Available online at www.derpharmachemica.com

ISSN 0975-413X
CODEN (USA): PCHHAX

Der Pharma Chemica, 2016, 8(2):248-255
(http://derpharmachemica.com/archive.html)

Studies on some 2-methoxybenzohydroxamate complexes of aryltellurium(IV) and diaryltellurium(IV)

Sonu Chauhan, Deepak, Sapana Garg and Krishan K. Verma*

Department of Chemistry, Maharshi Dayanand University, Rohtak(Haryana), India

---

ABSTRACT

Twelve new complexes of the 2- methoxybenzohydroxamate with aryltellurium(IV) and diaryltellurium(IV) of type $RTeCl_2(L)$, $RTeCl(L)_2$, $R_2TeCl(L)$ and $R_2Te(L)_2$; (where R = p-methoxyphenyl, p-hydroxyphenyl, 3-methyl-4-hydroxyphenyl and *L = 2-methoxybenzo- hydroxamate) have been synthesized by reactions of potassium 2-methoxybenzohydroxamate with corresponding aryltellurium(IV) chlorides . They have been characterized by elemental analyses, molar conductance, infrared and proton magnetic resonance spectroscopy. The spectral studies predict the uninegative bidentate [O, O'] nature of the ligand to give penta- and hexa- coordinated tellurium (IV) complexes. The complexes also have been screened for their antimicrobial activity against various bacteria and fungi organisms and it has been observed that some of these possess substantial antimicrobial activity.*

Keywords: 2-Methoxybenzohydroxamate, Aryltellurium(IV), Diaryltellurium(IV), Antimicrobial Activity.

INTRODUCTION

Hydroxamic acids are one of most important families of organic bioligands, which possess a wide spectrum of biological activities [1] and can form coordination compounds with a variety of metals ions [2-4]. They acts as selective inhibitors of many enzymes and consequently possess hypotensive, anticancer, antimalarial, antituberculosis, antifungal properties and hence have been used in the design of therapeutic targets for a number of diseases [5-10]. Also, hydroxamates including aryl hydroxamates are known to form stable complexes with different metal ions, where they can exhibit different coordination modes [11-20]. Also, aryltellurium (IV) trichlorides [21-34] and diaryltellurium(IV) dichlorides [35-37] are known to behave as lewis acids and form complexes with various N-, O- and S- donor and chelating ligands.

In view of biological relevance of hydroxamates and acceptor properties of aryltellurium(IV) trichlorides and dichlorides and in continuation of our earlier work [38-40] on hydroxamates of tellurium(IV), we report herein the synthesis, characterization and antimicrobial studies on some new hydroxamate complexes of the type $RTeCl_2(L)$, $RTeCl(L)_2$, $R_2TeCl(L)$ and $R_2Te(L)_2$; where R = *p*-methoxyphenyl, *p*-hydroxyphenyl and 3-methyl-4-hydroxyphenyl and L = 2-methoxybenzohydroxamate.

MATERIALS AND METHODS

All the chemicals used were of Analytical Reagent Grade. All preparations were carried out under an atmosphere of dry nitrogen. The solvents were purified and dried by standard method and stored under dry conditions.

Carbon, hydrogen and nitrogen analyses were obtained microanalytically on a ThermoFinnigan CHNS analyser from SAIF, Panjab University Chandigarh. Conductance measurements were carried out on a microprocessor based conductivity bridge type MICROSIL in DMSO at 25±2˚C with a dip type conductivity cell (cell constant = 1.017).

IR spectra were recorded in KBr pellets on a Alpha BRUKER F.T. Infra-Red Spectrophotometer in the region 4000-400 cm^{-1}. ^1H NMR Spectra were recorded on BRUKER AVANCE II 400 NMR spectrometer in DMSO-d_6 using TMS as an internal reference at SAIF, Panjab University Chandigarh..

Antimicrobial activity was evaluated in acetone against bacterial strain: *Staphylococcus aureus* ATCC 11632 and *Bacillus cereus* MTCC 7350 (Gram positive), *Escherichia coli* ATCC 35218, *Pseudomonas aeruginosa* ATCC 23564, *Providencia rettgeri* DRDE strain and *Salmonella typhi* ATCC 15499 (Gram negative); fungal strains *Aspergillus niger*, *Aspergillus fumigates* and *Aspergillus flavus* using Macrobroth or Tube dilution method [41]. Dilution of test and standard compounds were prepared double strength nutrient broth- I.P (Antibacterial) and Sabouraud Dextrose Broth –I.P (Antifungal) [42]. This procedure involved preparing two-fold dilutions of compounds (20, 10, 5, 2.5, 1.25, 0.625 µg/mL) in a liquid growth medium dispensed in test tubes. The drug containing tubes were inoculated with a standard bacterial strains and fungal strains. The tubes with bacterial strain were incubated for 24h at 37˚C whereas the fungal strain tubes were incubated for 7 days at 25±2˚C, the tube were examined for visible bacterial and fungal growth as evidenced by turbidity.

Preparation of aryltellurium(IV) trichlorides and diaryltellurium(IV) dichlorides

Aryltellurium(IV) trichlorides , $RTeCl_3$ and diaryltellurium(IV) dichlorides, R_2TeCl_2 (R = *p*-methoxy-, *p*-hydroxy-, 3-methyl-4-hydroxyphenyl) were prepared by the methods reported in the literature [43-47].

Preparation of Potassium 2- methoxybenzohydroxamate (KL)

It has been prepared in two steps.

a) Preparation of ethyl ester of 2-methoxybenzoic acid [48]

To 0.25 mole of 2-methoxybenzoic acid, was added an excess (upto 2.5 moles) of ethyl alcohol and 1 mL of conc. H_2SO_4 in a reaction flask. The contents were then refluxed for about 3- 6 hours till whole of the acid dissolved in ethanol. The reaction mixture was cooled and transferred to about 75 mL of water in a separating funnel. This was shaken thoroughly and then allowed to settle. The lower layer of ester was removed and was washed with saturated sodium bicarbonate till no effervescence. Finally ester layer was washed with water and dried over anhydrous Na_2SO_4.

b) Preparation of potassium salt of 2- methoxybenzohydroxamic acid

The potassium salt was obtained by the method reported by Houser and Renfrow [49]. Cooled solution of KOH (28.05 g in about 70 mL methanol) was added to methanolic solution of hydroxylamine hydrochloride (23.27 g in about 120 mL) with constant shaking and cooling. The mixture was allowed to cool for 24 hours in an ice bath to ensure complete precipitation of KCl, which was removed by filteration. To the filtrate was added 25 mL of ethyl ester of 2-methoxybenzohydroxamic acid prepared above. The reaction mixture was kept in air tight flask at room temperature for 2-3 days to obtain the fine crystals of potassium 2-methoxybenzohydroxamate. This was filtered and dried in air. Yield 75%, m. pt. >300˚C (dec.).

Preparation of 2- methoxybenzohydroxamate complexes of aryltellurium(IV)

Aryltellurium(IV) trichlorides, $RTeCl_3$ (R = *p*-methoxyphenyl, *p*-hydroxyphenyl, 3-methyl-4-hydroxyphenyl), when reacted with potassium 2-methoxybenzohydroxamate in different molar ratios, yield $RTeCl_2(L)$ and $RTeCl(L)_2$ type complexes.

$RTeCl_2(L)$

A warm saturated methanolic solution of potassium 2- methoxybenzohydroxamate (0.41 g, 2 mmol) was added dropwise to a solution of aryltellurium(IV) trichloride (2 mmol) in about 20 mL chloroform/methanol. This resulted in precipitation of KCl, which was removed by filteration. The filterate was refluxed for 3-4 hours to precipitate out any KCl and clear solution was then concentrated to about one third of the original volume and kept overnight to get crystalline product. This was filtered, washed with chloroform and dried in a vacuum desiccator over P_4O_{10}.

$RTeCl(L)_2$

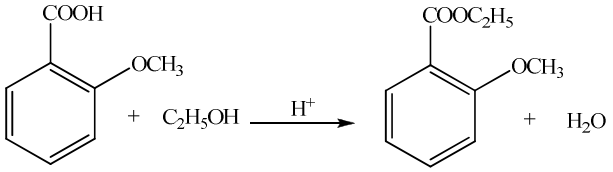
The saturated solution of aryltellurium(IV) trichloride (2 mmol) in chloroform/ methanol was added dropwise with constant stirring to a saturated methanolic solution of potassium 2- methoxybenzohydroxamate (0.82 g, 4 mmol). An immediate change in colour with precipitation of KCl took place, which was removed by filteration. The contents were then refluxed for about 3-4 hours. The clear solution thus obtained was concentrated to about one third of original volume and left overnight to obtain coloured crystalline product. This was filtered, washed with chloroform and dried in a vacuum desiccator over P_4O_{10}.

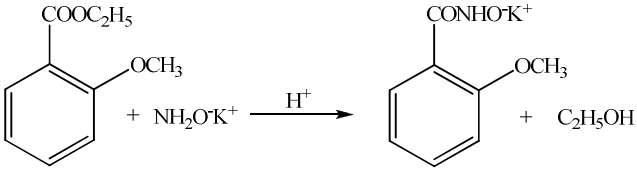
Preparation of 2- methoxybenzohydroxamate complexes of diaryltellurium(IV)

Diaryltellurium(IV) dichlorides, R_2TeCl_2 (R = *p*-methoxyphenyl, *p*-hydroxyphenyl and 3-methyl-4-hydroxyphenyl), when treated with potassium 2- methoxybenzohydroxamate yield both 1:1 and 1:2 complexes of the type $R_2TeCl(L)$ and $R_2Te(L)_2$. These have been synthesized by the same procedure as for 2- methoxybenzohydroxamates of aryltellurium(IV) described above.

RESULTS AND DISCUSSION

The formation of potassium 2- methoxybenzohydroxamate can be represented as below:





(KL)

Aryltellurium(IV) trichlorides and diaryltellurium(IV) dichlorides upon reaction with potassium 2-methoxybenzohydroxamate (KL) in 1:1 and 1:2 molar ratios give the corresponding aryltellurium(IV) hydroxamates.

$$RTeCl_3 + KL \longrightarrow RTeCl_2(L) + KCl$$
$$RTeCl_3 + 2\,KL \longrightarrow RTeCl(L)_2 + 2\,KCl$$
$$R_2TeCl_2 + KL \longrightarrow R_2TeCl(L) + KCl$$
$$R_2TeCl_2 + 2\,KL \longrightarrow R_2Te(L)_2 + 2\,KCl$$

The analytical data, physical properties and yields for these aryltellurium(IV) 2- methoxybenzohydroxamates are compiled in Table 1.

Conductance studies

Molar conductance, Λ_M data at *ca.* 10^{-3} M for aryltellurium(IV) benzohydroxamates in DMSO lie in the range 35.60- 65.90 S cm^2 mol^{-1}, which predict the weak to 1:1 electrolyte [50,51] type behaviour of these hydroxamates in DMSO, probably due to ionization into $RTeCl(L)^+$/ $RTe(L)_2^+$/ $R_2Te(L)^+$ and Cl^- in DMSO. The dissociation for $R_2Te(L)_2$ which do not contain any Cl^-, may be due to steric factors and donor behaviour of DMSO to result in solvated cation $R_2Te(L)DMSO^+$ and L^- ions.

Table 1: Analytical Data, Molar Conductance and Physical Properties of 2- Methoxybenzohydroxamates Complexes

Compound Number	Complex (R)	Empirical Formula (Formula Wt.)	Analyses % Found (Calculated)					M. P., (°C) dec.	Colour (Yield, %)	Λ_M at *ca.* 10^{-3}M S cm^2mol^{-1} in DMSO
			Te	Cl	C	H	N			
1	$RTeCl_2(L)$ (*p*-methoxyphenyl)	$C_{15}H_{15}Cl_2NO_4Te$ (471.67)	26.90 (27.05)	14.86 (15.05)	37.93 (38.19)	3.37 (3.18)	2.49 (2.97)	192-194	White (70)	61.12
2	$RTeCl(L)_2$ (*p*-methoxyphenyl)	$C_{23}H_{23}ClN_2O_7Te$ (602.31)	20.99 (21.18)	5.67 (5.89)	45.21 (45.86)	3.99 (3.82)	4.37 (4.65)	148-150	Light cream (75)	36.71
3	$RTeCl_2(L)$ (*p*-hydroxyphenyl)	$C_{14}H_{13}Cl_2NO_4Te$ (457.66)	27.51 (27.87)	15.23 (15.51)	36.33 (36.74)	2.71 (2.84)	2.90 (3.06)	168-170	Off white (65)	54.82
4	$RTeCl(L)_2$ (*p*-hydroxyphenyl)	$C_{22}H_{21}ClN_2O_7Te$ (588.30)	21.34 (21.68)	5.89 (6.03)	44.47 (44.91)	3.28 (3.57)	4.39 (4.76)	132-134	Pale yellow (70)	39.87
5	$RTeCl_2(L)$ (3-methyl-4-hydroxyphenyl)	$C_{15}H_{15}Cl_2NO_4Te$ (471.67)	26.87 (27.05)	14.72 (15.05)	37.82 (38.19)	2.96 (3.18)	2.81 (2.97)	106-108	Light brown (80)	41.60
6	$RTeCl(L)_2$ (3-methyl-4-hydroxyphenyl)	$C_{23}H_{23}ClN_2O_7Te$ (602.31)	20.86 (21.18)	5.47 (5.89)	45.49 (45.86)	4.11 (3.82)	4.38 (4.65)	94-98	Brown (60)	52.88
7	$R_2TeCl(L)$ (*p*-methoxyphenyl)	$C_{22}H_{22}ClNO_5Te$ (543.30)	23.17 (23.48)	6.27 (6.53)	48.42 (48.63)	4.23 (4.05)	2.31 (2.58)	70-72	Brown (65)	54.71
8	$R_2Te(L)_2$ (*p*-methoxyphenyl)	$C_{30}H_{30}N_2O_8Te$ (673.94)	18.62 (18.92)	–	53.12 (53.47)	4.51 (4.45)	3.89 (4.16)	58-60	Light yellow (70)	35.60
9	$R_2TeCl(L)$ (*p*-hydroxyphenyl)	$C_{20}H_{18}ClNO_5Te$ (515.28)	24.57 (24.76)	6.59 (6.89)	46.38 (46.61)	3.77 (3.49)	2.53 (2.72)	126-128	Dark brown (80)	55.94
10	$R_2Te(L)_2$ (*p*-hydroxyphenyl)	$C_{28}H_{26}N_2O_8Te$ (645.92)	19.32 (19.75)	–	51.76 (52.06)	4.25 (4.02)	4.23 (4.34)	80-82	Light brown (85)	37.83
11	$R_2TeCl(L)$ (3-methyl-4-hydroxyphenyl)	$C_{22}H_{22}ClNO_5Te$ (543.30)	23.01 (23.48)	6.32 (6.53)	48.13 (48.63)	3.89 (4.05)	2.43 (2.58)	88-90	Reddish brown (65)	56.13
12	$R_2Te(L)_2$ (3-methyl-4-hydroxyphenyl)	$C_{30}H_{30}N_2O_8Te$ (673.94)	18.17 (18.92)	–	53.00 (53.47)	4.78 (4.45)	3.94 (4.16)	Hygroscopic	Cream (60)	65.90

Infrared spectral studies

The infrared spectral data of the ligand and complexes are compiled in Table 2. The spectra of the aryltellurium(IV) 2- methoxybenzohydroxamates are quite complexes and an attempt has therefore been made to identify the donor sites of 2- methoxybenzohydroxamate ligand by comparing the spectra with those of parent aryltellurium(IV) chlorides and potassium 2- methoxybenzohydroxamate, which indicated clear differences.

The principle infrared absorption bands of ligand, KL are due to $\nu_{(C=O)}$, $\nu_{(C-N)}$, $\nu_{(N-O)}$ and $\nu_{(N-H)}$ stretching vibrations of the hydroxamate group which appeared in the spectrum at 1636 cm^{-1}, 1404 cm^{-1}, 979 cm^{-1} and 3223 cm^{-1} respectively.

The absorption band occurring at 1636 cm^{-1} in parent hydroxamate attributes to $\nu_{(C=O)}$ mode which is shifted to lower wave numbers and appeared at 1580-1596 cm^{-1} in aryltellurium(IV) 2- methoxybenzohydroxamates. This band in some cases appears as a shoulder, which may be due to mixing of $\nu_{C=C}$ of aryl moiety. The absorption band due to $\nu_{(C-N)}$ mode occurring at 1404 cm^{-1} in free KL has been found to shift towards higher wave number at 1435-1463 cm^{-1} in the complexes. The band at around 3223 cm^{-1} due to $\nu_{(N-H)}$ mode in KL did not undergo any significant change in the complexes, however could not be ascertained due to phenolic OH group in some of the aryltellurium moieties. This rules out the involvement of coordination through nitrogen atom. The sharp band occurring at 979 cm^{-1} in potassium 2- methoxybenzohydroxamate ascribed to $\nu_{(N-O)}$ mode has been observed to move towards higher wave number and appeared at about 1009-1051 cm^{-1} in aryltellurium(IV) hydroxamates. A shift in $\nu_{(C=O)}$ mode to lower wave number and $\nu_{(N-O)}$ mode to higher wave numbers are suggestive of bonding of 2- methoxybenzohydroxamate ion *via* oxygen atoms of carbonyl and hydroxylamine group [52-56]. The formation of Te–O bond however, could not be confirmed due to non availability of far IR data.

Table 2: IR Data (cm^{-1}) for Potassium 2- Methoxybenzohydroxamate and Complexes

Compound	$\nu_{(C=O)}$	$\nu_{(C-N)}$	$\nu_{(N-O)}$
KL	1636 s	1404 vs	979 s
1	1585 vs	1463 m	1022 m
2	1592 s	1461 m	1023 s
3	1586 s	1438 m	1013 m
4	1590 vs	1435 m	1016 s
5	1587 vs	1436 m	1014 m
6	1592 vs	1452 m	1011 m
7	1581 vs	1452 m	1021 s
8	1591 s	1461 m	1022 s
9	1584 s	1437 s	1051m
10	1580 s	1436 m	1018 m
11	1596 vs	1451 sh	1009 m
12	1592 s	1452 m	1011 m

s = strong, vs = very strong, m = medium, w = weak, sh = shoulder.

Proton Magnetic Resonance Spectra

Proton magnetic resonance spectra of aryltellurium(IV) 2- methoxybenzo hydroxamates are very complex and a lot of overlapping of aryl proton singals of the ligand and aryltellurium(IV) moiety takes place, thus making the independent assignment almost impossible. The chemical shift data for the complexes are presented in the Table 3.
Free 2- methoxybenzohydroxamic acid shows [57,58] two downfield singlets at 11.2-11.4 and 9.0 δ ppm due to NH and NOH protons, the aryl protons resonate at 6.77-7.29 δ ppm.

The complexes show downfield singlets at around 12.5 δ ppm, which may be assigned to –NH of benzohydroxamate group, which rules out the linkage of 2- methoxybenzohydroxamate through nitrogen atom. Absence of NOH proton signals around 9.0 δ ppm confirms the deprotonation of this proton and subsequently linkage to the tellurium atom. These signals are not well resolved in some cases due to poor solubility of the complexes.

Further, the aryl protons of aryltellurium(IV), diaryltellurium(IV) and 2- benzohydroxamate groups exhibit a lot of mixing of signals and are observed as complex multiplets in the region 6.64 - 8.37 δ ppm, as observed in ^{1}H NMR Spectra of organotin(IV) and aryltellurium(IV) complexes of hydroxamic acids [38-40, 52]. Also, a careful examination of ^{1}H NMR Spectra of complexes reveal the shielding of aryl protons of RTe/R_2Te compared to $RTeCl_3/R_2TeCl_2$ [46,47,59,60] due to flow of electron density from the ligand to the aryltellurium moiety as a result of complexation.

Thus, on the basis of infrared and proton magnetic resonance spectral studies it may be concluded that 2-methoxybenzohydroxamate acts as a bidentate [O, O$'$] ligand involving the hydroxamate (–NHO) and carbonyl oxygens, giving rise to penta coordinated tellurium complexes in $RTeCl_2(L)$ and $R_2TeCl(L)$ and hexa coordinated in $RTeCl(L)_2$ and $R_2Te(L)_2$. The suggested structures are as shown in figure 1.

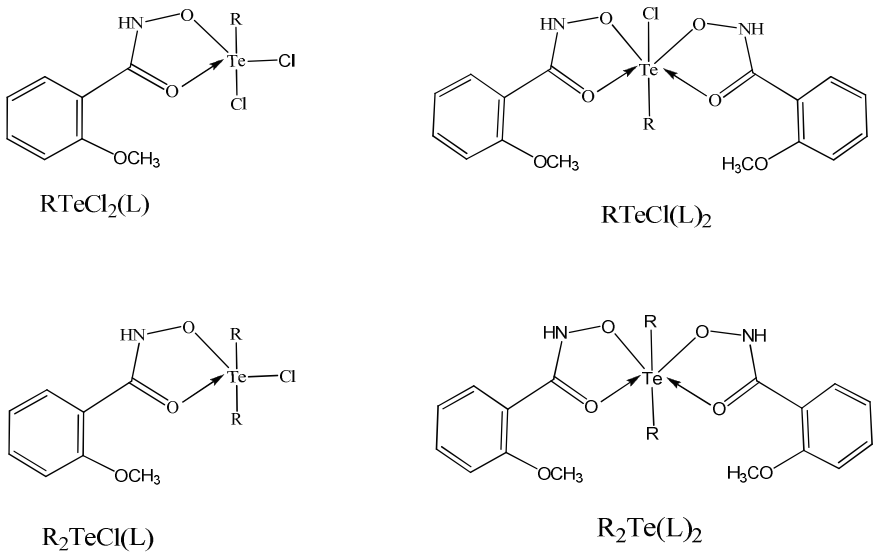


Figure 1: Proposed Structures of 2-Methoxybenzohydrxamate Complexes

Table 3: ^{1}H NMR Spectral Data of 2- Methoxybenzohydroxamate Complexes

Compound Number	Chemical shift, δ ppm in DMSO-d_6
1	3.362, 3.826(s, 6H, OCH_3), 6.935-8.372(cm, 8H, aromatic protons of L and RTe), 12.492(bs, 1H, NH)
2	3.658, 3.808(s, 9H, OCH_3), 6.92-8.276(cm, 12H, aromatic protons of L and RTe), 12.50(bs, 2H, NH)
3	3.421, 3.831(s, 3H, OCH_3), 6.827-8.253(cm, 8H, aromatic protons of L and RTe), 9.956(bs, 1H, phenolic OH of RTe), 12.492(bs, 1H, NH)
4	3.830(s, 6H, OCH_3), 6.862-8.246(cm, 13H, aromatic protons of L and RTe and phenolic OH of RTe), 12.50(bs, 2H, NH)
5	2.189(s, 3H, CH_3), 3.837(s, 3H, OCH_3), 6.843-8.123(cm, 7H, aromatic protons of L and RTe), 9.89(bs, 1H, phenolic OH of RTe), 12.533 (bs, 1H, NH)
6	2.173(s, 3H, CH_3), 3.845(s, 6H, OCH_3), 6.845-8.189(cm, 11H, aromatic protons of L and RTe), 9.865(bs, 2H, phenolic OH of RTe), 12.492(bs, 2H, NH)
7	3.837(s, 9H, OCH_3), 6.708-8.206(cm, 12H, aromatic protons of L and R_2Te), 12.49(bs, 1H, NH)
8	3.851(s, 12H, OCH_3), 6.879-8.252(cm, 16H, aromatic protons of L and R_2Te), 12.50(bs, 1H, NH)
9	3.409, 3.819(s, 3H, OCH_3), 6.644-8.179(cm, 12H, aromatic protons of L and R_2Te), 9.905(bs, 2H, phenolic OH of R_2Te), *
10	3.811(s, 6H, OCH_3), 6.789-8.215(cm, 16H, aromatic protons of L and R_2Te), 10.107(bs, 2H, phenolic OH of R_2Te), *
11	2.112(s, 6H, CH_3), 3.727(s, 3H, OCH_3), 6.774-8.270(cm, 10H, aromatic protons of L and R_2Te), 8.536(bs, 2H, phenolic OH of R_2Te), *

*s = singlet, cm = complex multiplet, bs = broad singlet; * poor resolution due to low solubility.*

Biological Studies

The 2- methoxybenzohydroxamate (KL) and newly synthesized aryltellurium(IV) hydroxamate complexes were evaluated for *in vitro* antibacterial and antifungal activity and the results in terms of minimum inhibitory concentration are presented in Table 4. It has been observed that compound 6, 8 and 10 possess antibacterial activity against *S. aureus* and *B. cereus* comparable to parent ligand and compound 5, 8 and 9 show more antibacterial activity against *S. typhi*, *E. coli* and *P. rettgeri*. Antifungal data indicate that compound 1 and 7 possess better activity against *A. niger and A. fumigates* and compound 5 and 9 show comparable activity in *A. flavus* with respect to potassium 2-methoxybenzohydroxamate.

Table 4: Minimum Inhibitory Concentration of Potassium 2-Methoxybenzohydroxamate and Complexes, MIC (µg/mL); (-) Resistant

Compound	Bacterial strains						Fungal strains		
	S. aureus (ATCC 11632)	***S. typhi*** (ATCC 15499)	***P. aeruginosa*** (ATCC 23564)	***E. coli*** (ATCC35218)	***B. cereus*** (MTCC 7350)	***P. rettgeri*** (DRDE strain)	***A. niger***	***A. fumigates***	***A. flavus***
KL	1.25	2.5	1.25	2.5	0.625	1.25	-	-	1.25
1	10	10	20	-	5	5	-	**1.25**	5
2	20	-	20	-	10	20	5	-	-
3	-	-	5	10	2.5	20	-	-	-
4	-	20	10	5	1.25	-	5	10	5
5	5	10	5	20	-	**0.625**	20	5	**1.25**
6	**1.25**	2.5	**1.25**	5	-	-	-	10	-
7	5	-	-	-	1.25	2.5	**1.25**	10	-

8	**1.25**	-	5	**1.25**	**0.625**	-	20	5	10
9	-	**1.25**	2.5	-	-	2.5	-	-	**1.25**
10	2.5	-	**1.25**	-	**0.625**	5	-	10	2.5
11	5	-	-	-	5	1.25	-	-	2.5

CONCLUSION

Aryltellurium(IV) trichlorides and diaryltellurium(IV) dichlorides when reacted with potassium 2-methoxybenzohydroxamate form 1:1 and 1:2 (Te:L) type complexes. In these aryltellurium(IV) methoxybenzohydroxamate, 2-methoxybenzohydroxamate acts as uninegative bidentate [O,O] donor to yield penta- and hexa- coordinated tellurium(IV) complexes. Some of these complexes have been observed to possess substantial antimicrobial and antifungal.

Acknowledgement
The authors are grateful to M. D. University, Rohtak for providing the necessary facilities. One of the authors (SC) is also thankful to UGC, New Delhi for providing SRF. We also thank SAIF, Panjab University Chandigarh for providing the CHN analyses and NMR spectral data.

REFERENCES

[1] S. P. Gupta; Ed., Hydroxamic Acids: A Unique Family of Chemicals with Multiple Biological Activities, **2013,** Springer-Verlag Berlin, Heidelberg.
[2] H. Kehl; Chemistry and Biology of Hydroxamic Acids, **1982**, Karger, New York.
[3] B. Kurzac, H. Kozlowski, E. Farkas, *Coord. Chem. Rev.*, **1992**, 114, 169.
[4] R. C. Mehrotra; in: Comprehensive Coordination Chemistry, **1982,** Pergamon, Oxford, Section 15.9.
[5] W. P. Steward, A. L. Thomas, *Expert Opin. Invest. Drugs*, **2000**, 9, 2913**.**
[6] W. P. Steward, *Cancer Chemother. Pharmacol*., **1999**, 43(Suppl), S56.
[7] J. L. Domingo, *Reprod. Toxicol.*, **1998**, 12, 499**.**
[8] Z. I. Cabantchik, *Parasitol. Today*, **1995**, 11, 74.
[9] I. Turcot, A. Stintzi, J. Xu, K. N. Raymond, *J. Biol. Inorg. Chem.*, **2000**, 5, 634.
[10] M. J. Miller, *Chem. Rev*., **1989**, 89, 1563.
[11] E. M. Muri, M. J. Nieto, R. D. Sindelar, J. S. Williamson, *Curr. Med. Chem*., **2002**, 9, 1631.
[12] R. Ge, Z. Chen, Q. Zhou, *Metallomics*, **2012**, 4, 239.
[13] R. Codd, *Coord. Chem. Rev*., **2008**, 252, 1387.
[14] S. Mizukami, K. Nagata, *Coord. Chem. Rev.*, **1968**, 3, 267.
[15] B. Chatterjee, *Coord. Chem. Rev*., **1978**, 26, 281.
[16] D. I. Ugwa, B. E. Ezema, F. U. Eze, J. I. Ayugu, C. G. Ezema, D. I. UgWuja, *Am. J. Org. Chem*., **2014**, 4, 26.
[17] S. Sharma, N. Sharma, *Der Chemica Sinica*, **2013**, 4, 108.
[18] R. Sharma, N. Sharma, *J. Therm. Anal. Calorim*., **2012**, 110, 539.
[19] A. Phathak, V. L. Blair, R. L. Ferrero, M. Mehring, P. C. Andrews, *Chem. Commun.*, **2014**, 50, 15232.
[20] A. Phathak, V. L. Blair, R. L. Ferrero, P. C. Junk, R. F. Tabor, P. C. Andrews, Dalton Trans., **2015**, 44, 16903.
[21] K. J. Wynne, P. S. Pearson, *Inorg. Chem*., **1971,** 10, 2735.
[22] K. J. Wynne, P. S. Pearson, *J. Chem. Soc. Commun*., **1970**, 556.
[23] K. J. Wynne, A. J. Clark, M. Berg, *J. Chem. Soc. Dalton*, **1972**, 2370.
[24] E. R. Clark, A. J. Collet, D. G. Naik, *J. Chem. Soc. Dalton*, **1973**, 1961.
[25] M. C. Berg, *Diss. Abstr. Int*., **1972**, **33**, 2982.
[26] T. N. Srivastava, M. Singh, H. B. Singh, *Indian J. Chem*., **1982**, 21A, 307.
[27] T. N. Srivastava, R. C. Srivastava, M. Srivastava, *Indian J. Chem*., **1982**, 21A, 539.
[28] T. N. Srivastava, R. C. Srivastava, V. K. Srivastava, *J. Indian Chem. Soc.*, **1983**, 60, 891.
[29] M. V. Garad, *Polyhedron*, **1985**, 4, 1353.
[30] K. K. Verma, Reena, Synth. React. Inorg. Met. –Org. Chem., **1999**, 29, 499.
[31] K. K. Verma, Reena Dahiya, Daya Soni, *Synth. React. Inorg. Met. –Org. Chem*., **1999**, 29, 1033.
[32] K. K. Verma, Reena Dahiya, *Synth. React. Inorg. Met. –Org. Chem.*, **1999**, 29, 1299.
[33] K. K. Verma, Reena, *Phosphorus, Sulfur and Silicon and the Related Elements*, **1999**, 148, 227.
[34] K. K. Verma, Seema, *Int. J. Chem. Sci*., **2008**, 6, 371.
[35] S. Srivastava, D. K. Soni, H. S. Gupta, *J. Indian Chem. Soc*., **1996**, 73, 255.
[36] J. K. Narwal, S. Chhabra, R. K. Malik, S. Garg, K. K. Verma, *Oriental J. Chem*., **2013**, 29, 1339.
[37] S. Chhabra, K. K. Verma, *J. Chem. Pharm. Res*., **2010**, 2, 569.
[38] S. Chauhan, S. Garg, K. K. Verma, *Chem. Sci. Trans.*, **2016,** accepted.
[39] S. Chauhan, S. Garg, K. K. Verma, *Res. J. Pharma. Biol. Chem. Sci.*, **2016**, accepted.
[40] S. Chauhan, Deepak, S. Garg, K. K. Verma, *Int. J. Chem. Sci*., **2016**, accepted.

[41] J. H. Jorgensen, M. J. Ferraro, *Med. Microbiol.*, **2009**, 49, 1749.
[42] Pharmacopoeia of India, Controller of Publication, Ministry of Health Department, Government of India, New Delhi, **2007**, 1, 37.
[43] G. T. Morgan, R. E. Kellet, *J. Chem. Soc*., **1926**, 1080.
[44] N. Petragnani, H. A. Stefani, Tellurium in Organic Chemistry, Academic Press, London, **2007**, 2, 67, 76.
[45] J. Bergman, *Tetrahedron*, **1972**, 28, 3323.
[46] B. L. Khandelwal, K. Kumar, F. J. Berry, *Inorg. Chim. Acta*, **1981**, 99, 135.
[47] B. L. Khandelwal, K. Kumar, K. Raina, *Synth. React. Inorg. Met. –Org. Chem*., **1981**, 11, 65.
[48] A. I. Vogel, A Text Book of Organic Chemistry, Longmans, London, **1975**, 3rd Edn.
[49] C. R. Hauser, W. B. Renfrow, *J. Org. Synth*., **1953**, 2, 67.
[50] W. J. Geary, *Coord. Chem. Rev.*, **1971**, 7, 81.
[51] N. N. Greenwood, B. P. Straughan, A. E. Wilson, *J. Chem. Soc. A*, **1968**, 2209.
[52] Naqeebullah, Y. Farina, K. M. Chan, L. K. Mun, N. F. Rajab, T. C. Ooi, *Molecules*, **2013**, 18, 8696.
[53] S. Shahid, S. Ali, M. Hussain, M. Mazhar, S. Mahmood, S. Rehman, *Turk. J. Chem*., **2002**, 26, 589.
[54] J. Selbin, *Coord. Chem. Rev*., **1966**, 1, 293.
[55] N. Sharma, S. S. Kanwar, R. Gupta, L. Kumari, L. Sharma, *Bull. Chem. Soc. Jpn.*, **2012**, 85, 1310.
[56] T. K. Banerjee, S. K. Brahma, S. P. Bag, *Ind. J. Chem*., **1992**, 31A, 202.
[57] J. Schraml, M. Tkadlecova, S. Pataridis, L. Soukupova, V. Blechta, J. Roithova, O. Exner, *Magn. Reson. Chem.*, **2005**, 43, 535.
[58] D. A. Brown, R. A. Coogan, N. J. Fitzpatrick, W. K. Glass, D. E. Abukshima, L. Shield, M. Ahlgren, K. Smolander, T. T. Pakkanen, T. A. Pakkanen, M. Perakyla, *J. Chem. Soc. Perkin Trans*. **1996**, 2, 2673.
[59] K. Raina, B. L. Khandelwal, *Indian J. Chem*., **1976**, 14A, 63.
[60] F. J. Berry, E. H. Kustan, M. Roshani, B. C. Smith, *J. Organometal. Chem.*, **1975**, 99, 115.