



## Synthesis, Characterization & Biological Activity of Some New Schiff Base Complexes Derived From Thiosemicarbozone

## KEYWORDS

Thiosemicarbazone / Schiff bases/ Mo (V) and W (VI) / Biological Activity).

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243005, (India)**ABSTRACT**

The Schiff bases anisaldehyde thiosemicarbazone (ATC), 3-4, dimethoxy benzaldehyde thiosemicarbazone (DMBTC), thiophene-2 aldehyde thiosemicarbazone (TATC), 2-acetyl pyridine thiosemicarbazone (APTC) and acetyl acetone thiosemicarbazone (AATC) were prepared by standard methods and characterised by M.P. & I.R. Spectra. Their complexes with Molybdenum {(Mo ATC), (Mo DMBTC), (Mo TATC), (Mo APTC), (Mo AATC)} Tungsten {(W ATC), (W DMBTC), (W TATC), (W APTC), (W AATC)} have been prepared by standard method and characterised by elemental analyses, electrical conductance, magnetic susceptibility, IR and electronic spectral studies molar conductance & T.G.A.. Both the ligands and their complexes have been screened for their fungicidal & bactericidal activities and the results indicate that they exhibit significant antimicrobial properties.

**INTRODUCTION :**

The Schiff base compounds have been used as fine chemicals and medical substrates in the field of coordination chemistry. Schiff bases and their metal complexes have been studied for their application in biological, clinical and pharmacological areas.<sup>(1-4)</sup> The chemistry of molybdenum has aroused considerable interest in view of its biological importance<sup>(5)</sup>. The effect of MO(V) and W(VI) metal compounds on biological systems has evoked considerable interest<sup>(6-9)</sup>. Keeping in view these facts we have synthesised and characterised the complexes of these metals with ATC, DMBTC, TATC, APTC and AATC. The obtained results are reported here.

**MATERIALS AND METHODS :**

Materials used in the preparation of ligands (schiff bases) were different aldehydes and ketons. All used chemicals were of analytical grade and purchased from (Sigma/Aldrich). The aldehydes used were anisaldehyde (BDH), 3,4-dimethoxy benzaldehyde (sigma), thiophene-2-aldehyde (Fluka), 2-acetyl pyridine (BDH) and ketone was acetyl acetone (BDH) and thiosemicarbazide (Aldrich). Metals used in the preparation of complexes were molybdenum and tungsten. Molybdenum used as molybdenum (V) chloride (Sigma) and tungsten as tungsten VI chloride (Fluka).

**Instrumentation :**

Elemental analyses were carried out at R.S.I.C. Dept. C.D.R.I. Lucknow. Conductivity measurements were carried out at Philips conductivity bridge model PR 9500, with a dip type conductivity cell at department of chemistry B.C.B. The conductances of the complexes were measured in methanol, dimethyl formamide and dimethyl sulphoxide at  $10^{-3}$  M dilution at 30°C. The infra red studies of the complexes were made with Perkin-Elmer spectrophotometer model 651 (U.S.A.) in KBR as well as Nuzol phase from 4000  $\text{cm}^{-1}$  to 200  $\text{cm}^{-1}$  at R.S.I.C. Department C.D.R.I. Lucknow. Magnetic susceptibility of the complexes was determined by the Gouy method at the dept of chemistry, University of Roorkee, Roorkee. The sample tube was calibrated with  $\text{CuSO}_4$ . TGA analysis was carried out at the chem. deptt. G.N.D. University. Amritsar Visible spectra were recorded with Beckman DV-2 spectrophotometer in the range of 300  $\text{cm}^{-1}$  to 750  $\text{cm}^{-1}$  at Deptt. of Chemistry, Bareilly College, Bareilly.

**PREPARATION OF LIGANDS :**

The Schiff bases were prepared by the condensation of respective aldehyde/ketone with thiosemicarbazide. The amino compound was dissolved in ethanol and refluxed for

about half an hour. The requisite amount of the respective aldehyde/ketone was then added to the flask. The mixture was then refluxed for about six hours. The reaction mixture was kept for 24 hours. The crystals of the ligand were obtained which were purified by recrystallization. The purity of the ligands were characterised by elemental analyses, Milting Point and IR spectra.

**PREPARATION OF COMPLEXES****Preparation of Oxomolybdenum (V) Complexes:**

A methanolic solution of metal chloride was added in small quantities with stirring to a hot solution of the ligand in methanol. The pH of the reaction mixture was adjusted to 6 NaOAc/HOAc buffer and stirring continued for 10-15 min. The solid complex that separated was washed with aq. methanol and dried over  $\text{P}_4\text{O}_{10}$  under vacuum.

**Preparation of dioxotungsten (VI) Complexes :**

The solution of metal salt was dissolved in 10 ml of NaOH solution by heating on a water bath and was filtered. The Schiff base was dissolved in 20 ml of NaOH solution. The solution of the Schiff base was added to the above solution of metal salt. The precipitate so obtained was filtered washed with water followed by ether and dried in vacuum over silica gel.

**RESULT AND DISCUSSION:**

The elemental analyses of the complexes indicate that Mo(V) reacts with ligand in the molar ratio of 1:2. On this basis, the composition of the complexes comes out to be  $[\text{MoO}(\text{L})_2\text{Cl}_2]$ . The molar conductance in MeOH, DMSO & DMF at  $10^{-3}$  M dilution indicate the non-electrolytic nature of the complexes<sup>(10)</sup>. The elemental analyses of the complexes reveals that dioxotungsten reacts with ligand in the molar ratio of 1:2 and the complexes appears to have the composition of  $[\text{WO}_2(\text{L})_2\text{Cl}_2]$ . The molar conductance value of the complexes in DMF at  $10^{-3}$  M dilution shows that the complexes were non electrolyte<sup>(11)</sup>.

**Oxomolybdenum (V) Complexes****Electronic Spectra :**

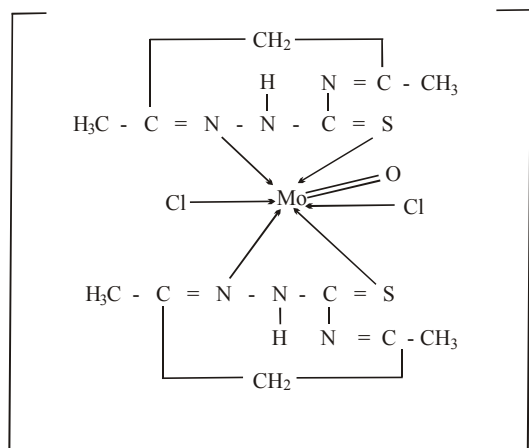
The electronic spectra of oxomolybdenum (V) complexes were best considered as octahedral with a strong tetragonal distortion resulting from molybdenum oxygen bond. The complex exhibit three distinct absorption bands in the ligand field region<sup>(12)</sup>. The low intensity absorption peaks in the long wave length region were possibly due to first crystal field transition  ${}^2\text{B}_2 \rightarrow {}^2\text{E}$  (dxy dxz, dyz). This transition were observed at 12820 - 16000  $\text{cm}^{-1}$ . The second crystal field transition were ob-

served at 18750 - 21000  $\text{cm}^{-1}$  due to transition  ${}^2B_2 \rightarrow {}^2B_1$  ( $dxy \rightarrow dx^2-y^2$ ). The third peak appeared at 22000 - 30000  $\text{cm}^{-1}$  and was due to transition  ${}^2B_2 \rightarrow {}^2A_1$  ( $dxy \rightarrow dz^2$ ). The spectral band at 15151  $\text{cm}^{-1}$  indicates octahedral geometry for the complexes in agreement with Ballhausen Gray Scheme<sup>(13)</sup>.

#### Magnetic Moment :

The oxomolybdenum (V) complexes show magnetic moment value of 1.63 - 1.68 B.M. which correspond to the spin only value (1.73 B.M.) expected for oxomolybdenum (V) complex showing the absence of any Mo-Mo interaction. Thus the complexes were found to be paramagnetic as expected for a  $d^1$ - system<sup>(14)</sup>.

#### I.R. Spectra :



Acetyl acetone thiosemicarbazone molybdenum (V) chloride

The I.R. spectra of the ligand and its metal complexes have been recorded. The comparison of the IR spectral bands of free ligands & the metal complexes indicates that in the complexes both  $\nu(\text{C}=\text{N})$  &  $\nu(\text{C}=\text{S})$  have appeared with lowering of  $\nu(\text{C}=\text{N})$  by  $\sim 15 \text{ cm}^{-1}$  and  $\nu(\text{C}=\text{S})$  by  $\sim 80 \text{ cm}^{-1}$ . These shifts indicate the co-ordination through nitrogen of azomethine group and sulphur of  $(\text{C}=\text{S})$  group<sup>(15)</sup>. It appears therefore, in these complexes the ligand functions in a bidentate manner bonding through nitrogen and sulphur. The IR spectra of the complexes also exhibited two more bands which may be due to  $(\text{Mo}=\text{O})$  stretching and  $(\text{Mo}-\text{Cl})$  bond<sup>(16,17)</sup>.

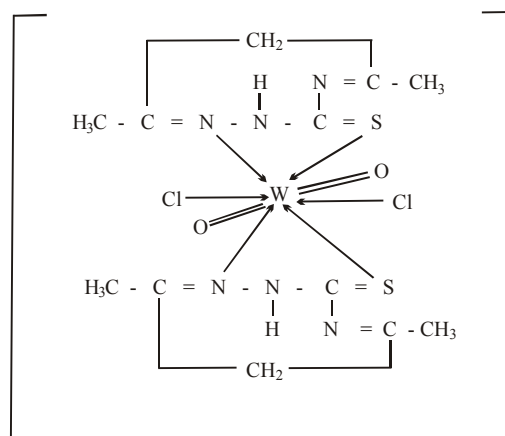
#### Dioxotungsten (VI) Chloride

##### Electronic & Magnetic Moment Spectra :

The electronic spectra of the complexes show a strong band at 24850  $\text{cm}^{-1}$ . This may be due to ligand to metal charge transfer transition between the highest occupied ligand molecular orbital and the lowest empty tungsten d orbital<sup>(18)</sup>. The magnetic moment data indicate its diamagnetic nature<sup>(19)</sup> as expected for  $d^0$  system and the stabilization of higher oxidation through complex formation.

#### I.R. Spectra :

In the IR spectra of the ligands show two important bands which may be due to  $\nu(\text{C}=\text{N})$  group &  $\nu(\text{C}=\text{S})$  group. On complexation these bands have shifted to lower frequencies indicating the coordination through nitrogen of  $(\text{C}=\text{N})$  group and sulphur of  $(\text{C}=\text{S})$  group. The ligand appears to be behaving in bidentate manner. The IR spectra of the complexes also exhibited two more bands which may be due to  $(\text{W}=\text{O})$  stretching and the presence of  $(\text{W}-\text{Cl})$  bond<sup>(20)</sup>.



Acetyl acetone thiosemicarbazone dioxotungsten (VI) chloride

#### CONCLUSION :

On the basis of above discussions, it appears that the ligands act in a bidentate manner coordinated through nitrogen & sulphur. The complexes may be assigned an octahedral geometry with a slight distortion. Out of its six positions four are occupied by two ligand molecules and two by chlorine atoms.

Table-1 CHARACTERIZATION OF OXOMOLYBDENUM (V) COMPLEXES

Sl. No.	Name and Molecular Formula of the complex	Colour	M.P./D.T. °C	Elemental Analyses					Molar Conductance $\text{Ohm}^{-1} \text{cm}^2 \text{Mol}^{-1}$			Magnetic Moments in B.M.
				C%	H%	N%	S%	Pd%	Methanol	DMF	DMSO	
1.	Acetyl acetone thiosemicarbazone oxomolybdenum (V) chloride $\{\text{MoO}(\text{C}_5\text{H}_9\text{N}_3)_2\text{Cl}_2\}$	Yellow	275	30.16 (29.20)	4.25 (3.65)	18.79 (17.04)	14.45 (13.01)	20.27 (19.47)	7	13	16	1.68
2.	Bis (anisaldehyde) thiosemicarbazone oxomolybdenum (V) chloride $\{\text{MoO}(\text{C}_{17}\text{H}_{17}\text{N}_3\text{O}_2\text{S})_2\text{Cl}_2\}$	brown	259	49.06 (48.74)	5.51 (4.06)	11.26 (10.03)	8.13 (7.64)	11.15 (11.47)	5	9	12	1.66
3.	Bis (3,4-dimethoxy benzaldehyde) thiosemicarbazone oxomolybdenum (V) chloride $\{\text{MoO}(\text{C}_{19}\text{H}_{21}\text{N}_3\text{O}_4\text{S})_2\text{Cl}_2\}$	Orange	225	48.29 (47.65)	4.98 (4.38)	9.19 (8.77)	7.21 (6.68)	11.94 (10.03)	8	10	15	1.65
4.	Bis (thiophene-2-aldehyde) thiosemicarbazone oxomolybdenum (V) chloride $\{\text{MoO}(\text{C}_{11}\text{H}_7\text{N}_3\text{S})_2\text{Cl}_2\}$	Pale Yellow	255	36.53 (35.62)	3.19 (2.43)	12.09 (11.34)	26.33 (25.91)	13.92 (12.95)	10	9	16	1.64
5.	Bis (2-acetyl pyridine) thiosemicarbazone oxomolybdenum (V) chloride $\{\text{MoO}(\text{C}_{12}\text{H}_{12}\text{N}_3\text{S})_2\text{Cl}_2\}$	Red	295	47.06 (46.33)	4.12 (3.86)	19.22 (18.02)	9.39 (8.23)	13.93 (12.35)	13	8	15	1.63

Figures in parenthesis are calculated values.

**Table-2**  
**CHARACTERIZATION OF DIOXO TUNGSTEN (VI) COMPLEXES**

Sl. No.	Name and Molecular Formula of the complex	Colour	M.P./D.T. °C	Elemental Analyses					Molar Conductance Ohm <sup>-1</sup> Cm <sup>2</sup> Mol <sup>-1</sup> DMF	Magnetic Moments in B.M.
				C%	H%	N%	S%	Pd%		
1.	Acetyl acetone thiosemicarbazone dioxotungsten (VI) chloride [WO <sub>2</sub> (C <sub>5</sub> H <sub>9</sub> N <sub>3</sub> ) <sub>2</sub> Cl <sub>2</sub> ]	OrangeYellow	252	23.38 (22.74)	3.11 (2.84)	14.68 (13.27)	11.88 (10.11)	30.56 (29.06)	1.9	dia magnetic
2.	Bis (anisaldehyde) thiosemicarbazone dioxotungsten (VI) chloride [WO <sub>2</sub> (C <sub>17</sub> H <sub>17</sub> N <sub>2</sub> O <sub>2</sub> S) <sub>2</sub> Cl <sub>2</sub> ]	Dark Yellow	202	42.47 (41.76)	4.85 (3.48)	9.12 (8.60)	7.46 (6.55)	19.24 (18.83)	-	dia magnetic
3.	Bis (3,4-dimethoxy benzaldehyde) thiosemicarbazone dioxotungsten (VI) chloride [WO <sub>2</sub> (C <sub>19</sub> H <sub>21</sub> N <sub>3</sub> O <sub>4</sub> S) <sub>2</sub> Cl <sub>2</sub> ]	Brown	235	42.69 (41.56)	4.09 (3.83)	8.28 (7.66)	6.92 (5.83)	17.72 (16.77)	1.8	dia magnetic
4.	Bis (thiophene-2-aldehyde) thiosemicarbazone dioxotungsten (VI) chloride [WO <sub>2</sub> (C <sub>11</sub> H <sub>7</sub> N <sub>3</sub> S <sub>3</sub> ) <sub>2</sub> Cl <sub>2</sub> ]	Yellow	260	30.02 (29.96)	2.93 (2.04)	10.51 (9.53)	22.32 (21.79)	21.06 (20.89)	2.1	dia magnetic
5.	Bis (2-acetyl pyridine) thiosemicarbazone dioxotungsten (VI) chloride [WO <sub>2</sub> (C <sub>15</sub> H <sub>15</sub> N <sub>5</sub> S) <sub>2</sub> Cl <sub>2</sub> ]	Brownish Yellow	265	40.24 (39.08)	4.77 (3.26)	16.25 (15.21)	7.86 (6.95)	20.76 (19.98)	2.2	dia magnetic

Figures in parenthesis are calculated values.

**Table-3 INFRARED SPECTRA FOR MOLYBDENUM (V) COMPLEXES**

S.No.	Name of the complexes	Bands (Cm <sup>-1</sup> )
1.	Acetyl acetone thiosemicarbazone	Ligand 3410 (s) 2071 (m) 1157 (w) 665 (m)
	Acetyl acetone thiosemicarbazone oxomolybdenum (V) chloride	Complex 3481 (w) 2071 (m) 1353 (w) 736 (vs)
2.	Bis (anisaldehyde) thiosemicarbazone	Ligand 3400 (s) 2018 (m) 1357 (s) 721 (s)
	Bis (anisaldehyde) thiosemicarbazone oxomolybdenum (V) chloride	Complex 3304 (w) 1583 (vs) 1038 (w) 556 (w)
3.	Bis (3,4-dimethoxy bezaldehyde) thiosemicarbazone	Ligand 3350 (m) 1809(vw) 1238 (m) 683 (m)
	Bis (3,4-dimethoxy bezaldehyde) thiosemicarbazone oxomolybdenum (V) chloride	Complex 3381 (w) 1601 (vs) 1032 (m) 670 (w)
4.	Bis (thiophene-2-aldehyde) thiosemicarbazone	Ligand 3486 (m) 2829 (w) 1257 (w) 840 (vs)
	Bis (thiophene-2-aldehyde) thiosemicarbazone oxomolybdenum (V) chloride	Complex 3320 (w) 1603(vs) 1249 (w) 756 (vs)

5.	Bis (2-acetyl pyridine) thiosemicarbazone	Ligand	3515 (m) 2092 (w) 1264 (w) 815 (vs)	3458 (w) 1635 (vs) 1174 (w) 720 (s)	3305 (m) 1546 (w) 1026 (s) 510 (m)	2947 (w) 1320 (m) 949 (w)
	Bis (2-acetyl pyridine) thiosemicarbazone oxo-molybdenum (V) chloride	Complex	3310(vw) 1470 (w) 920 (s) 645 (m)	3079 (w) 1285 (m) 832 (w) 519 (w)	2940 (w) 1154 (m) 752 (vs) 340 (vs)	1602 (vs) 1080 (w) 711 (s)

Table-4 SPECTRA FOR TUNGSTEN (VI) COMPLEXES

S.No.	Name of the complexes	Bands (Cm <sup>-1</sup> )				
1.	Acetyl acetone thiosemicarbazone	Ligand	3410 (s) 2071 (m) 1157(w) 665 (m)	3290 (w) 1069 (vs) 1056 (s) 583 (w)	3018 (vw) 1475 (w) 946 (m) 418 (w)	2876 (m) 1286 (m) 824 (vs)
	Acetyl acetone thiosemicarbazone dioxotungsten (VI) chloride	Complex	3419 (m) 2079 (m) 1105 (m) 638 (w)	3291 (vw) 1585 (vs) 913 (m) 476 (m)	3083 (w) 1414 (w) 850 (s) 365 (s)	2993 (w) 1292 (m) 745 (s)
2	Bis (anisaldehyde) thiosemicarbazone	Ligand	3400 (s) 2018 (m) 1357 (s) 721 (s)	3286 (w) 1604 (vs) 1081 (w) 597 (m)	3146 (m) 1530 (w) 1013 (s) 512 (s)	2886 (m) 1525 (sh) 820 (vs)
	Bis (anisaldehyde) thiosemicarbazone dioxotungsten (VI) chloride	Complex	3357 (w) 2091 (m) 1187 (m) 766 (s)	3218 (m) 1587 (vs) 1004 (w) 590 (m)	3139 (vw) 1467 (w) 935 (m) 360 (w)	2958 (m) 1383 (m) 880 (vs)
3	Bis (3,4-didmethoxy bezaldehyde) thiosemicarbazone	Ligand	3350 (m) 1809(vw) 1238 (m) 683 (m)	3272 (w) 1630 (vs) 1173 (s) 547 (w)	3049 (m) 1558 (w) 951 (m) 458 (w)	2825 (w) 1337 (w) 835 (vs)
	Bis (3,4-didmethoxy bezaldehyde) thiosemicarbazone dioxotungsten (VI) chloride	Complex	3405 (w) 2014 (w) 1020 (w) 539 (m)	3290 (m) 1596 (vs) 915 (m) 417 (w)	3110 (m) 1487 (w) 875 (s) 340 (s)	2924 (m) 1256 (m) 790 (vs)
4.	Bis (thiophene-2-aldehyde) thiosemicarbazone	Ligand	3486 (m) 2829 (w) 1257 (w) 840 (vs)	3216 (w) 2027 (m) 1138 (s) 698 (m)	3105 (m) 1622 (vs) 1048 (m) 487 (w)	2990 (w) 1418 (m) 942 (vw)
	Bis (thiophene-2-aldehyde) thiosemicarbazone dioxotungsten (VI) chloride	Complex	3350 (w) 2062 (w) 1129 (m) 686 (m)	3269 (w) 1597 (vs) 989 (w) 543 (w)	3017 (m) 1455 (w) 905 (s) 325 (s)	2923 (m) 1357 (m) 953 (s)
5.	Bis (2-acetyl pyridine) thiosemicarbazone	Ligand	3515 (m) 2092 (w) 1264 (w) 815 (vs)	3458 (w) 1635 (vs) 1174 (w) 720 (s)	3305 (m) 1546 (w) 1026 (s) 510 (m)	2947 (w) 1320 (m) 949 (w)
	Bis (2-acetyl pyridine) thiosemicarbazone dioxotungsten (VI) chloride	Complex	3475 (m) 2064 (m) 1147 (m) 567 (m)	3343 (w) 1645 (vs) 923 (m) 413 (w)	3112 (w) 1477 (m) 860 (s) 315 (s)	2904 (w) 1238 (w) 739 (s)

**Antimicrobial Screening :**

The antifungal activity was evaluated by the radial growth method using Czapek's agar medium having the composition, glucose 20g, starch 20g, agar-agar 20g and distilled water 10000 ml. To this medium was added requisite amount of the compound after being dissolved in DMF so as to obtain certain final concentrations (25, 50, 100 & 200 ppm) the organism use in these investigations included alternaria alternate, Rhizoctinia bataticola. The fungicidal activity of the ligands and their metal complexes against pathogenic fungi is recorded in Table-5.

The activity against bacteria was evaluated by the inhibition zone technique (paper-disc plate method), 15 ml nutrient agar medium having the composition peptone 5g, beef extract 5 g, NaCl 5gm, agar-agar 20 g and distilled water 1000 ml., was pipetted into the petri dish. The organisms

used in the present investigations included Staphylococcus aureus and Xanthomonas compestris. The compound were dissolved in DMF in 500 and 1000 ppm concentrations. The bactericidal activity of the ligands and their metal complexes against pathogenic bacteria is recorded in Table-6.

The free ligands and their respective metal chelates were screened against selected fungi and bacteria to assess their potential as antimicrobial agents. The results are quite promising. The antimicrobial data reveal that the complexes are superior to the free ligands. The enhanced activity of the metal chelates may be ascribed to the increased lipophilic nature of these complexes arising due to the chelation<sup>(21,22)</sup>. The toxicity increased as the concentration was increased.

Table-5 Fungicidal screening data for the ligands and their metal complexes

Compound	Inhibition after 96 h(%) (conc. in ppm)					
	Alternaria alter-nate			Rhizoctonia bata-ticola		
	50	100	200	50	100	200
AATC	41	53	60	40	52	56
ATC	30	42	48	34	38	45
DMBTC	44	55	65	40	52	59
TATC	41	55	60	41	62	60
APTC	36	43	52	37	41	52
[MoO (AATC) <sub>2</sub> Cl <sub>2</sub> ]	40	55	63	45	57	62
[MoO (ATC) <sub>2</sub> Cl <sub>2</sub> ]	38	43	53	37	48	52
[MoO(DMBTC) <sub>2</sub> Cl <sub>2</sub> ]	46	50	65	42	55	62
[MoO (TATC) <sub>2</sub> Cl <sub>2</sub> ]	46	62	66	45	63	65
[MoO (APTC) <sub>2</sub> Cl <sub>2</sub> ]	40	45	53	40	41	55
[WO <sub>2</sub> (AATC) <sub>2</sub> Cl <sub>2</sub> ]	41	53	62	42	55	59
[WO <sub>2</sub> (ATC) <sub>2</sub> Cl <sub>2</sub> ]	36	43	52	36	40	51
[WO <sub>2</sub> (DMBTC) <sub>2</sub> Cl <sub>2</sub> ]	46	55	61	45	56	63
[WO <sub>2</sub> (TATC) <sub>2</sub> Cl <sub>2</sub> ]	49	63	68	46	62	67
[WO <sub>2</sub> (APTC) <sub>2</sub> Cl <sub>2</sub> ]	41	46	55	42	44	53
Bavistin	33	94	100	85	96	100

Table-6 Antibacterial screening data for the ligands and their metal complexes

Compound	Diameter of Inhibition Zone (mm) (conc. in ppm)			
	Staphylococcus aureus		Xanthomonas compestris	
	500	1000	500	1000
AATC	8	11	7	9
ATC	6	9	8	10
DMBTC	9	11	12	10
TATC	6	10	8	12
APTC	9	12	10	13
[MoO (AATC) <sub>2</sub> Cl <sub>2</sub> ]	10	15	9	12
[MoO (ATC) <sub>2</sub> Cl <sub>2</sub> ]	7	11	10	10
[MoO(DMBTC) <sub>2</sub> Cl <sub>2</sub> ]	10	12	11	13
[MoO (TATC) <sub>2</sub> Cl <sub>2</sub> ]	8	12	11	13
[MoO (APTC) <sub>2</sub> Cl <sub>2</sub> ]	10	11	12	14
[WO <sub>2</sub> (AATC) <sub>2</sub> Cl <sub>2</sub> ]	12	14	9	12
[WO <sub>2</sub> (ATC) <sub>2</sub> Cl <sub>2</sub> ]	8	12	12	14
[WO <sub>2</sub> (DMBTC) <sub>2</sub> Cl <sub>2</sub> ]	12	15	12	10
[WO <sub>2</sub> (TATC) <sub>2</sub> Cl <sub>2</sub> ]	9	12	10	12
[WO <sub>2</sub> (APTC) <sub>2</sub> Cl <sub>2</sub> ]	10	13	11	16
Streptomycin	15	19	16	19

## REFERENCE

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