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Synthesis, Characterization and Antibacterial studies of New Organotellurium Carboxylates

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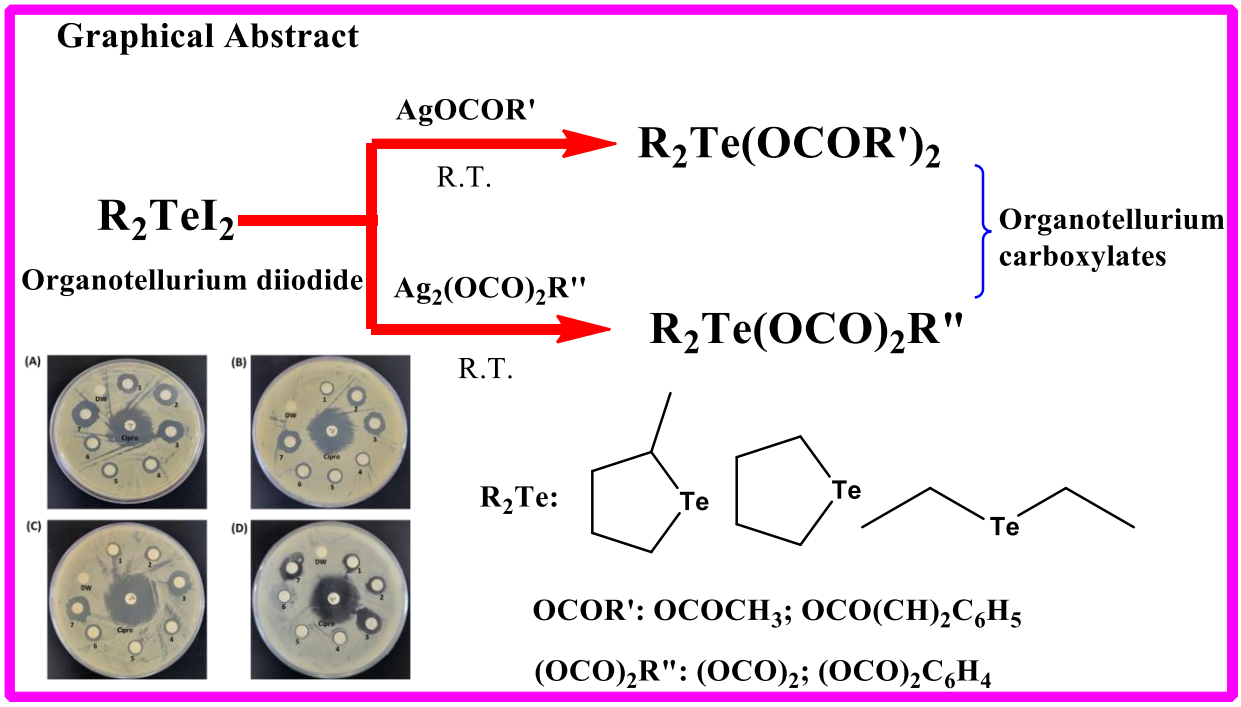
Abstract

Seven novel organotellurium derivatives of carboxylic acids have been synthesized by the reaction of 1, 1-diiodo-1-telluracyclopentane, 1, 1-diodo-2-methyl-1-telluracyclopentane, and 1,1-diiodo-1,1-diethyltellurium (IV) with silver salts of corresponding carboxylic acids in 1:1/ 1:2 molar ratio. The characterization of the synthesized organotellurim carboxylates was carried out using IR spectroscopy, NMR (^{1}H & $^{13}C\{^{1}H\}$) spectroscopy, and elemental analysis. The results of these studies suggested the general formula of the compounds as $[R_2Te(OCOR')_2]$, and $[R_2Te(OCO)_2R"]$ (where R_2= C_4H_7 (CH_3), C_4H_8, $(C_2H_5)_2$; R'= CH_3, $CH{=}CHC_6H_5$; $(OCO)_2R"$= $(OCO)_2$, $(OCO)_2C_6H_4$. The compounds were screened against *P. aeruginosa*, *E. coli*, *S. aureus*, and *K. pneumoniae* using broth microdilution and agar disc diffusion methods. Only two compounds showed significant activity at lower concentrations against all tested bacterial strains. However some others showed potent activity against specific bacterial strains.

Keywords: Organotellurium, carboxylates, characterization, spectroscopy, antibacterial.

Graphical Abstract



Introduction

Organotellurium carboxylates are compounds having at least one Te-C bond between the tellurium atom and the carbon atom of an organic group [1] and contain at least one carboxylate group. Organotellurium derivatives of carboxylic acids have a covalent bond between the tellurium atom of organotellurium moiety and the oxygen atom of a carboxylic group. Thus they form a sub-class of telluroxanes which contain a Te-O covalent bond [2]. Telluroxanes are center of attraction for researchers due to their various applications and interesting structural properties [3, 4, 5, 6, 7, 8, 9, 10, 11]. Applications of organic telluroxanes in organic as well as organometallic transformations have been reported [2, 12, 13, 14, 15, 16]. Telluroxanes have also been found to be applicable in material chemistry, biology, and carbon dioxide fixation [17, 18, 19]. Thus during the last few decades, many efforts have been made by researchers to synthesize the new telluroxanes and study their properties. Vernon reported the synthesis of α- base $TeMe_2(OH)_2$ and β-base $TeMe_2O$ [20]. Synthesis of oligotelluroxanes by oxidation of diaryltelluride [21] and ditelluroxanes by the thermal dehydration of diaryltellurium hydroxide halides and related compounds [22, 23, 24, 25, 26, 27] are available in the literature. Liu et al. reported the preparation of diaryltellurium dicarboxylates by the action of phenyliodine (III) dicarboxylates on diaryltellurides [28]. Chandrasekhar et al. synthesized diallyl tellurium dicarboxylates using carboxylic acids and diallyltelluroxides [29]. They also reported the synthesis of tellurium ferrocene carboxylates by the same procedure [30]. We reported synthesis and crystal structure of $[(CH_3)_2Te\ NO_3]_2O$ and $[R_2TeOC_6H_2(NO_2)_3]_2O$ [R_2= $(CH_3)_2$, C_4H_8] [31]. We have also reported some novel cyclic and acyclic organotellurium carboxylates with their crystal structures [32, 33,

34]. Tetraorganoditelluronic acids, $[RR'Te(\mu\text{-}O)(OH)_2]_2$, where R = 2-$NMe_2CH_2C_6H_4$, R′ = C_6H_5, 2-MeC_6H_4, 2,6-MeC_6H_3, and 2,6-$^{i}PrC_6H_3$ have been synthesized by Gupta and coworkers [35]. Synthesis of cyclic, zwitterionic organotellurolate IV) species and chlorotellurane species with their molecular structures has been reported by Tripathi et al. [36]. Recently, Shibuya et al. reported the synthesis of a variety of functionalized diaryl tellurium dicarboxylates by a concise and efficient one-pot synthesis method based on mild photosensitized oxygenation of carboxylic acids [37]. Considering the above facts and to gain more knowledge in chemistry and applications of telluroxanes, in the present work we synthesized seven novel organotellurium carboxylates. Their characterization and antibacterial study are also discussed in this paper.

Experimental Section

General Procedure

The chemical reagents and the organic solvents used in the synthesis were of analytical grade and procured commercially from Sigma Aldrich and Merck. The organic solvents were properly dried and distilled before use [38]. IR spectrum was recorded using an Agilent Cary 630 FTIR Spectrometer in the frequency range 4000-450 cm^{-1} with the sample in $CDCl_3$. The ^{1}H and $^{13}C\{^{1}H\}$ NMR spectrums were recorded at 300 MHz using Bruker Avance 400/ Avill HD-300 (FT NMR) Spectrometer in acetone containing tetramethyl silane as an internal standard. Elemental analysis for H, C, and N has been performed on the Euro Vector Elemental Analyser. The tellurium [39] content was determined in the laboratory volumetrically. Melting points were recorded in open capillary and are uncorrected. The compounds were screened against bacterial strains *Pseudomonas aeruginosa* (*P. aeruginosa*), *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), and *Klebsiella pneumoniae* (*K. pneumoniae*). Antibacterial activity was studied using the broth microdilution and disc diffusion methods. Nutrient broth (NB), Mueller Hinton Agar (MHA), and MH broth were purchased from Hi-Media. 96-well culture plates were purchased from Tarsons. Bacterial strains were provided by the Department of Microbiology, Central University of Punjab, Bathinda, India.

Preparation of $C_4H_7(CH_3)TeI_2$, $C_4H_8TeI_2$, and $(C_2H_5)_2TeI_2$

Organotellurium diiodides were prepared using the methods available in the literature. 1, 1-diodo-2-methyl-1-telluracyclopentane $C_4H_7(CH_3)TeI_2$ was prepared by the refluxing tellurium metal with sodium iodide and 1,4-dibromopentane in 2-butoxyethanol [40]. 1, 1-diiodo-1-telluracyclopentane $C_4H_8TeI_2$ was prepared by refluxing tellurium metal with 1, 4-diiodobutane [41]. 1, 1-diiodo-1, 1-diethyltellurium (IV) $(C_2H_5)_2TeI_2$ was prepared by heating tellurium metal with ethyliodide in a sealed tube [42].

Synthesis of silver salts of carboxylic acids

Silver salts of cinnamic acid, acetic acid, phthalic acid, and oxalic acid were prepared by the usual method. Silver nitrate was reacted with sodium salts of corresponding carboxylic acid in a 1:1 or 2:1 molar ratio respectively in deionized water at room temperature. The precipitated silver carboxylates were filtered and washed with methanol and solvent ether several times. For each reaction silver carboxylates were freshly prepared.

Synthesis of organotellurium derivatives of carboxylic acids

Synthesis of Dicinnamato-2-methyl-1-telluracyclopentane $C_4H_7(CH_3)Te(OCOCH{=}CHC_6H_5)_2$ ***(1)***

1,1-diiodo-2-methyl-1-telluracyclopentane (1.00 g, 2.22 mmol) was stirred in 25 ml of dry acetone with freshly prepared silver salt of cinnamic acid (1.13 g, 4.43 mmol) at room temperature. After 4-5 h reaction mixture was filtered to eliminate the unidentified material. The filtrate was poured in a Petri dish and kept overnight. White flakes were obtained. M.p. 118 °C, Yield: 0.75 g (69.26%), Anal. Calc. for $C_{23}H_{24}O_4Te$: C, 56.14; H, 4.92; Te, 25.93%, Found: C, 55.89; H, 4.74; Te, 26.29%, FT-IR($CDCl_3$, cm^{-1}): 1639 (ν_{asy} CO); 1329 (ν_{sy} CO); 686 (ν OCO); 557 (ν $TeCH_2$), ^1H NMR ($(CD_3)_2CO$) δ ppm: 7.64-7.36 (m, 10H, C_6H_5); 6.51-6.43 (dd, 4H, -CH=CH-); 3.67-3.48 (m, 3H, $TeCH_2$, TeCH); 2.97-2.87 (m, 4H, $TeCCH_2$); 1.75 (d, 3H, $TeCCH_3$), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 143.7, 136.0, 130.6, 129.7 (C_6H_5); 128.8, 121.6 (-CH=CH-); 172.7 (CO); 60.7 (TeCH); 43.9 ($TeCH_2$); 42.1, 31.7 ($TeCCH_2$); 17.0 ($TeCCH_3$)

Synthesis of Phthalato-2-methyl-1-telluracyclopentane $C_4H_7(CH_3)Te(OCO)_2C_6H_4$ (2)

Compound **2** was synthesized by the reaction of 1,1-diiodo-2-methyl-1-telluracyclopentane (1.0 g, 2.22 mmol) with silver salt of phthalic acid (0.85 g, 2.22 mmol) using the same procedure as for compound **1**. A light orange crystalline solid was obtained which was recrystallized from benzene. M.p. 110 °C, Yield: 0.48 g (60.0%), Anal. Calc. for $C_{13}H_{14}O_4Te$: C, 43.15; H, 3.90; Te, 35.26%, Found: C, 42.96; H, 4.10; Te, 35.41%, FT-IR($CDCl_3$, cm^{-1}): 1636 (ν_{asy} CO); 1388 (ν_{sy} CO); 640 (ν OCO); 560 (ν $TeCH_2$), ^1H NMR ($(CD_3)_2CO$) δ ppm: 7.76-7.57 (m, 4H, C_6H_4); 4.23-3.71 (m, 3H, $TeCH_2$, TeCH); 3.01-2.45 (m, 4H, $TeCCH_2$); 1.91 (d, 3H, $TeCCH_3$), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 131.6, 129.7 (C_6H_5); 169.4 (CO); 60.3 (TeCH); 43.5 ($TeCH_2$); 41.9, 31.4 ($TeCCH_2$); 17.0 ($TeCCH_3$)

Synthesis of Oxalato-2-Methyl-1-telluracyclopentane $C_4H_7(CH_3)Te(OCO)_2$ (3)

Compound **3** was synthesized by the reaction of 1,1-diiodo-2-methyl-1-telluracyclopentane (1.0 g, 2.22 mmol) with silver salt of oxalic acid (0.67 g, 2.22 mmol) by the same process. A light orange crystalline solid was obtained which was recrystallized from benzene. M.p. 100 °C, Yield: 0.44 g (69.62%), Anal. Calc. for $C_7H_{10}O_4Te$: C, 29.42; H, 3.53; Te, 44.65%, Found: C, 26.50; H, 3.62; Te, 44.43%, FT-IR($CDCl_3$, cm^{-1}): 1636 (ν_{asy} CO); 1384 (ν_{sy} CO); 669 (ν OCO); 554 (ν $TeCH_2$), ^1H NMR ($(CD_3)_2CO$) δ ppm: 4.33-3.82 (m, 3H, $TeCH_2$, TeCH); 3.05-2.48 (m, 4H, $TeCCH_2$); 1.93 (d, 3H, $TeCCH_3$), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 143.8 (CO); 60.0 (TeCH); 49.8 ($TeCH_2$); 43.9, 33.3 ($TeCCH_2$); 19.0 ($TeCCH_3$)

Diacetato-2-Methyl-1-telluracyclopentane $C_4H_7(CH_3)Te(OCOCH_3)_2$ (4)

Compound **4** was synthesized by the reaction of 1,1-diiodo-2-methyl-1-telluracyclopentane (1.0 g, 2.22 mmol) with silver salt of acetic acid (0.74 g, 4.45 mmol) using the same procedure as for compound **1**. A light orange crystalline solid was obtained which was recrystallized from benzene. M.p. 136 °C, Yield: 0.64 g (91.95%), Anal. Calc. for $C_9H_{16}O_4Te$: C, 43.15; H, 3.90; Te, 35.26%, Found: C, 42.96; H, 4.10; Te, 35.41%, FT-IR($CDCl_3$, cm^{-1}): 1636 (ν_{asy} CO); 1338 (ν_{sy} CO); 642 (ν OCO); 558 (ν $TeCH_2$), ^1H NMR ($(CD_3)_2CO$) δ ppm: 4.36-3.73 (m, 3H, $TeCH_2$, TeCH); 3.09-2.51 (m, 4H, $TeCCH_2$); 1.96 (d, 3H, $TeCCH_3$); 2.83 (s, 3H,CH_3, acetato), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 176.5 (CO); 60.0 (TeCH); 49.8 ($TeCH_2$); 44.0, 33.3 ($TeCCH_2$); 19.3 ($TeCCH_3$); 20.0 (CH_3, acetato)

Phthalato-1-telluracyclopentane $C_4H_8Te(OCO)_2C_6H_4$ (5)

Compound **5** was synthesized by the reaction of 1,1-diiodo-1-telluracyclopentane (1.0 g, 2.29 mmol) with silver salt of phthalic acid (1.09 g, 2.29 mmol) using the procedure as above. A light orange crystalline solid was obtained which was recrystallized from benzene. M.p. 170 °C, Yield: 0.32 g (40.4%), Anal. Calc. for $C_{12}H_{12}O_4Te$: C, 41.44; H, 3.48; Te, 36.69%, Found: C, 41.56; H, 3.40; Te, 36.52%, FT-IR($CDCl_3$, cm^{-1}): 1636 (ν_{asy} CO); 1390 (ν_{sy} CO); 671 (ν OCO); 552 (ν $TeCH_2$), ^{1}H NMR ($(CD_3)_2CO$) δ ppm: 7.78-7.60 (m, 4H, C_6H_4); 4.05-3.74 (m, 4H, $TeCH_2$); 3.60-2.84 (m, 4H, $TeCCH_2$), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 131.8, 129.7 (C_6H_5); 168.8 (CO); 46.5 ($TeCH_2$); 34.7 ($TeCCH_2$)

Diacetato-1-telluracyclopentane $C_4H_8Te(OCOCH_3)_2$ (6)

Compound **6** was synthesized by the reaction of 1,1-diiodo -1-telluracyclopentane (1.0 g, 2.29 mmol) with silver salt of acetic acid (0.76 g, 4.58 mmol) using the procedure as above. A light orange crystalline solid was obtained which was recrystallized from benzene. M.p. 94 °C, Yield: 0.44 g (63.95%), Anal. Calc. for $C_8H_{14}O_4Te$: C, 31.83; H, 4.68; Te, 42.28%, Found: C, 31.70; H, 4.52; Te, 42.40%, FT-IR($CDCl_3$, cm^{-1}): 1636 (ν_{asy} CO); 1384 (ν_{sy} CO); 667 (ν OCO); 554 (ν $TeCH_2$), ^{1}H NMR ($(CD_3)_2CO$) δ ppm: 4.13-3.72 (m, 3H, $TeCH_2$); 3.68-2.76 (m, 4H, $TeCCH_2$), 2.99 (s, 3H,CH_3, acetato), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 176.4 (CO); 46.7 ($TeCH_2$); 34.8 ($TeCCH_2$); 20.6 (CH_3, acetato)

Diethylphthalato tellurium (IV) $(C_2H_5)_2Te(OCO)_2C_6H_4$ (7)

1,1-diiodo-1,1-diethyltellurim(IV) (1.0 g, 2.27 mmol) was ground in a mortar with silver salt of phthalic acid (0.87 g, 2.27 mmol) and small amount of deionized water to make thin paste till reddish-brown crystals disappeared. Grinding was continued for 1 h more followed by extraction with hot deionized water. Filtrate was kept in a Petri dish. Light chocolate-coloured crystals were obtained after 2 days. M.p. 115 °C, Yield: 0.43 g (54.21%), Anal. Calc. for $C_{12}H_{14}O_4Te$: C, 41.20; H, 4.03; Te, 36.47%, Found: C, 41.36; H, 3.91; Te, 35.35%, FT-IR($CDCl_3$, cm^{-1}): 1629 (ν_{asy} CO); 1383 (ν_{sy} CO); 645 (ν OCO); 527 (ν $TeCH_2$), ^{1}H NMR ($(CD_3)_2CO$) δ ppm: 7.73-7.59 (m, 4H, C_6H_4); 3.05-2.91 (q, 4H, $TeCH_2$); 0.83-0.87 (t, 6H, $TeCCH_3$), $^{13}C\{^1H\}$ NMR ($(CD_3)_2CO$) δ ppm: 132.1, 129.9 (C_6H_5); 169.1 (CO); 30.0 ($TeCH_2$); 8.4 ($TeCCH_3$)

Antbacterial study

Broth microdilution method

The MIC value is the lowest concentration of an antibiotic agent at which bacterial growth is almost completely inhibited. The broth microdilution method was employed to examine the antimicrobial efficacy [43] of compounds **1-7**. MICs are used to examine the antibacterial activity of the compounds by measuring the effect of the minimum concentration of the drug over a defined period in terms of inhibition of microbial population growth. The bacterial cells were inoculated in NB medium at 37°C, with shaking overnight. The overnight grown culture was subcultured in sterile NB broth till OD_{600} nm reached 0.4 (TECAN, Spark). The cells were diluted in 1:1000 ratios in MH broth to reach the 1×10^6 CFU/ml bacterial culture density. A volume of 100µl of this bacterial solution was poured into 96 wells of transparent, flat bottom, sterile culture plate (cell culture plate SPL, Life Sciences, Korea), and mixed with an equal volume of two-fold serially

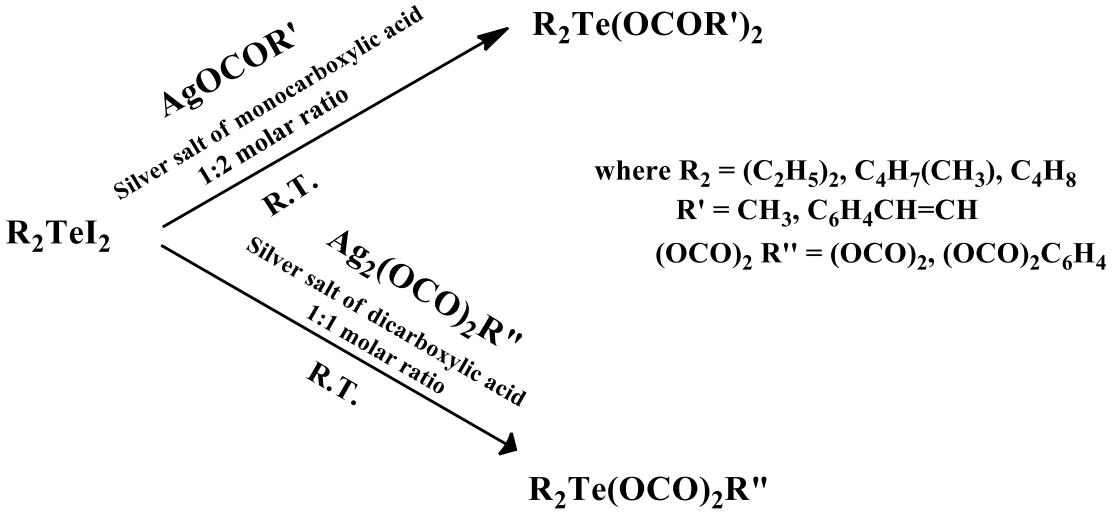
diluted with a starting concentration of 500 µg/ml of each **1**, **2**, **3**, **4**, **5**, **6**, and **7** compounds. The growth was visually observed after 16 hours of incubation.

Disc diffusion method

The disc diffusion method was used to evaluate the antibacterial activity of **1-7**. In brief, *P. aeruginosa, E. coli, S. aureus,* and *K. peumoniae,* bacterial cells were inoculated in a Nutrient broth (NB) medium and incubated overnight at 37°C at 200 rpm (Orbital shaking incubator, Creative lab world). The overnight grew culture was sub-cultured (1%) in NB broth and incubated till the optical density (OD) reached 0.4 at 600 nm. Meanwhile, Muller Hilton agar (MHA) media was poured into a sterile Petri dish (90*15 mm, Genaxy, India) and kept for solidification. 150µl of the above bacterial culture (OD_{600} nm 0.4) were spread over the MHA plate [44]. Then, sterile blank discs were placed over MHA plates. Further, blank sterile discs were wetted with 30 µl (500 µg/ml concentration) of each compound (1, 2, 3, 4, 5, 6, and 7), and a sterile blank disc was wetted with DW (sterile Distilled water) for negative control and ciprofloxacin (5 µg/ml concentration) as a positive control. These plates were incubated at 37°C overnight. After 16 hours of incubation, the zone of inhibition was analyzed around the discs.

Results and Discussion

Organotellurium(IV) diiodides, 1, 1-diodo-2-methyl-1-telluracyclopentane $C_4H_7(CH_3)TeI_2$, 1, 1-diiodo-1-telluracyclopentane $C_4H_8TeI_2$, and 1, 1-diiodo-1,1-diethyltellurium (IV) $(C_2H_5)_2TeI_2$, were reacted with freshly prepared silver salts of cinnamic acid, phthalic acid, acetic acid and oxalic acid at room temperature to yield corresponding carboxylates (**1-7**) as shown in **Scheme 1**. The molecular structures proposed for these compounds are shown in **Figure 1**. The physical properties, analytical data, and spectroscopic data of the synthesized carboxylates are presented in the Experimental section. The analytical data and spectroscopic studies suggested the general formula of the compounds as $[R_2Te(OCOR')_2]$ (compounds **1, 4, and 6**), and $[R_2Te(OCO)_2R"]$ (compounds **2, 3, 5,** and **7**).



Scheme1. Synthesis of organotellurium derivatives of carboxylic acids (**1-7)**

Spectroscopic studies

The important IR peaks and their assignments for organotellurium carboxylates (**1-7**) are given in the Experimental section. In the IR spectra of the synthesized carboxylates, ν (asymmetric CO) appeared at 1636 cm^{-1} except for **1** and **7** for which ν (asymmetric CO) appeared at 1639 cm^{-1} and 1929 cm^{-1} respectively. Whereas for **1-7** ν (symmetric CO) appeared in the range 1329-1390 cm^{-1}. Δ ν [ν (asymmetric CO) - ν (symmetric CO)] ≈ 246- 310 cm^{-1} indicate the monodentate nature of carboxylate groups in **1**, **4**, and **6** except in the case of **2**, **3**, **5**, and **7,** which appears to contain bidentate carboxylate groups [45]. In **1-7** ν (Te-CH_2) appeared in the range 527-560 cm^{-1} and ν (OCO) appeared in the range 640-686 cm^{-1} [45, 46]

In NMR spectra of compounds (**1-6)** TeCH and $TeCH_2$ protons appeared in the range 4.36-3.48 ppm as multiplets and $TeCCH_2$ protons appeared in the range of 3.68-2.45 ppm as multiplets. In compound **7** $TeCH_2$ protons appeared at 3.05-2.91 as quartet and $TeCCH_3$ protons appeared at 0.87-0.83 as triplet. The proton NMR spectra of **1-4** contained the doublets in the range 1.96-1.75 ppm due to $TeCCH_3$ protons. In compounds **1**, **2**, **5**, and **7** protons of the benzene ring appeared in the range of 7.78-7.36 ppm as multiplets. In compounds **4** and **6** CH_3 protons of the acetate group appeared at 2.83 ppm and 2.99 ppm respectively as singlet. In compound **1** methine (-CH=CH-) protons appeared at 6.51-6.43 as a double doublet.

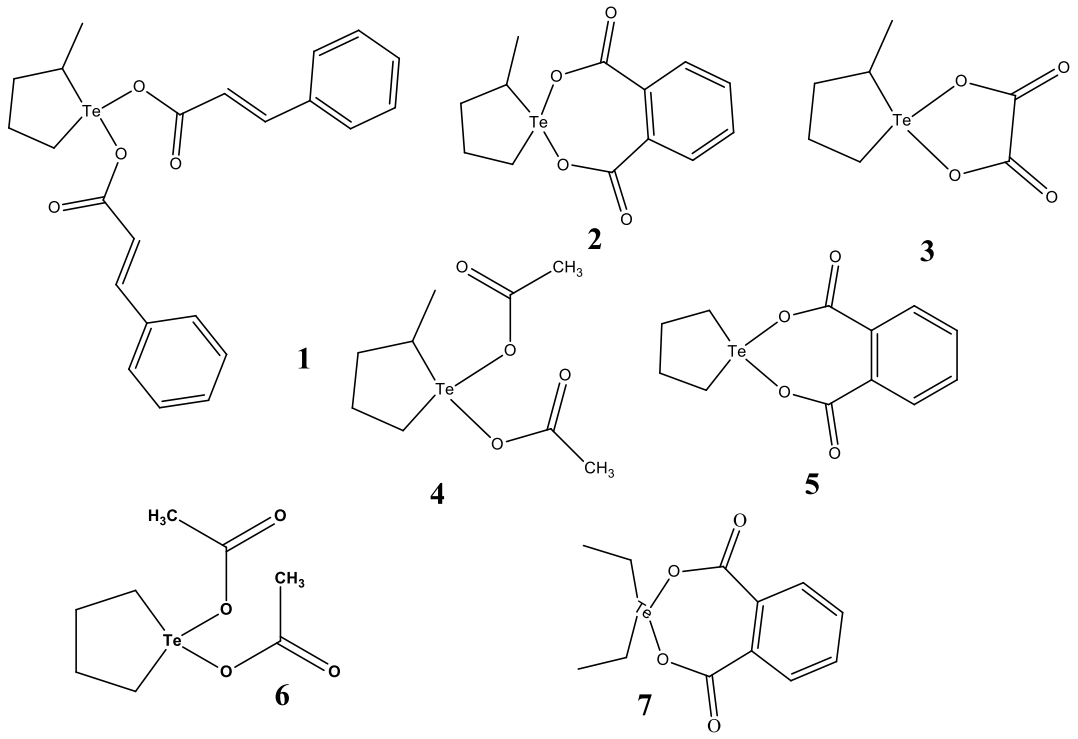


Figure 1. Molecular structures of organotellurium carboxylates 1-7

In carbon NMR spectra of the compounds **1-7,** $TeCH_2$ carbons appeared in the range 49.8-30.0 ppm as singlet. In **1-6** $TeCCH_2$ carbon appeared in the range 44.0-31.4 ppm. In compounds **1-4,**

TeCH carbons appeared at ≈60.0 ppm and $TeCCH_3$ carbons appeared in the range of 19.3-17.0 ppm. In compound **7,** $TeCCH_3$ carbon appeared at 8.4 ppm. In compounds **1**, **2**, **5**, and **7** carbons of benzene ring appeared in the range 143.7-129.7 ppm. In **1** –CH=CH- carbons appeared at 128.8 ppm and 121.6 ppm as a singlet. In **1-7,** carbonyl carbons appeared in the range 176.5-143.8 ppm. The results of IR and NMR studies are in close agreement with the proposed structures for the synthesized organotellurium carboxylates (**1-7**).

Antibacterial studies using Broth microdilution method

The broth microdilution method examined the antibacterial inhibitory efficacy of compounds **1-7**. The resultant data suggested that all the compounds inhibited bacterial strains *P. aeruginosa, E. coli, S. aureus,* and *K. pneumoniae* with specific MIC values among the concentration gradients. The MIC value for compounds against *P. aeruginosa, E. coli, S. aureus,* and *K. pneumoniae* was observed to significantly between 15.62 µg/ml to 125µg/ml **(Table 1**). Consequently, the attachment with membrane and DNA causes inhibition of bacterial cells [47 -50].

Table1: Showing MIC values of compounds 1, 2, 3, 4, 5, 6, and 7 against, *P. aeruginosa, E. coli, S. aureus,* and *K. peumoniae*.

MIC (µg/ml)				
Compounds/ Bacterial Strains	***P. aeruginosa***	***E. coli***	***S. aureus***	***K. pneumoniae***
1	31.25	31.25	15.62	62.5
2	15.62	15.625	15.62	62.5
3	15.62	15.625	15.62	31.25
4	62.5	62.5	31.25	250
5	62.5	62.5	31.25	125
6	62.5	62.5	31.25	125
7	15.62	15.62	15.62	31.25

Antibacterial studies using Disc diffusion method

Four bacterial strains i.e.; *P. aeruginosa, E. coli, S. aureus,* and *K. pneumoniae* from both gram-positive and gram-negative categories were used to see the efficacy of the compounds (**1-7**). Diffusion of compounds into MHA media prompts hindrance of bacterial growth and forming of a clear zone of inhibition (ZoI) around the discs **(Figure: 2)**. At 2x MIC concentration, bacterial strains were inhibited. Sterile DW (Distilled water) was the negative control and ciprofloxacin (5µg/ml) was the positive control. We observed the activity of compounds against *P. aeruginosa, E. coli, S. aureus,* and *K. pneumoniae.* All carboxylates showed antibacterial activity **(Figure: 2; A, B, C, D)** simultaneously, with specific ZoI **(Table: 2)**. The ZoI in disc diffusion assay of compounds against different bacterial strains clearly showed the antibacterial effects and significant inhibition. Negative control (DW) does not show any ZoI against bacterial pathogen and positive control (Ciprofloxacin; 5 µg/ml) showed clear ZoI.

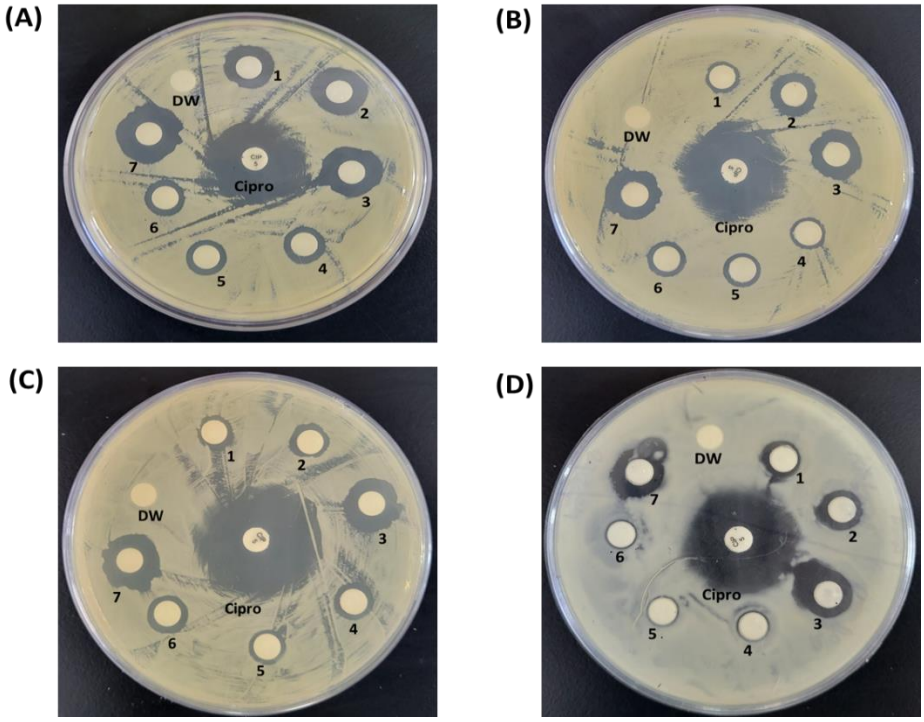


Figure 2: Antibacterial activity of compounds 1, 2, 3, 4, 5, 6, and 7 against (A) *P. aeruginosa,* (B) *E. coli,* (C) *S. aureus*, and (D) *K. pneumoniae*. Ciprofloxacin at 5 mcg, antibiotic was used as a positive control, and sterile DW was used

Table: 2 Zone of inhibitions of compounds 1-7 and ciprofloxacin against Bacterial pathogen strains.

	Bacterial Pathogens							
	P. aeruginosa		***E. coli***		***S. aureus***		***K. pneumoniae***	
Compounds (2x MIC)	**Conc. (µg/ml)**	ZoI	**Conc. (µg/ml)**	ZoI	**Conc. (µg/ml)**	ZoI	**Conc. (µg/ml)**	ZoI
1	**62.5**	13 mm	**15.62**	09 mm	**31.25**	10 mm	**125**	11 mm
2	**31.25**	15 mm	**31.25**	13 mm	**31.25**	10 mm	**125**	12 mm
3	**31.25**	16 mm	**31.25**	15 mm	**31.25**	15 mm	**62.5**	16 mm
4	**125**	11 mm	**125**	09 mm	**62.5**	11 mm	**500**	09 mm
5	**125**	11 mm	**125**	10 mm	**62.5**	10 mm	**250**	09 mm
6	**125**	11 mm	**125**	10 mm	**62.5**	11 mm	**250**	09 mm
7	**31.25**	16 mm	**31.25**	15 mm	**31.25**	16 mm	**62.5**	14 mm
	Control							
Ciprofloxacin (5 µg/ml)	25 mm		28 mm		30 mm		29 mm	

Conclusion

The synthesis, IR and NMR spectroscopic study, and antibacterial study of novel organotellurium-carboxylates have been described. The compounds have been synthesized by reaction of organotellurium diiodides with silver salts of carboxylic acids in a 1:1/1:2 molar ratio at room temperature. The antibacterial activity of the carboxylates was studied using broth microdilution and disc diffusion methods. Against *P. aeruginosa and E. coli* compounds **1** (62.5 µg/ml & 15.62 µg/ml respectively), **2**, **3**, and **7** (31.25 µg/ml) showed antibacterial activity at a lower concentration. But, compounds **4**, **5**, and **6** (125 µg/ml) showed antibacterial activity at a higher concentration. Against *S. aureus* compounds **1**, **2**, **3**, **7** (31.25 µg/ml), **4**, **5**, and **6** (62.5 µg/ml) showed antibacterial at a lower concentration. Similarly against *K. pneumoniae*, compounds **3** and **7** (62.5 µg/ml) showed antibacterial at a lower concentration. But, compounds **1, 2** (125 µg/ml), **4** (500 µg/ml), **5,** and **6** (250 µg/ml) showed antibacterial activity at a higher concentration. Based on the above results we conclude that compounds **3** and **7** showed antibacterial activity at lower concentrations (31.25µg/ml and 62.5 µg/ml) against all the bacterial strains. Some other compounds showed potent antibacterial activity against specific bacterial strains.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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