Heterocyclic Letters
Vol. 11| No.2|213-230| Feb-April |2021
ISSN : (print) 2231–3087 / (online) 2230-9632
CODEN: HLEEAI
http://heteroletters.org

INVESTIGATION ON DESIGN, GREEN AND CONVENTIONAL SYNTHESIS, CHARACTERIZATION, ELECTROCHEMICAL AND BIOLOGICAL STUDIES OF SOME NEW AZOMETHINES AND THEIR VANADIUM (V) COMPLEXES

Arghya De[a], Sumit Srivastava[b], Ayantika De[c], Renu Rathore[a] and Ritu Tomar[a*]

[a],Department of Chemistry, Bhupal Noble's University, Udaipur,313001, India
[b] Department of Chemistry, University of Rajasthan, Jaipur,302004,India
[C] Department of Bioengineering and Biosciences, Lovely Professional University, Phagwara, 144001, India
E-mail: arghyade1994@gmail.com

Abstract: Synthesis of some new Vanadium (V) complexes of biologically potent (N∩O and N∩S) donor azomethines by classical thermal and microwave-irradiation techniques and characterized by the elemental analysis, IR, UV and EPR spectral and X-ray powder diffraction studies. The azomethine, 2-acetyl-5-methyl furan hydrazine carboxamide (L^1H), 3-acetyl coumarin hydrazine carboxamide (L^2H), 2-acetyl-5-methyl furan hydrazine carbothioamide (L^3H) and 3-acetyl coumarin hydrazine carbothioamide (L^4H) have been prepared from the condensation of 2-acetyl-5-methyl furan and 3-acetyl coumarin with semicarbazide hydrochloride and thiosemicarbazide in 1:1 molar ratio, respectively. The Vanadium (V) complexes have been prepared by mixing vanadium oxytrichloride ($VOCI_3$) in 1:1 and 1:2 molar ratios with monofunctional bidentate ligands. The structure of the ligands and their transition metal complexes were confirmed by the elemental analysis, molecular weight determinations, IR, electronic and EPR spectral studies. On the basis of these studies it is clear that the ligands coordinated to the metal atom in a monobasic bidentate mode, by O∩N donor system. Thus a penta-coordinated environment around the Vanadium (V) ion has been proposed. The antimicrobial activity of Schiff base ligands and their respective Vanadium (V) complexes were tested against some of pathogenic bacterial and fungal strains. The results indicated that the complexes showed higher activity than the parent ligands.
The spectral data suggested that complexes have penta-coordinated environment around the central metal ion.

Keywords**:** Vanadium (V) complexes; Schiff base; Antimicrobial activity; microwave.

1. Introduction

The approach, of the Green chemistry is the elimination of hazardous waste, rather than generating it. Green chemistry is diffusing throughout the chemical industries and includes the use and development of new substances and processes that impact various sectors such as agriculture, healthcare, automotive, aerospace, energy, electronics and advanced materials.

In context of environment friendly Green chemistry, the applications of the microwave technology or solvent free technology has lead to the development of many reaction procedures which are environment benign and come in the domain of Green chemistry[1-6]. Nowadays, the microwave technology is being used for the synthesis of organic and inorganic compounds, as well as for thermal treatment of many materials at laboratorial and industrial scales[1-5].

The bioactivity of heterocyclic Schiff bases as well as of their metal complexes is of interest, especially due to their pharmacological properties. Considerable importance has been paid to the transition metal complexes of azomethine ligands on account of their significant biological properties[6].The coordination chelates of sulfur, oxygen, nitrogen and other donor heterocyclic azomethine systems [7] have been widely investigated and they frequently show novel structural features[8], unusual spectral, catalytical[9] and electrochemical[10] properties and relevance to biological systems[11].

Vanadium plays a very limited role in biology[12]. A vanadium-containing nitrogenous is used by some nitrogen-fixing micro-organisms, such as *Azotobacter*[13].Vanadyl sulfate may improve glucose control in people with type-2 diabetes[14].Momentum to the coordination chemistry of vanadium in medical applications arises from the ability of vanadium complexes to promote insulin mimetic activity in the pathophysiological state of diabetes mellitus in humans[15].

Research importance of vanadiumin coordination chemistry is due to its applications in many biological and industrial processes[16]. The coordination chemistry of vanadium has regained interest after the discovery of vanadium in certain organisms like Ascidians and Amanita mushrooms and in vanadate-dependent haloperoxidases and vanadium nitrogenaseas a part of the co-factors. Recent advances in catalytic and medicinal properties of vanadium complexes have accelerated further developments related to their design and synthesis. The biochemical aspects of vanadium complexes have further promoted because of its presence in abiotic and biotic systems[17]

2. Experimental

All the chemicals and reagents used were of AR grade and dried and distilled before use. The $VOCl_3$ was purchased from Alfa aesar. 1-(2-furanyl) ethanone, 1-(2-thienyl) ethanone, 1-(2-pyridyl) ethanone and 1-(2-naphthyl) and isonicotinic acid hydrazide were purchased from Sigma Aldrich. All the reactions carried out in under anhydrous conditions.

2.1. Preparation of the ligands (L^1H, L^2H, L^3H and L^4H)

Two different routes were used for the synthesis of ligands (L^1H, L^2H, L^3H and L^4H):-

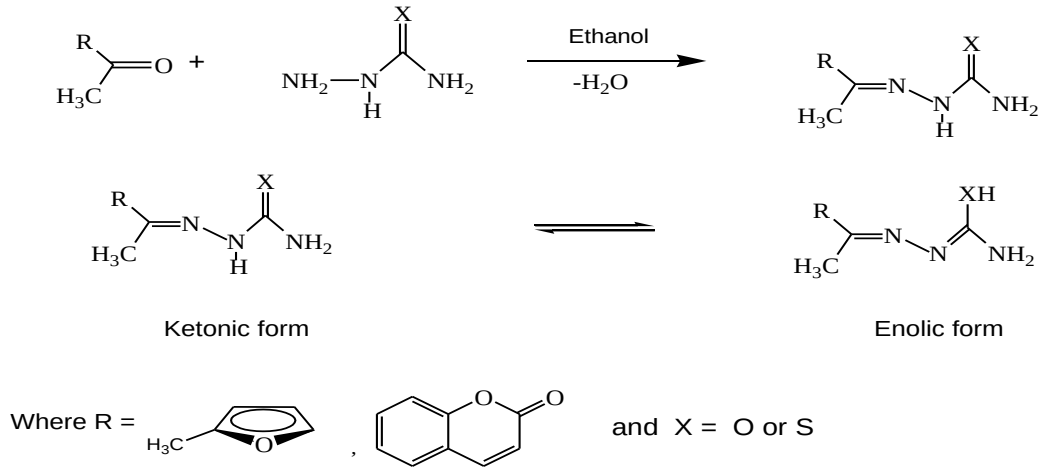
(A) Microwave method: In microwave assisted synthesis of the ligands, 2-acetyl-5-methyl furan hydrazine carboxamide (L^1H), 3-acetyl coumarinhydrazine carboxamide (L^2H), 2-acetyl-5-methyl furan hydrazine carbothioamide (L^3H) and 3-acetyl coumarinhydrazinecarbothioamide (L^4H) were obtained by the condensation of 2-acetyl-5-methyl furan and 3-acetyl coumarinwith semicarbazide hydrochloride (in presence of sodium acetate) and thiosemicarbazide in 1:1 molar ratio in a microwave oven using 5 mL ethanol as solvent, respectively. The progress of reaction was monitored by TLC. The reactions were completed in a short period of 6–10 min. The solution was then concentrated under reduced pressure, which on cooling gave dark yellow/whitish creamy / creamcolored crystalline precipitates (84-93% yield). These were washed and recrystallized from ethanol.

(B) Thermal method: Above mentioned ligands were synthesized by conventional heating method to compare with microwave synthesis.2-Acetyl-5-methyl furan and 3-acetyl coumarinwas mixed separately with hot ethanolic solution (50-80 mL) of semicarbazide hydrochloride (in presence of sodium acetate) and thiosemicarbazide in 1:1 molar ratio. The

contents were refluxed for about 3-4 hrs on a water bath. The solution was then concentrated under reduced pressure, which on cooling gave dark yellow/whitish creamy/creamcolored crystalline precipitates (65-70 % yield). These were washed and recrystallized in ethanol.

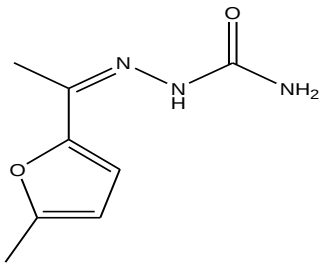
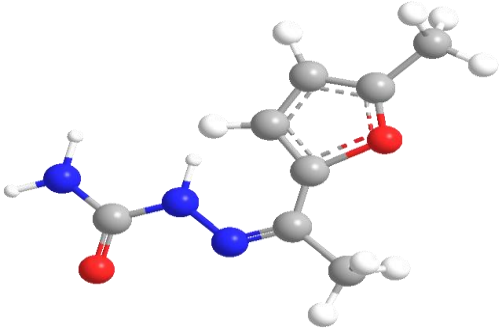
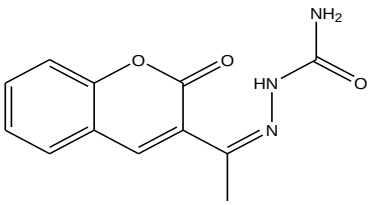
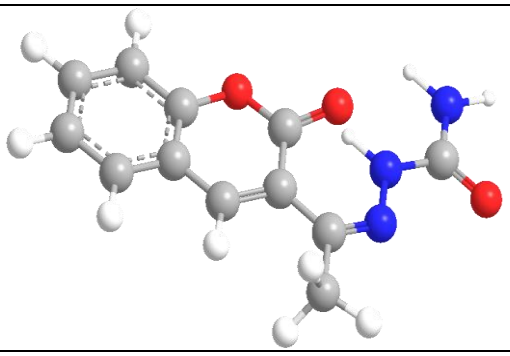
(C) General reaction scheme for synthesis of ligands

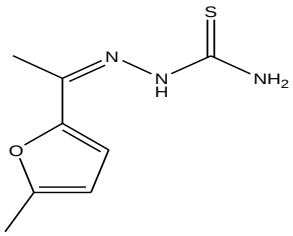
The general reaction for the synthesis ligands is shown in **Scheme 1.1**

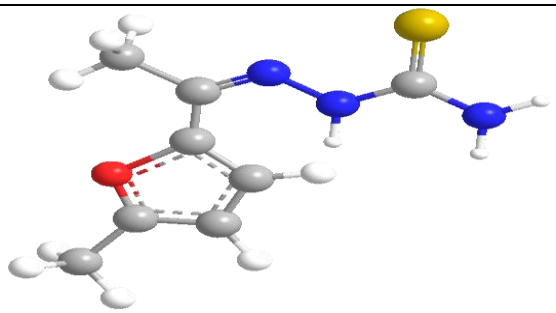


Scheme 1.1 Reaction scheme for the synthesis of ligands

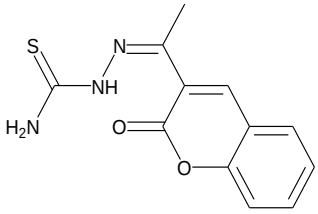
(D) Structure of the ligands (L^1H, L^2H, L^3H and L^4H)

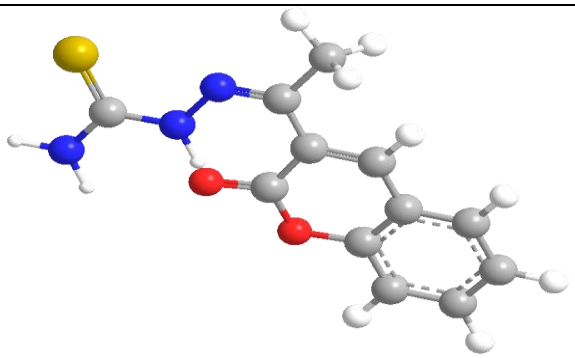
	
2-Acetyl-5-methyl furanhydrazine carboxamide (L^1H)	
	
3-Acetylcoumarinhydrazinecarboxamide(L^2H)	





2-Acetyl-5-methyl furanhydrazinecarbothioamide (L^3H)





3-Acetyl coumarinhydrazinecarbothioamide (L^4H)

Fig.1.1 Structure of the azomethine ligands (L^1H- L^4H)

(E) Comparison between thermal and microwave methods

A comparison between thermal and microwave method is given in **Table 1.1.**

Table 1.1 Comparison between thermal and microwave methods

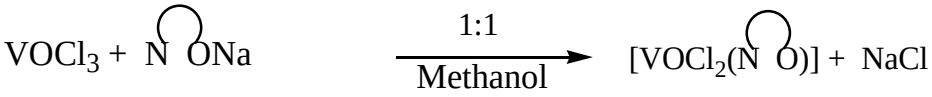
Ligands Synthesized	**Yield (%)**		**Solvent used (mL)**		**Time**	
	Thermal method	**Microwave Method**	**Thermal Method**	**Microwave method**	**Thermal method (hrs)**	**Microwave method (min)**
L^1H	70	90	50	7	3	8
L^2H	68	93	60	5	4	6
L^3H	70	86	80	7	3	8
L^4H	65	84	70	5	4	10

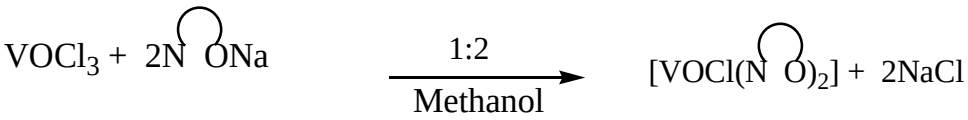
2.2. Preparation of the complexes

Preparation of the vanadium (V) complexes of L^1H-L^4H ligands

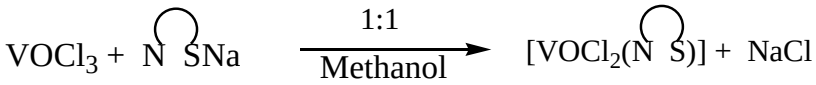
The reaction of ligands (L^1H, L^2H, L^3H and L^4H) with vanadium oxytrichloride ($VOCl_3$) have been carried out in 1:1 and 1:2 molar ratios. The weighed amount of vanadium oxytrichloride ($VOCl_3$) in dry methanol was added to the methanolic solution of sodium salt

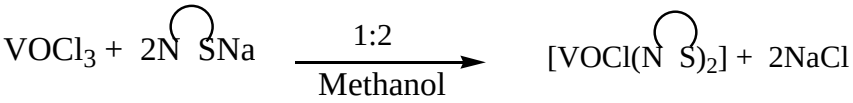
of the ligands in 1:1 and 1:2 molar ratios. The resulting mixture was refluxed for 10-12 hours in thermal process and 7-8 minutes in microwave method **(Table 1.2)**. After the complete precipitation and removal of sodium chloride formed during the course of the reaction, the resulting mixture was then concentrated under reduced pressure. The resulting compounds were washed with methanol and n-hexane followed by drying in *vacuum* for about one hour to get the final products. These were further subjected to TLC to check their purity using silica gel. The general reactions can be represented by the following equations: (**Scheme 1.2)**





(Where, N O is the donor system of the hydrazinecarboxamides (L^1H and L^2H)





(Where, N S is the donor system of the hydrazinecarbothioamides, (L^3H and L^4H)

Scheme 1.2

Table 1.2 Thermal and microwave methods for the synthesis of vanadium (V) complexes

Complexes compound	**Yield (%)**		**Solvent (mL)**		**Time**	
	Thermal method	**Microwave method**	**Thermal method**	**Microwave method**	**Thermal method (hrs)**	**Microwave method (min)**
$[VOCl_2(L^1)]$	75	83	40	5	12	8
$[VOCl(L^1)_2]$	75	84	39	3	11	8
$[VOCl_2(L^2)]$	75	86	40	5	10	8
$[VOCl(L^2)_2]$	77	86	38	5	11	7
$[VOCl_2(L^3)]$	78	85	41	4	11	8
$[VOCl(L^3)_2]$	77	87	40	3	11	7
$[VOCl_2(L^4)]$	75	89	38	3	10	8
$[VOCl(L^4)_2]$	75	90	40	4	12	7

The reason for synthesizing metal complexes by microwave method is due to its ecofriendly nature. The microwave mediated reactions occur more safely, reduce the amount of waste products and increases the yield of pure required products.

3. Physical measurements and analytical methods

The molecular weights were determined by the Rast Camphor method[18]. The metal contents were analysed gravimetrically. Sulfur and nitrogen were determined by Messenger's[19] and Kjeldahl's methods[20], respectively. Carbon and hydrogen analyses were performed at the CDRI, Lucknow. Infrared spectra were recorded on a Nicolet Megna FTIR-550 spectrophotometer using KBr pellets. The electronic spectra were recorded on a Varian–Cary/5E spectrophotometer. EPR spectra of the complexes were monitored on Varian E-4X band spectrometer.

4. Results and discussion of vanadium complexes

Physical properties and elemental analysis of ligands (L^1H-L^4H) and their vanadium (V) complexes

The vanadium (V) azomethine complexes have been synthesized by the reactions of the semicarbazone and thiosemicarbazone ligands with $VOCl_3$ in 1:1 and 1:2 molar ratios. The resulting vanadium (V) complexes have been obtained as coloured solids and are insoluble in most of the common organic solvents but their solubility is appreciable in methanol, dimethylformamide and dimethylsulfoxide. The physical properties and elemental analysis of the synthesized compounds are reported in the **Table 1.3.**

Table 1.3 Physical properties and elemental analysis of vanadium (V) complexes

Compounds synthesized	Colour	M.P. (^{0}C)	Found (Calculated.) (%)						Mol. Wt. Found(Calculated)
			C	H	N	S	M	Cl	
$[VOCl_2(L^1)]$	Light brown	263	30.10 (30.2)	3.50 (3.47)	13.10 (13.16)	-	15.93 (15.96)	22.34 (22.24)	319.30 (319.12)
$[VOCl(L^1)_2]$	Light yellow	243(d)	41.20 (41.34)	4.80 (4.77)	18.00 (18.07)	-	10.83 (10.95)	11.96 (11.12)	464.08 (464.8)
$[VOCl_2(L^2)]$	Light yellow	173(d)	39.30 (39.25)	3.20 (3.01)	11.30 (11.44)	-	13.93 (13.87)	19.23 (19.33)	367.12 (367.16)
$[VOCl(L^2)_2]$	Light yellow	170(d)	51.12 (51.39)	3.80 (3.95)	15.06 (14.98)	-	9.01 (9.08)	9.52 (9.66)	560.62 (560.88)
$[VOCl_2(L^3)]$	Light yellow	225(d)	28.42 (28.66)	3.42 (3.3)	12.24 (12.53)	6.35 (6.45)	15.02 (15.19)	22.34 (22.24)	335.82 (335.18)
$[VOCl(L^3)_2]$	Light brown	240(d)	38.42 (38.66)	4.32 (4.46)	16.78 (16.91)	12.68 (12.90)	10.12 (10.25)	11.04 (11.12)	496.28 (496.92)
$[VOCl_2(L^4)]$	Pale yellow	176(d)	37.42 (37.6)	2.73 (2.89)	10.75 (10.96)	5.20 (5.40)	13.02 (13.29)	18.66 (18.52)	383.04 (383.22)
$[VOCl(L^4)_2]$	Light brown	175(d)	48.56 (48.66)	3.88 (3.73)	14.02 (14.17)	10.60 (10.81)	8.88 (8.59)	9.20 (9.26)	593.82 (593.44)

4. Electronic spectral data of vanadium (V) complexes

The electronic spectra of vanadium (V) azomethine complexes were recorded in the range 200-800 nm in the methanol. The spectra of the complexes show a broad band at 35050-

32550 cm^{-1} which can be assigned to the n-π* transitions of the azomethine group which undergoes a blue shift in the complexes due to the polarization within the >C=N chromophore caused by the metal-ligand interaction. The spectrum shows an absorption peak at 45460 - 42370cm^{-1} due to the π → π * transition of the aromatic ringazomethine group. The band at 24390-22660$cm^{-1}$is due to charge transfer (LMCT) transitions[21,22](**Table 1.4**).

Table 1.4 Electronic spectral data of vanadium (V) complexes

Synthesized compounds	**Transitions**	**Spectral bands (cm^{-1})**
$[VOCl_2(L^1)]$	π − π* n → π * LMCT	42440(235.63) 32650(306.28) 24390(410.00)
$[VOCl(L^1)_2]$	π − π* n → π * LMCT	43850(228.05) 32580(306.94) 23390(427.53)
$[VOCl_2(L^2)]$	π − π* n → π * LMCT	42850(233.37) 33550(298.06) 23580(424.09)
$[VOCl(L^2)_2]$	π − π* n → π * LMCT	45460 (219.97) 33880 (295.16) 24390(410.00)
$[VOCl_2(L^3)]$	π − π* n → π * LMCT	44450(224.97) 34465(290.15) 23890(418.59)
$[VOCl(L^3)_2]$	π − π* n → π * LMCT	42370(236.02) 33455(298.91) 22860(437.45)
$[VOCl_2(L^4)]$	π − π* n → π * LMCT	44660(223.91) 32550(307.22) 22660(441.31)
$[VOCl(L^4)_2]$	π − π* n → π * LMCT	44340(225.53) 35050(285.31) 24390 (410.00)

5. IR spectral data of the vanadium (V) complexes with L^1H-L^4H ligands

In the IR spectra of the ligands (L^1H-L^4H), two common bands observed around 3400-3350 cm^{-1} due to $\nu_{sym.}$ and $\nu_{asym.}$vibrations of NH_2 group reducedin the vanadium (V) complexes due to the involvement of NH group (**Table 1.4**). The IR spectra of the of complexes display absorption bands at 1692-1680 cm^{-1}, 1594-1580 and 1040-1035 cm^{-1} due to ν(C=O, ν(C=N), and ν(C=S) at lower frequency as compared to ligands indicating that the chelation takes place through the azomethine nitrogen[23], enolic oxygen and thiolic sulfur to the central metal ion. This fact further supported by the appearance of non ligand bands at 472-440 cm^{-1} [24, 25], 575-548 cm^{-1},348-320 cm^{-1} [26] and366-350 cm^{-1} have been assigned to ν(V←N), ν(V−O),ν(V–Cl) and ν(V-S), respectively in the far IR spectra of the vanadium (V) complexes[27]. The lower frequency shift of ν(C=N) band observed in the spectra of metal complexes indicate the involvement of azomethine nitrogen upon complexation[28-31].

Table 1.4 IR (cm^{-1}) Spectral data of the ligands and their vanadium (V) complexes

Synthesized compounds	IR Spectral data (cm^{-1})						
	ν(C=O)	ν(C=N)	ν(C=S)	ν(V-N)	ν(V-O)	ν(V-S)	ν(V-Cl)
$[VOCl_2(L^1)]$	1680	1580	-	455	575	-	340
$[VOCl(L^1)_2]$	1684	1582	-	445	572	-	345
$[VOCl_2(L^2)]$	1690	1594	-	472	548	-	348
$[VOCl(L^2)_2]$	1692	1592	-	465	560	-	345
$[VOCl_2(L^3)]$	-	1590	1040	464	-	354	320
$[VOCl(L^3)_2]$	-	1585	1038	440	-	366	320
$[VOCl_2(L^4)]$	-	1588	1035	457	-	361	317
$[VOCl(L^4)_2]$	-	1576	1039	468	-	350	324

6. NMR spectral data of the ligands L^1H-L^4H and their vanadium (V) complexes

In order to substantiate the nature of bonding in the metal complexes discussed above, the ^1H NMR and ^{13}C NMR spectra of the ligands (L^1H – L^4H) and their corresponding vanadium (V) complexes have been recorded in DMSO-d_6 using TMS as internal standard. The spectral data of the ligands and their complexes are listed in **Table 1.5**. The ^1H NMR spectra of the ligands show a signal at δ 10.62-11.62 ppm which is due to NH proton. This NH proton signal disappears in the complexes indicating the bond formation to the metal atom after enolization and deprotonation of the NH group of the ligand molecules. The proton signals due to the azomethine methyl protons (N=C-CH_3) are shifted downfield in the spectra of the metal complexes due to the coordination through the nitrogen atom of the azomethine group. The appearance of a signal due to NH_2 (δ 2.86 and 2.68 ppm) at almost the same position in the ligands and their corresponding vanadium (V) complexes show its non-involvement in complex formation. A multiplet due to aromatic protons in the spectra of metal complexes resonates nearly at the same position as that of free ligands.

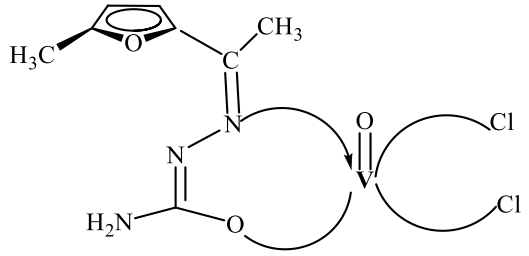
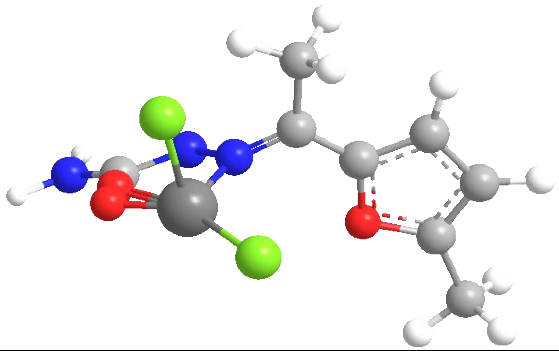
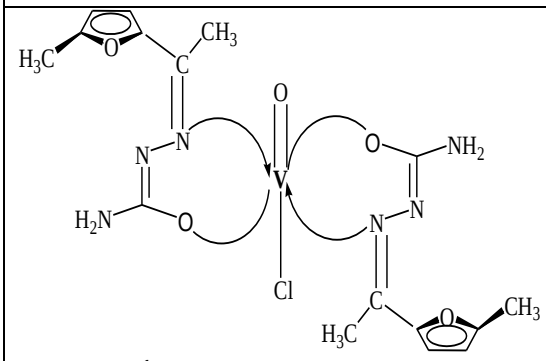
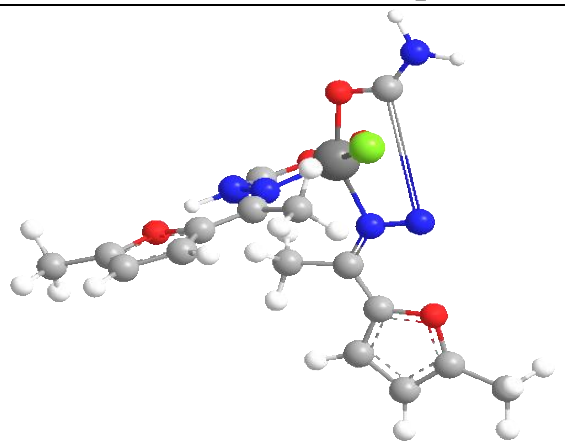
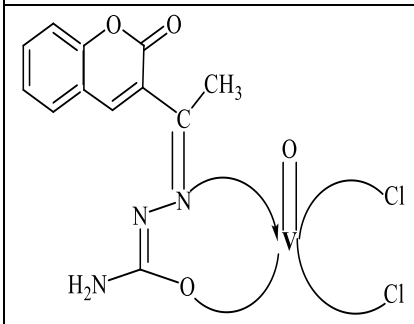
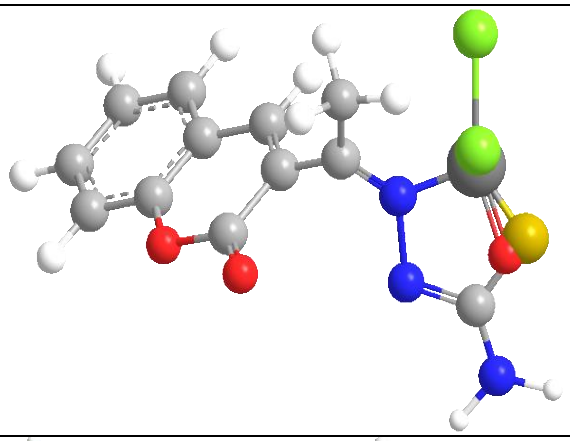
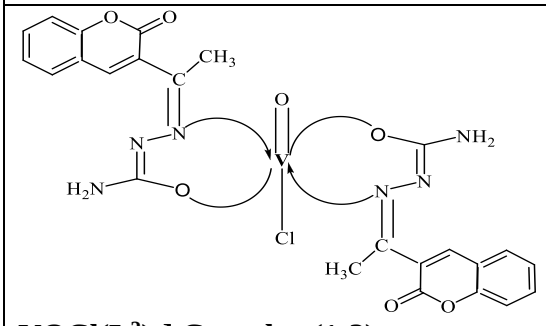
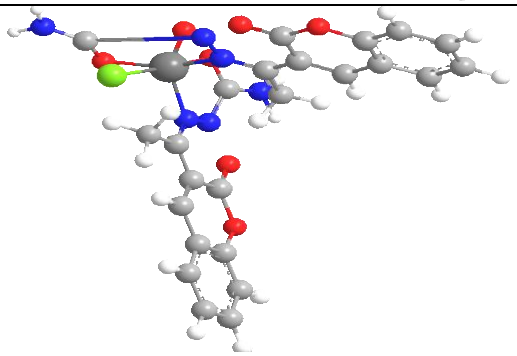
The ^{13}C NMR signals due to azomethine carbon (>C=N) in the ligands, (L^1H and L^4H) appeared at *δ*153.73-172.03 ppm and on complexation these show a downfield shift to *δ*156.03-175.64 ppm suggesting the involvement of azomethine nitrogen in the complexation. The spectra of the ligands exhibit intensive resonance signals at *δ*158.03 -165.72 ppm due to the amido (>C=O) group and the signals at *δ*178.03 -193.97 ppm due to the >C=S group which undergo downfield shift in the spectra of metal complexes, suggesting the involvement of enolic-oxygen in coordination with the metal atom (**Table 1.5**).

Table 1.5 ^1H NMR and ^{13}C NMR Spectral data of the ligands and their vanadium (V) complexes

^1H NMR Spectra (δ ppm)				^{13}C NMR Spectra (δ ppm)			
Synthesis compounds	**NH**	**NH_2**	**Aromatic protons**	**>(C=N)**	**(>C=S)**	**(C=O)**	**Aromatic carbon**
L^1H	10.62	2.68	7.05-7.62	153.73	-	156.03	155.08, 153.40 112.70, 108.08
$[VOCl_2(L^1)]$	-	2.78	7.05-7.62	163.03	-	165.08	155.08, 153.40, 112.78, 108.18

[VOCl $(L^1)_2$]	-	2.86	7.05-7.62	163.08	-	165.72	155.40, 153.72, 112.78, 108.18
L^2H	11.62	2.60	7.32-7.82	153.73	-	158.40	172.03, 152.72, 143.01, 133.38132.08, 131.04, 128.17, 126.79, 121.42
[$VOCl_2(L^2)$]	-	2.59	7.33-7.83	158.40	-	163.73	172.73,152.78, 143.07, 133.39,132.79, 131.08, 128.79, 126.47, 121.42
[VOCl $(L^2)_2$]	-	2.60	7.32-7.85	158.73	-	164.03	172.78, 152.79, 143.37, 134.89,133.79, 131.08, 128.79, 126.47, 121.43
L^3H	11.10	2.86	7.05-7.65	163.70	187.08	-	156.08, 155.43 112.78, 108.08,
[$VOCl_2(L^3)$]	-	2.76	7.05-7.65	168.70	193.08	-	156.30, 155.48, 112.88, 108.70
[VOCl $(L^3)_2$]	-	2.86	7.05-7.62	168.79	193.97	-	156.89, 155.49, 112.78, 108.87
L^4H	11.10	2.70	7.32-7.83	172.03	178.03	-	153.15, 152.72, 143.01, 133.38,132.08, 131.73, 128.17, 126.79, 120.42
[$VOCl_2(L^4)$]	-	2.62	7.30-7.83	175.15	185.03	-	156.22, 153.72, 143.02, 133.39, 132.82, 131.77, 128.22, 126.74, 120.47
[VOCl $(L^4)_2$]	-	2.67	7.30-7.83	175.64	185.87	-	156.47, 153.79, 143.15, 133.47, 132.82, 131.77, 128.22, 126.74, 120.77

Thus on the basis of the above observations from various spectral and analytical techniques, following penta and hexa coordinated environment have been proposed around the vanadium (V) metal atom for the (1:1) and (1:2) vanadium (V) complexes, respectively (**Fig. 1.2**).

 **[$VOCl_2(L^1)$] Complex(1:1)**	
 **[$VOCl(L^1)_2$] Complex (1:2)**	
 **$VOCl_2(L^2)$] Complex (1:1)**	
 **$VOCl(L^2)_2$] Complex (1:2)**	

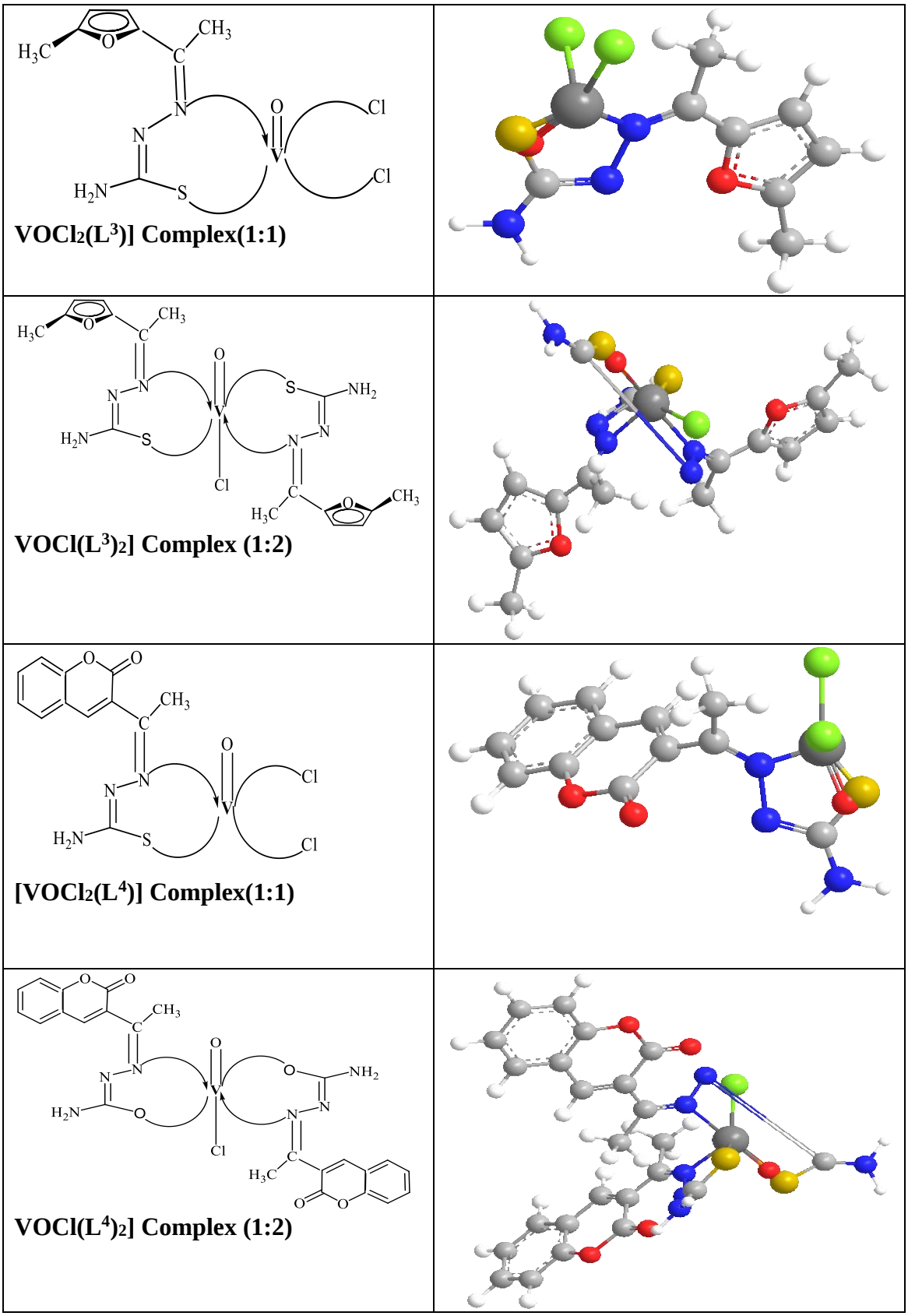


Fig. 1.2 Structure of 1:1 and 1:2 vanadium (V) complexes

7. Antimicrobial assay

Determination of minimum inhibitory concentration (MIC) of the synthesized metal complexes were carried out on selected fungi, *Candida albicans* and *Aspergillus niger* and two bacteria, Gram-positive (*Bacillus subtilis),* and Gram-negative (*Escherichia coli)* and the MIC values calculated for the ligands and their vanadium (V) complexes as shown in (Table 5). The results indicated that the ligands and their metal complexes were the most active in inhibiting the growth of the tested organisms between 18-28 μg/mL MIC values for selected bacteria and fungi. The results showed that all the free ligands were appreciably less active compared to their vanadium (V) complexes. This indicated that the complexation to metal enhances the activity of the ligand. This may be explained by Tweedy's chelation theory[32], according to which chelation reduces the polarity of the central metal atom because of partial sharing of its positive charge with the ligand, due to which the lipophilic character of the metal chelate increases and favours its permeation through the lipid layer of cell membrane. It has also been proposed that the ultimate action of the compounds is the denaturation of one or more proteins of the cell as a result of which normal cellular processes are impaired[33] and deactivation of various cellular enzymes that play a vital role in different metabolic pathways of these microorganisms.

7.1.1 MIC values of antifungal activity of vanadium complexes

The MIC values for vanadium (V) metal complexes are given in **Table 1.6**

Table 1.6 MIC (μg/mL) values for vanadium (V) and their complexes

Synthesized compounds	***Candida albicans***	***Aspergillus niger***
$[VOCl_2(L^1)]$	23.0±0.3	22.0±0.3
$[VOCl(L^1)_2]$	21.0±0.2	21.0±0.1
$[VOCl_2(L^2)]$	24.0±0.1	23.0±0.1
$[VOCl(L^2)_2]$	22.0±0.1	21±0.1
$[VOCl_2(L^3)]$	21.0±0.2	22.0±0.2
$[VOCl(L^3)_2]$	20.0±0.3	21.0±0.2
$[VOCl_2(L^4)]$	21.0±0.3	23.0±0.3
$[VOCl(L^4)_2]$	18.0±0.2	20.0±0.1
Fluconazole	12±0.2	12±0.2

7.1.1 MIC values for antibacterial activity of vanadium complexes

The MIC values for vanadium (V) metal complexes are given in **Table 1.7**.

Table 1.7 MIC (μg/mL) values for vanadium (V) complexes

Synthesized compounds	***Bacillus subtilis***	***Escherichia coli***
$[VOCl_2(L^1)]$	20.0±0.2	18.0±0.3
$[VOCl(L^1)_2]$	28.0±0.2	16.0±0.2
$[VOCl_2(L^2)]$	23.0±0.1	22.0±0.2
$[VOCl(L^2)_2]$	20.0±0.1	20.0±0.1
$[VOCl_2(L^3)]$	25.0±0.1	22.0±0.3
$[VOCl(L^3)_2]$	21.0±0.4	20.0±0.3
$[VOCl_2(L^4)]$	22.0±0.2	21.0±0.3
$[VOCl(L^4)_2]$	20.0±0.2	18.0±0.2
Streptomycin	10±0.2	09±0.2

7.2. *Antifungal studies*

Bio efficacies of the synthesized compounds were checked *in vitro*. The *in vitro* antifungal activities of the ligands and their complexes have been evaluated against two pathogenic fungi, *Candida albicans* and *Aspergillus niger* using by the agar plate technique[34]. The antifungal screening data of compounds were compared with the standard (Fluconazole).

Table 1.8 Antifungal screening data for the ligands (L^1H and L^2H) and their vanadium (V) complexes

Synthesized compounds	% Inhibition after 96 hrs					
	Candida albicans		*Aspergillusniger*		*Alternariaalternata*	
	100 ppm	200 ppm	100 ppm	200 ppm	100 ppm	200 ppm
L^1H	32	38	30	44	38	40
L^2H	34	42	32	48	40	45
$[VOCl_2(L^1)(H_2O)]$	62	63	64	68	64	67
$[VOCl(L^1)_2]$	68	69	66	75	75	76
$[VOCl_2(L^2)(H_2O)]$	64	65	65	74	67	68
$[VOCl(L^2)_2]$	67	70	67	79	78	82
Fluconazole	70	73	68	85	89	90

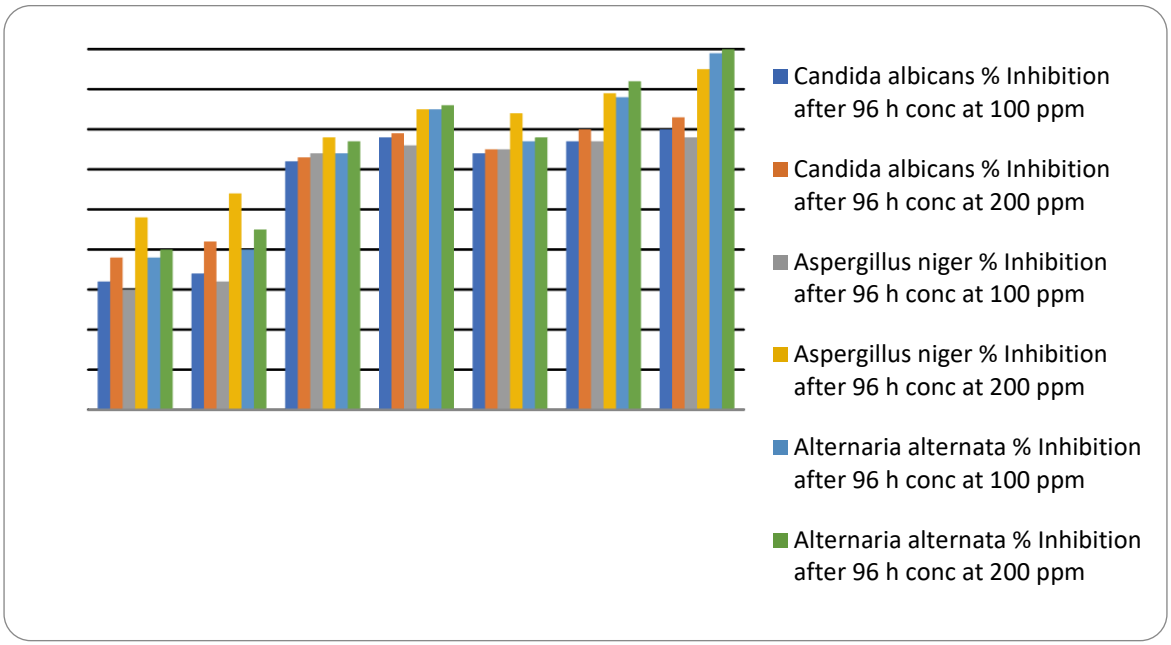


Fig. 1.3

Table 1.9 Antifungal screening data for the ligands (L^3H and L^4H) and their vanadium (V) complexes

Synthesized compounds	% Inhibition after 96 hrs					
	Candida albicans		*Aspergillus niger*		*Alternaria alternata*	
	100 ppm	200 ppm	100 ppm	200 ppm	100 ppm	200 ppm
L^3H	34	42	32	46	46	52
L^4H	36	46	34	52	45	49
$[VOCl_2(L^3)(H_2O)]$	58	62	58	64	74	77
$[VOCl(L^3)_2]$	66	69	66	73	83	86
$[VOCl_2(L^4)(H_2O)]$	61	65	62	77	79	82
$[VOCl(L^4)_2]$	68	70	67	82	86	88
Fluconazole	70	73	68	85	89	90

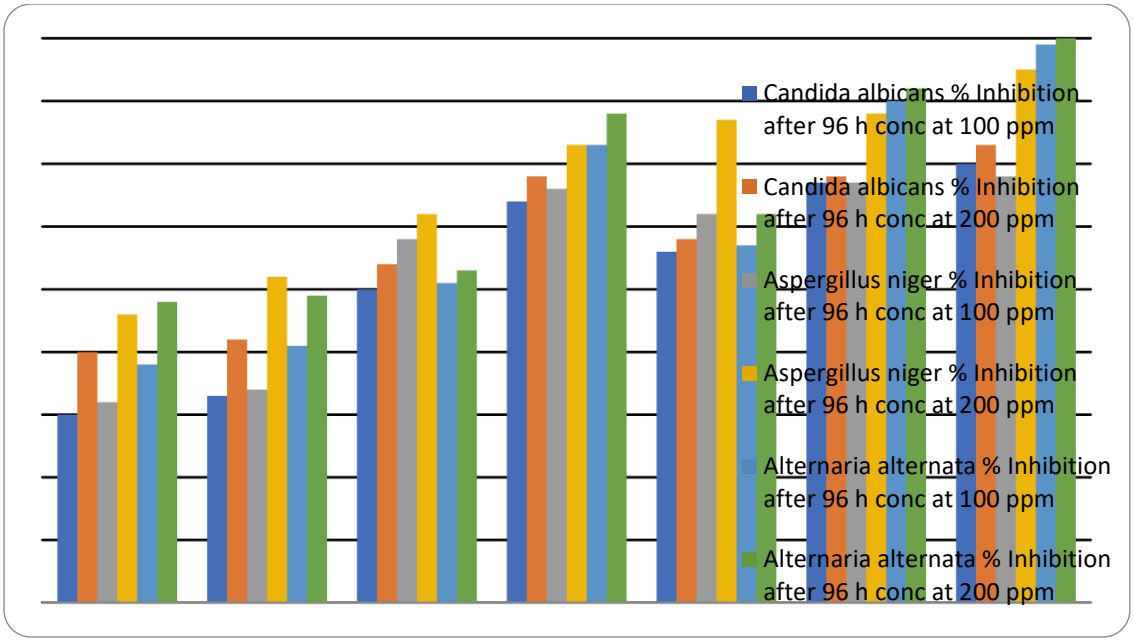


Fig.1.4

7.3. *Antibacterial screening*

In vitro antibacterial screening is generally performed by disc diffusion method[35] for primary selection of the compounds as therapeutic agents. The antibacterial activity of the ligands and their manganese complexes were evaluated against of two bacteria including Gram-positive (*Bacillus subtilis)* and Gram-negative (*Escherichia coli)*. The diameters of the zone of inhibition produced by the compounds were compared with the standard antibiotic (Streptomycin). The zone of inhibition thus formed around each disc containing the test compounds was measured accurately in mm.

Table 1.10 Antibacterial screening data for the ligands (L^1H and L^2H) and their vanadium (V) complexes

Synthesized compounds	% Inhibition after 24 hrs					
	Bacillus subtilis		Eschirichia coli		Staphylococcus aureus	
	500ppm	1000ppm	500ppm	1000 ppm	500 ppm	1000 ppm
L^1H	14	15	13	16	16	18
L^2H	15	16	14	15	17	19
$[VOCl_2(L^1)(H_2O)]$	16	17	15	17	18	20
$[VOCl(L^1)_2]$	17	19	16	19	20	22
$[VOCl_2(L^2)(H_2O)]$	17	18	16	18	19	21
$[VOCl(L^2)_2]$	18	20	17	19	21	23
Streptomycin	19	22	18	21	25	26

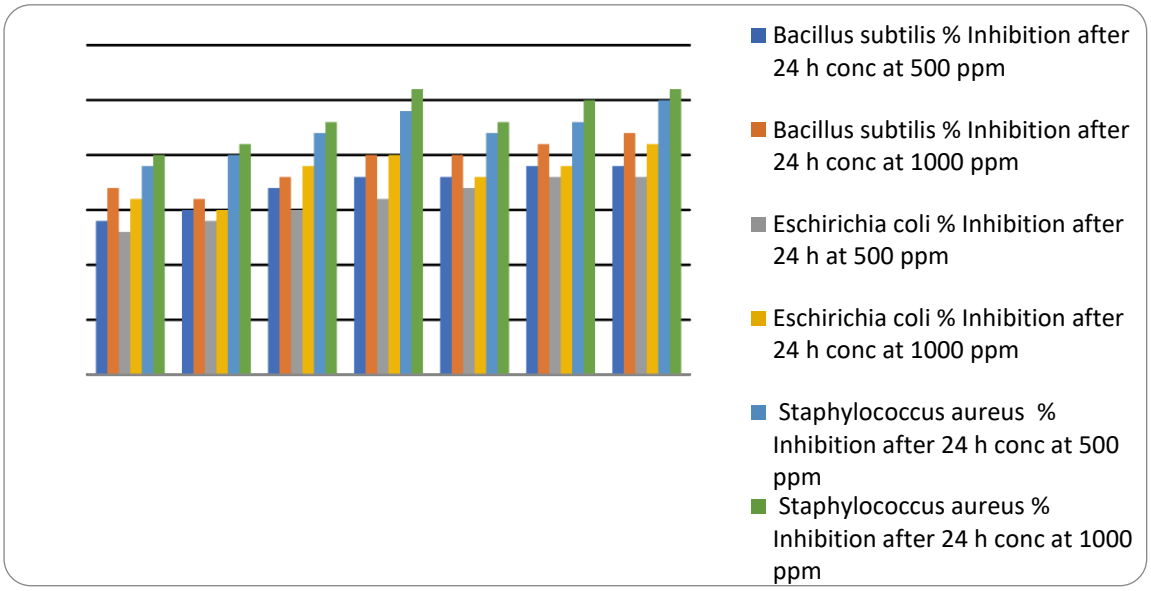


Fig. 1.5

Table 1.11 Antibacterial screening data for the ligands (L^3H and L^4H) and their vanadium (V) complexes

Synthesized compounds	% Inhibition after 24 hrs					
	Bacillus subtilis		Eschirichia coli		Staphylococcus aureus	
	500 ppm	1000 ppm	500 ppm	1000 ppm	500 ppm	1000 ppm
L^3H	15	17	14	16	19	20
L^4H	16	18	15	17	20	21

$[VOCl_2(L^3)(H_2O)]$	17	18	16	17	21	22
$[VOCl(L^3)_2]$	18	19	17	19	22	24
$[VOCl_2(L^4)(H_2O)]$	18	19	16	18	22	23
$[VOCl(L^4)_2]$	**19**	21	17	**21**	24	25
Streptomycin	19	22	18	21	25	26

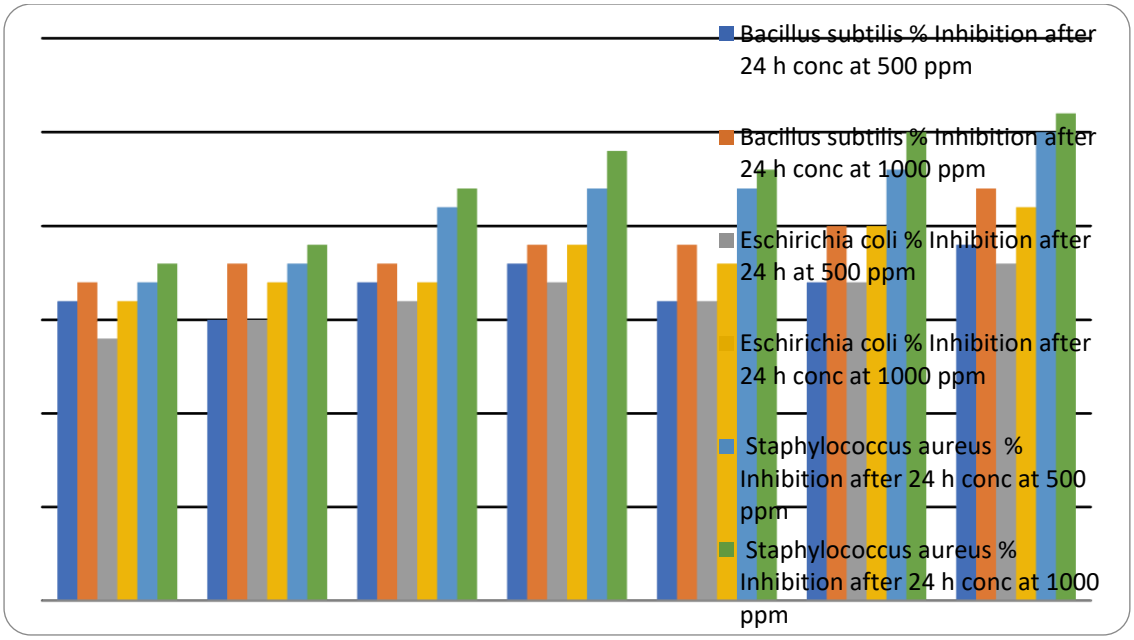


Fig. 1.6

8. Conclusions

- Microwave (MW) irradiation is an efficient and environmentally-benign method to accomplish various inorganic and organic syntheses to afford products in higher yields in shorter reaction periods.
- Vanadium (V) complexes synthesized in 1:1 and 1:2 molar ratios were found to possess penta- and hexa-coordinated tetrahedral structure.

9. References

1. **Sharma SK, Chaudhary A and Singh RV.** Gray chemistry versus Green chemistry: challenges and opportunities. *Rasayan J Chem* 1(1): 68-92, 2008.
2. **Rajendran A and Karthikeyan C.** Silica sulphuric acid catalyzed Fischer esterification reaction under solventless condition a novel green chemical reaction. *J Am Chem Sci* 1(1): 28-36, 2011.
3. **Dhakite PA and Kadam NS.** Microwave synthesis - a potential tool for Green chemistry. *J Online Int Res* 4: 208-214, 2014.
4. **Gude VG, Patil P, Martinez-Guerra E, Deng S and Nirmalakhandan N.** Microwave energy potential for biodiesel production. *Sustainble Chem Process* 15: 1-31, 2013.
5. **Yamgar RS, Nivid Y, Nalawade S, Mandewale M, Atram RG and Sawant SS.** Novel Zn(II) complexes of heterocyclic ligands as antimicrobial agents: synthesis, characterisation, and antimicrobial studies. Bio Inorg. *Chem Appl* 27: 1-10, 2014.

6. **Ramakrishana RK, Madhusudan RK and Mahendra KN.** Co (II), Ni (II), Cu (II), Zn (II), Cd (II), Hg (II), UO_2 (IV) and Th (IV) complexes from Schiff base ligand. *J Chil Chem Soc* 53(4): 1653-1657, 2008.
7. **Wu JC, Tang N, Liu WS, Tan MY and Chin ASC.** Intramolecular hydrogen bond self-template synthesis of some new Robson-type macrocyclic ligands. *Chem Lett* 12: 757-761, 2001.
8. **Garg R, Saini MK, Fahmi N and Singh RV.** Study of some biorelevant complexes of manganese (II) with active imines. *Ind J Chem* 44(A): 2433-2438, 2005.
9. **Venkatachalam G, Maheswaran S and Ramesh R.** Synthesis, spectra, redox property and catalytic activity of Ru (III) Schiff base complexes. *Ind J Chem* 44(A): 705-709, 2005.
10. **Nagajothi A, Kiruthika A, Chitra S and Parameswari K.** Synthesis and characterization of tetradentate Co (II) Schiff base complexes: antimicrobial and DNA cleavage studies. *Int J Pharma and Biomedical Sci* 3:1768-1778**,** 2012.
11. **Gupta YK,Agarwal SC, Madnawat SPand Narain R.** Synthesis, characterization and antimicrobial studies of some transition metal complexesof Schiff bases. *Res J Chem Sci* 2(4): 68-71, 2012.
12. **Falandysz J, Kunito T, Kubota R, Lipka K, Mazur A, Falandysz J and Tanabe S.** Selected elements in fly agaric *Amanita muscaria. J EnvirSci Health Part A*42 (11): 1615-1623, 2007.
13. **Talbott SM and Hughes K,** *"Vanadium"The Health Professional's Guide to Dietary Supplements*. Lippincott Williams & Wilkins 419, 2007.
14. **Sakurai H, Kojima Y, Yoshikawa Y, Kawabc K and Yasui H.** Antidiabetic vanadium(IV) and zinc(II) complexes. *CoordChem Rev* 226(1-2): 187-198, 2002.
15. **Aureliano M and Crans DC.**Decavanadate $(V_{10}\ O_{28})^{-6}$ and oxovanadates: oxometalates with many biological activities. *JInorg Bio Chem*103: 536-546, 2009.
16. **Rehder D.** Biological asnd medicinal aspects of vanadium. *Inorg Chem Commun* 6(5): 604-617, 2003**.**
17. **Maurya MR, Khurana S, Shailendra, Azam A, Zhang W and Rehder D.** Synthesis, characterisation and antiamoebic studies of dioxovanadium (V) complexes containing ONS donor ligands derived from S-benzyldithiocarbazate. *Eur J Inorg Chem* 43: 1966-1973, 2003.
18. **Vogel,** A.I., A Textbook of Organic Quantitative Analysis, Fifth edition, 243, 2004.
19. **Vogel**, A.I., A Textbook of Quantitative Chemical Analysis, sixth edition, 498, 2006.
20. **Vogel**, A.I., A Textbook of Quantitative Chemical Analysis, sixth edition, 387, 2000**.**
21. **Bonadies J S and Carrano C J.** Vanadiumphenolates as models for vanadium in biological systems. Synthesis, spectroscopy, and electrochemistry of vanadium complexes of ethylenebis [(O-hydroxyphenyl)glycine] and its derivatives**.** *J Am Chem Soc* 108(14): 4088-4095, 1986**.**
22. **Dinda R, Sengupta P, Sutradhar M, Ghosh S and CW Thomas**.Solution study of a structurally characterized monoalkoxo-bound monooxo-vanadium (V) complex: spontaneous generation of the corresponding oxobridgeddivanadium (V,V) complex and its electroreduction to a mixed-valence species in solution. *MakInorg Chem* 47: 5634-5640, 2008.
23. **Thankamony M and MohananK.**Synthesis, spectral studies, thermal decomposition kinetics, reactivity and antibacterial activity of some lanthanide (III) nitrate complexes of 2-(N-indole-2-one) amino-3-carboxyethyl -4,5,6,7-tetrahydrobenzo[b] thiophene. *Ind J Chem* 46A: 247-251, 2007.
24. **Rajavel R, Vadivu MSand Anitha C.** Synthesis, physical characterization and

biological activity of some Schiff base complexes. E-J Chem 5(3): 620-626, 2008.

25. **Nakamoto K.** Infrared and raman spectra of inorganic and coordination, compounds applications in coordination, organometallic, and bioinorganic chemistry.*3rd Ed New York: Wiley*1997.
26. **Sharma N, Thakur M and Chaudhry SC.** Monooxovanadium(V) 2-phenylphenoxides: Synthesis, characterization, and antimicrobial potential.*JCoordChem*63(6): 1071-1079, 2010.
27. **Von Dreele RB and Fay RC**. Octahedral vanadium (IV) complexes. Synthesis and stereochemistry of vanadium (IV) β-diketonates.J Am Chem Soc 94: 7935-7936,1972.
28. **Selbin J.** Oxovanadium (IV) complexes**.** *Coord Chem Rev*1: 293-314, 1966.
29. **Sreeja PB and Kurup MRP.** Synthesis and spectral characterization of ternary complexes of oxovanadium (IV) containing some acid hydrazones and 2,2′-bipyridine. *Spectrochim Acta*61(1): 33-336, 2005.
30. **Mishra AP and Pandey LR**. Synthesis, structure and reactivity of oxovanadium (IV) Schiff base complexes. *Ind J Chem* 44A: 1800-1805, 2005.
31. **Weeks C, Song Y, Suzuki M, Chernova NA, Zavalij PY and Whittingham S.** The one dimensional chain structures of vanadylglycolate and vanadyl acetate. *J Mater Chem* 13: 1420-1423, 2003.
32. **Tweedy BG.** *Phytopathology*, 55, 910, 1964.
33. **Lehninger, AL**. Biochemistry, second edition, Worth Publishers, New York, 519, 1975
34. **Madigan M, Martinko J**., *Brock Biology of Microorganisms* (11th ed.), 2005 Prentice Hall. ISBN 0-13-144329-1.
35. **Zaidan MRS, Noor Rain A, Badrul A R, Adlin A and Norazah A.** *Tropical Biomedicine,* **,** 22(2), 165, 2005.

Received on February 17, 2021.