s, 2H), 6.93 (d, 4H), 6.65 (t, 2H), 4.41 (dd, 4H), 2.20 (s, 6H), 1.98 (s, 12H), 1.74 (m, 12H), 1.74 (t, 6H) ppm. Elemental analysis (%): Calculated: C: 64.35, H: 6.82, N: 3.95; Found: C: 64.48, H: 6.35, N: 4.21. Conductivity: 4.35 μS.

Complex **3:**

Yield: 67%. M.P.: 270 °C. ^{1}H NMR (300 MHz, CD_3OD): δ = 7.96 (s, 2H), 7.07 (d, 2H), 6.19 (d, 2H), 5.96 (s, 2H), 3.44 (m, 8H), 2.17 (s, 6H), 1.95 (d, 12H), 1.76 (m, 12H), 1.20 (t, 12H) ppm. Elemental analysis (%): Calculated: C: 66.08, H: 7.66, N: 7.34; Found: C: 65.84, H: 7.25, N: 7.67. Conductivity: 3.73 μS.

Complex **4:**

Yield: 75%. M.P.: >300 °C; ^{1}H NMR (300 MHz, CD_3-OD): δ = 8.79 (s, 2H), 7.88 (s, 2H), 7.25 (s, 8H), 7.07 (dd, 2H), 6.85 (t, 2H), 4.16 (m, 4H), 3.30 (s, 6H), 1.45 (t, 6H) ppm. Elemental analysis (%): Calculated: C: 61.89, H: 5.19, N: 4.51; Found: C: 61.43, H: 4.95, N: 5.01. Conductivity: 2.76 μS.

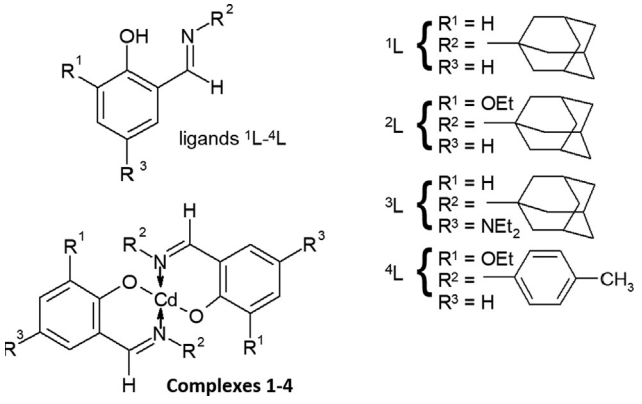
The structures of ligands and the complexes are shown in Scheme 1.

2.5. Thermal studies

Thermogravimetric studies of compounds were carried out in dynamic air atmosphere using SDT Q600 Thermo gravimetric analyzer. Approximately 2 mg of samples were heated with the heating rate of 50 °C per minute using platinum crucibles in temperature from ambient to 800 °C.

2.6. Conductivity measurements

Conductance values of complexes were noted at room temperature in DMSO using Conductivity meter SDT-600. Conductivity meter was calibrated with the solutions of standard potassium chloride electrolytes.



Scheme 1 Structures of ligands ^{1}L to ^{4}L and complexes **1**–**4**.

2.7. X-ray structure determination of ^{3}L

The absolute ethanol was used for recrystallization of Schiff bases. Fine crystals of Schiff base ^{3}L were selected for single crystal studies. The single crystal X-ray diffraction data of ^{3}L was measured on Bruker Kappa Apex-II diffractometer using *SAINT* (Bruker) for cell refinement and data reduction. The *SHELXS97* program (Sheldrick, 2008) was used to solve the structure.

2.8. Antimicrobial studies

Antibacterial activities of the ligands and their complexes were determined by reported methods (Carron et al., 1987). The bacteria strains used include: *Escherichia coli, Bacillus subtilis, Shigella flexeneri, Staphylococcus aureus, Pseudomonas aeruginosa* and *Salmonella typhi*. The 0.1 mg/mL of sample in DMSO was used for well of 6 mm diameter. 10 µg amikacin per disc was used as a standard drug.

2.9. Alkaline phosphatase (ALP) inhibition assay protocol

For the preparation of assay same method was used as reported earlier with slight modifications (Chaudhry et al., 1983; Hu et al., 2017). Working substrate was made by mixing the four parts of reagent A (diethanolamine pH 10.2, 1.4 mol/L and magnesium chloride 0.5 mmol/L) and one part of reagent B (*p*-nitrophenyl phosphate 50 mmol/L). Substrate was incubated for five minutes at 25 °C. In a cell cuvette 500 µL of the substrate and 10 µL of human serum were taken. After incubation of 1-minute absorbance was measured to check the activity of enzyme (ΔA/min) × 2750, which was found to be 172 U/I. ALP hydrolysed the *p*-NPP and yellow colored *p*-nitrophenol was produced that absorbs at 405 nm.

$$p-\text{Nitrophenyl phosphate} + Mg^{+2} + H_2O \xrightarrow{ALP} p-\text{Nitrophenol} + Pi$$

where Pi is inorganic phosphate.

Then various amounts of cadmium(II) complexes were added periodically from the 12.5 mmolar stock solution and again incubated for 3 min. Change in absorbance was recorded again after 1, 2, 3, 4 and 5 min thereafter. At the end their average was taken and % age inhibition was calculated.

3. Results and discussions

3.1. Synthesis of Schiff base ligands and complexes

The Schiff base ligands, ^{1}L, ^{2}L and ^{3}L were prepared by condensation of amantadine with aryl aldehydes *i.e.,* salicylaldehyde, 3-ethoxysalicylaldehyde and 4-(diethylamino) salicylaldehyde. The ligand ^{4}L was prepared by reacting 4-methylaniline with 3-ethoxysalicylaldehyde as represented in Scheme 2. The physical properties such as colors, melting points are given in Table S1 (Supplementary Information).

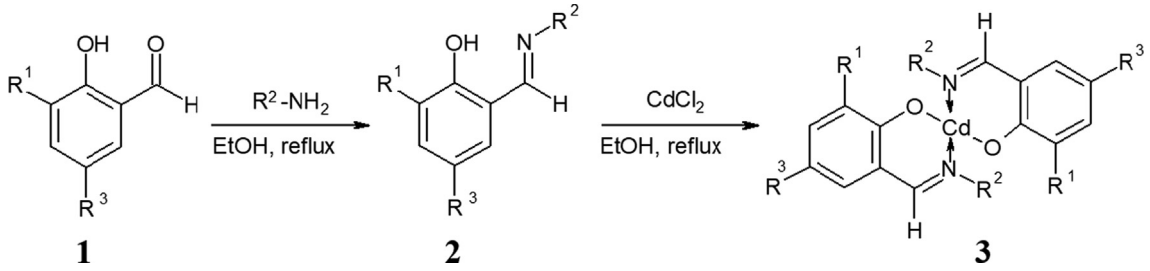
3.2. Spectroscopic studies

3.2.1. FT-IR

The Infra-red spectra of compounds were recorded in the range of 4000–400 cm^{-1}. In these spectra the absorptions for important functional groups like N—C, C=C, C—O, —OH and HC=N were observed and are listed in Table S2 (Supplementary Information). The absorption peaks were attributed to different functional groups with the help of the literature on IR spectroscopy. The peak characteristic of azomethine group (HC=N) of Schiff bases was observed in region of 1588–1691 cm^{-1}. In complexes, this absorption shifted towards lower frequencies due to coordination through nitrogen atom. Stretching vibrations in the region of 1446–1463 cm^{-1} were attributed to the unsaturation of aromatic ring, C=C. Sharp bands were observed in the region of 2904–2910 cm^{-1} due to C—H stretching. Phenolic C—O functional groups absorb at 1205–1255 cm^{-1}, while in complexes it shifted to 1190–1238 cm^{-1}, which indicates the binding of phenolic oxygen to the metal atom. Coordination of ligands to metal is further evidenced by absence of OH peaks in the spectra of complexes, which appear in the range of 3380–3465 cm^{-1} for ligands.

3.2.2. NMR

The detailed ^{1}H NMR data of the ligands and the complexes (**1**–**4**) is given in experimental section. The spectra of complexes show that the signal of phenolic proton is absent (present in ligand- spectra) confirming the binding of ligands to the metal atom. Moreover, small shifts of 0.2–0.3 ppm in peak positions of protons, as compared to ligands further suggest



1 **2** **3**

Scheme 2 Synthesis of ligands **2** and their complexes **3** from precursor aryl aldehydes **1** upon treatment with amantadine. R^1, R^2 and R^3 have been represented in Scheme 1.

the formation of complexes. In case of *N*-adamantylsalicylimine-Cd(II), the single resonance of azomethine proton was observed at 8.44 ppm. Multiple peaks were observed in the region of 6.67–7.32 ppm, which are attributed to the protons of aromatic ring. Three protons of amantadine gave signals at 2.20 ppm and the remaining protons in the range of 1.74–1.99 ppm. For complex **1**, a triplet was observed at 1.39–1.44 ppm, which is assigned to CH_3 of ethoxy substituent of salicylaldehyde. The CH_2 protons give quartet at 4.07–4.14 ppm. The peak at 8.44 ppm was attributed to the HC═N proton. The protons on phenolic ring give peaks in the range of 6.51–6.93 ppm. Complex **2** contains a Schiff base of amantadine and 4-diethylaminosalicylaldehyde. A doublet of single proton was observed at 7.04–7.07 ppm and attributed to the proton of benzene ring. A quartet of four protons of diethyl group was observed at 3.37–3.44 ppm and a quintet of the same substituent was observed at 1.15–1.20 ppm. Three protons of amantadine give singlet at 2.17 ppm. A singlet at 7.96 ppm was attributed to the azomethine proton. In case of **3**, the singlet of azomethine proton was observed at 8.79 ppm. The CH_3 protons of 4-methylaniline of ^{4}L show a triplet at 1.06–1.45 ppm. A quartet is observed at 4.09–4.16 ppm and attributed to the two protons of aniline. A doublet of doublets is observed for the protons of benzene ring of 3-ethoxysalicylaldehyde.

3.3. Thermal analysis

Thermal properties of the compounds were studied by TGA. All complexes show two stages of weight loss for ligands ^{1}L, ^{2}L, ^{3}L and ^{4}L. Table 1 shows the details of different stages of decomposition of the complexes. The weight loss was due to loss of metal oxide (CdO) residue upon heating.

3.4. Crystal structure of ^{3}L

The crystallographic data of compound ^{3}L is given in Table 2. The molecular structure of ^{3}L including the atom-numbering scheme is depicted in Fig. 1. The Compound crystallized in the solid state into the phenol-imine tautomeric form. In this compound the N1═C7 bond distance of 1.2791 Å is in agreement with the imine group. Furthermore, the ranges of this bond length and that between the C6 atom of the aromatic ring and the C7 atom of the imine group correspond to conjugated C═N group. The range of C-O bond length corresponds to the value described for the C-O bond in phenols (~1.36 Å). The group A (O1/C1/C2. . ./C7/N1) is planar with r. m. s. deviation of 0.006 Å. The dihedral angle between B (N2/C8/C9) and C (N2/C10/C11) is 63.24 (18)°. There exist an intramolecular H-bond between O1----H1. . .N1 forming an S(6) loop. The molecules are essentially stabilized due to van der Waals forces (Table 2).

Table 1 Stages of decomposition of complexes.

Complexes	Temp. range °C	% Weight loss	Residue
1	284–342	25.34	CdO
	579–746	40.70	(22.21%)
2	268–336	28.82	CdO
	336–541	18.28	(18.70%)
	541–679	27.84	
3	275–328	17.89	CdO
	328–591	15.14	(18.01%)
	591–835	45.20	
4	235–271	34.66	CdO
	271–357	17.27	(22.15%)
	357–576	8.62	
	576–775	10.23	

Table 2 Crystallographic data of compound ^{3}L.

Compound	^{3}L
Chemical Formula	$C_{21}H_{30}N_2O$
Formula weight	326.47
T (K)	296(2)
Wavelength (Å) Mo *Kα*	0.71073
Crystal system	Orthorhombic
Space group	$P2_12_12_1$
a (Å)	6.8045(4)
b (Å)	7.6589(5)
c (Å)	34.546(2)
V (Å^3)	1800.36(19)
Z	4
Absorption coefficient (mm^{-1})	1.204
F(000)	712
Crystal size (mm)	0.35 × 0.28 × 0.25
θ-range for data calculation (°)	2.687 to 26.00
Reflections collected	8068
Independent reflections	3241
Reflections ≥ 2σ(I)	2974
Goodness-of-fit on F^2	1.050
Final R indices	R_1 = 0.0328
[I > 2σ(I)]	wR_2 = 0.0784
R indices (all data)	R_1 = 0.0364
	wR_2 = 0.0877
Data/restrains/parameters	3241/0/222

3.5. Antimicrobial study

All the ligands were found to be mild active against the various strains of bacteria. The most significant activity was exhibited by complex **1** against *Staphylococcus aureus*, while other complexes did not show any significant activity. The positive control was carried out using amikacin as standard drug against antimicrobial analysis (Patil and Pawar, 2019; Rakshani et al., 2019). The results are summarized in Table 3. Our reported metal complexes exhibited better anti-bacterial activity against tested strain when amikacin was used as standard drug in comparison to the recent reported antibacterial organic smart molecular metal complexes (Mahmoud et al., 2015; Mosmann, 1983).

3.6. Alkaline phosphatase inhibition activity

Cadmium metal was found to be an inhibitor of ALP (Suzuki et al., 1989). The inhibition might be due to the blockage of the active sites of the enzyme by it. Enzyme was inhibited in the concentration-dependent manner.

Fig. 2 shows the ALP inhibition data of Cd(II) complexes **1**–**4**. The ligands itself was inactive against ALP and percentage inhibition for it is zero at all concentrations. Among the

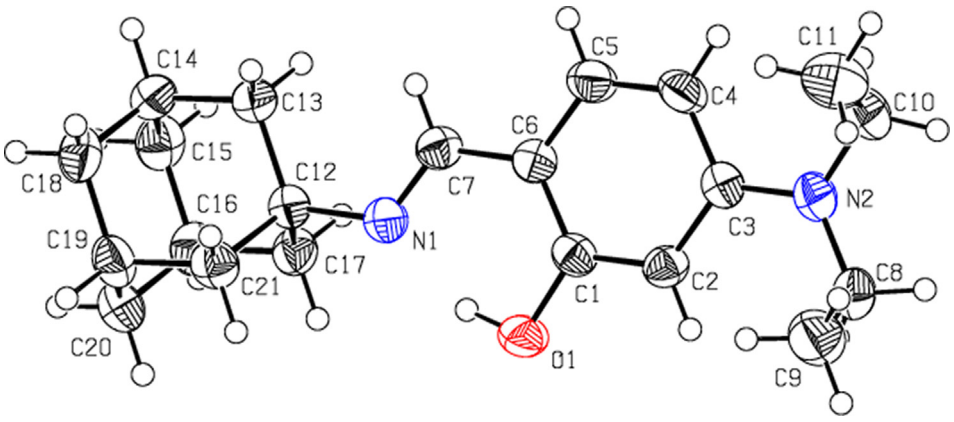


Fig. 1 Molecular structure of *N*-adamantyl(4-diethylamino)salicylimine (^{3}L).

Table 3 Antimicrobial screening (mm) of the ligands and complexes.

Samples *Standard*	*E. coli* *25*	*B. subtilis* *50*	*S. flexeneri* *28*	*S. aureus* *48*	*P. aeruginosa* *23*	*S. typhi* *28*
^{1}L	18 ± 0.31	32 ± 0.25	21 ± 0.25	30 ± 0.03	17 ± 0.03	20 ± 0.17
^{2}L	17 ± 0.31	30 ± 0.12	18 ± 0.25	27 ± 0.03	14 ± 0.03	17 ± 0.15
^{3}L	20 ± 0.31	34 ± 0.25	22 ± 0.20	31 ± 0.04	17 ± 0.03	21 ± 0.11
^{4}L	14 ± 0.31	31 ± 0.12	17 ± 0.20	27 ± 0.03	13 ± 0.05	16 ± 0.12
1	30 ± 0.31	56 ± 0.12	30 ± 0.20	52 ± 0.02	28 ± 0.02	31 ± 0.10
2	23 ± 0.31	42 ± 0.12	25 ± 0.25	42 ± 0.03	18 ± 0.03	22 ± 0.17
3	27 ± 0.31	46 ± 0.25	27 ± 0.25	48 ± 0.04	21 ± 0.03	26 ± 0.11
4	24 ± 0.31	45 ± 0.12	26 ± 0.25	46 ± 0.03	20 ± 0.03	25 ± 0.10

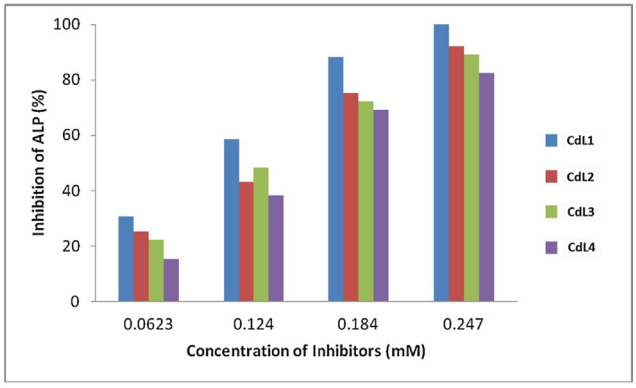


Fig. 2 Concentration dependent inhibition of alkaline phosphatase (ALP) by cadmium complexes.

complexes **1** showed maximum inhibition of ALP. The results revealed that inhibition of ALP by the synthesized complexes is concentration dependent. An increase in concentration of complexes decreased enzymes activity and there was total loss of activity at 0.247 mM concentration.

4. Conclusions

In summary, herein we have synthesized Schiff base ligands and their cadmium(II) complexes. Characterization of the synthesized materials were performed by FT-IR analysis, NMR spectroscopic analysis, elemental analysis, thermal analysis and conductivity measurements. For better insight toward the ligand structure, the fine crystal of ligand was grown and analyzed for Single crystal XRD analysis. In order to investigate the bioprofile of the synthesized material, the antimicrobial activities of ligands and their complexes were performed using various bacterial strains and the results showed better anti-microbial potential of the cadmium complexes in comparison of the ligands. In case of enzymatic inhibition analysis, the synthesized compounds were observed to exhibit appreciable response toward alkaline phosphatase inhibition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.arabjc.2021.103308.

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