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Synthesis, characterization, and biological evaluation of some 4-((thiophen-2-*yl*-methylene)amino)benzenesulfonamide metal complexes

E. Vijaya Sekhar[1], Subhas S. Karki[2], Javarappa Rangaswamy[3], Mahesh Bhat[1] and Sujeet Kumar[2*]

Abstract

Background: Sulfonamides (*sulfa drugs*) and the metals like mercury, copper, and silver bear antimicrobial properties. The discovery of broad-spectrum antibiotics such as penicillins, cephalosporins, and fluoroquinolones has reduced their use. However, in some instances these drugs are the first-line treatment. The metal-based sulfonamide (e.g., silver sulfadiazine) is considered as first choice treatment in post-burn therapy while the use of silver nanoparticle-cephalexin conjugate to cure *Escherichia coli* infection explains the synergistic effect of sulfa drugs and their metal conjugates. With growing interest in metal-based sulfonamides and the Schiff base chemistry, it was decided to synthesize sulfonamide Schiff base metal complexes as antioxidant and antimicrobial agent.

Results: The Fe (III), Ru (III), Co (II), Ni (II), Cu (II), Pd (II), Zn (II), Cd (II), and Hg (II) metal complexes of 4-((thiophen-2-ylmethylene)-amino)-benzenesulfonamide (TMABS) were prepared and studied for thermal stability, geometry, and other electronic properties. The ligand TMABS (Schiff base) and its metal complexes were screened in-vitro for 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging and antimicrobial properties against Gram-positive (+ve) *Bacillus subtilis* (MTCC-441), *Staphylococcus aureus* (MTCC 7443), Gram-negative (-ve) *Escherichia coli* (MTCC 40), *Salmonella typhi* (MTCC 3231), and fungal strains *Aspergillus niger* (MTCC-1344) and *Penicillium rubrum* by agar well diffusion method. Results summarized in Tables 3, 4, and 5 represent the inhibitory concentration (IC_{50}) in micromole (μM). The zone of inhibition (ZI) in millimeter (mm) represents antimicrobial properties of TMABS and its metal complexes.

Conclusions: The synthesized sulfanilamide Schiff base (TMABS) behaved as a neutral and bidentate ligand coordinating with metal ions through its azomethine nitrogen and thiophene sulfur to give complexes with coordination number of 4 and 6 (Fig. 3). The nucleophilic addition of sulfanilamide amino group ($–NH_2$) group to carbonyl carbon (>C=O) of benzaldehyde gave sulfanilamide Schiff base (imine) (Fig. 2). All the metal complexes were colored and stable at room temperature. With IC_{50} of 9.5 ± 0.1 and 10.0 ± 0.7 μM, the Co, Cu, and Pd complexes appeared better antioxidant than the ligand TMABS (155.3±0.1 μM). The zone of inhibition (ZI) of Hg (28 mm) and Ru complexes (20 mm) were similar to the ligand TMABS (20 mm) against *Aspergillus niger* (MTCC-1344) as in Figs. 4, 5, and 6. None of the synthesized derivatives had shown better antimicrobial properties than the standard streptomycin sulfate and fluconazole.

Keywords: Sulfanilamide, Schiff base, In vitro, Antioxidant, Antimicrobial

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1 Background

Gerhard Domagk introduced prontosil (1) in 1932 as an anti-streptococcal agent. Later, Ernest Fourneau reported its in vivo conversion to active metabolite sulfanilamide (2) (Fig. 1). The sulfanilamide derivatives used to treat diseases like influenza, meningitis, and urinary tract infections [2] were soon phased-out from the clinic. The bacteriostatic nature, narrow spectrum, rapid microbial resistance, dose-dependent systemic toxicity, and discovery of broad-spectrum antibiotics (β-lactams and fluoroquinolones) restricted sulfanilamide to topical applications only. Use of silver-sulfadiazine (a metal conjugate) to treat post-burn infections is an example of it [2].

Schiff bases are chemically imine or azomethine (-HC=N) with greater chemical and physical stability [3]. Easy to synthesize and excellent chelating property make Schiff bases an important tool in developing organometallic complexes of multiple geometry. Apart from catalyst in synthetic chemistry [4, 5], the Schiff bases and their metal complexes were also studied for antioxidant, antibacterial, antifungal, anticancer, anti-inflammatory, antimalarial, and DNA binding properties [6–10].

In this context, thiophene-2-carbaldehyde Schiff base of sulfanilamide (TMABS) and its metal complexes were synthesized and screened in vitro for the antioxidant and antimicrobial properties.

2 Methods

2.1 Chemicals and apparatus

Analytical grade reagents and solvents purchased from Sigma-Aldrich and Merck Chemicals (India) were used without further purification. Synthesis of 4-((thiophen-2-ylmethylene)-amino)-benzenesulfonamide (TMABS) was confirmed by thin layer chromatography (TLC) on a pre-coated Aluchrosep silica gel 60/UV254 plates (Sd Fine-Chem Ltd., India). Melting point (Mp) of ligand TMABS was recorded in an open capillary tube and reported uncorrected. The Fourier transform infrared (FTIR) spectra were recorded in potassium bromide (KBr) between 4000 and 450 per centimeter (cm^{-1}) on PerkinElmer 100 FTIR spectrophotometer. The liquid chromatography-mass spectrometry (LCMS) spectrum of ligand TMABS was recorded in positive mode on triple-quadrupole LCMS-6410 from Agilent Technologies. The electronic spectra of metal complexes were recorded on ultraviolet-visible (UV-vis) spectrophotometer (PerkinElmer) while the *carbon*, *hydrogen*, and *nitrogen* (CHN) elemental analyses of ligand and its metal complexes were done on PerkinElmer 240 CHN analyzer. The conductivity of metal complexes (*molar conductance*, Ω^{-1} cm^2mol^{-1}) were measured in dimethylformamide (DMF) at 10^{-3} mole (M) using Digisun (D-1909) digital conductivity meter. Gouy balance calibrated with $Hg[Co(NCS)_4]$ at 28 degree Celsius (℃) was used to measure magnetic susceptibility (μ_{eff}) in Bohr Magneton (BM). Electron spin resonance (ESR) spectrum of TMABS-Cu (II) was recorded in dimethylformamide (DMF) at 9.5 giga-Hertz (GHz) using WIN-EPR spectrophotometer (Bruker) at liquid nitrogen temperature (LNT). Thermogravimetric analysis of Ru (III), Ni (II), Cu (II), Pd (II), and Zn (II) complexes were recorded using thermal analysis instrument (TAI) SDT Q 600 between 0 and 700 °C.

2.2 Antioxidant property

2,2-Diphenyl-1-picrylhydrazyl (DPPH) scavenging study was done to evaluate antioxidant property of ligand TMABS and the metal complexes. Dimethyl sulfoxide (DMSO) was used as a solvent and butylated hydroxyanisole (BHA) as reference standard.

2.3 Bacterial and fungal strains

The four pathogenic bacterial strains of Gram-positive (+ve) *Bacillus subtilis* (MTCC-441), *Staphylococcus aureus* (MTCC-7443), Gram-negative (-ve) *Escherichia coli* (MTCC 40), *Salmonella typhi* (MTCC-3231), and two fungal strains of *Aspergillus niger* (MTCC-1344) and *Penicillium rubrum* were used for antimicrobial screening.

2.4 Culture medium and solvent

Culture medium in Tables 1 and 2 were used to inoculate the bacterial and fungal strains. DMSO was used as a solvent while streptomycin sulfate and fluconazole as standard against bacterial and fungal strains, respectively.

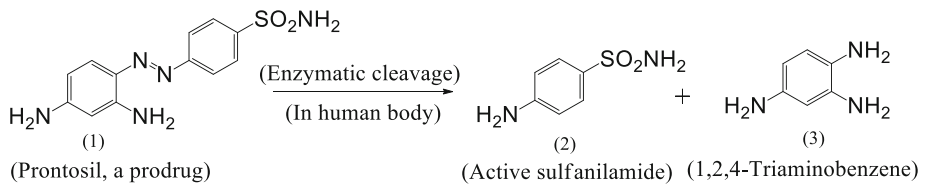

Fig. 1 Prontosil conversion to sulfanilamide [2]

3 Experimental part

3.1 Chemistry

3.1.1 Synthesis of 4-((thiophen-2-ylmethylene)amino)benzenesulfonamide [TMABS]

The ligand TMABS was prepared refluxing 0.1 M of thiophene-2-carbaldehyde (4) and 4-aminobenzene sulfonamide (5) in 50 milliliters (mL) of methanol and 0.5 mL of glacial acetic acid for 3 hours (h) (Fig. 2). The precipitated yellow mass (6) was filtered, washed with water, and recrystallized from methanol [11, 12].

3.1.2 General procedure for synthesis of TMABS metal complexes

Chloride salts of Fe (III), Ru (III), Co (II), Cu (II), Pd (II), and Hg (II) and acetate salts of Ni (II), Zn (II), and Cd (II) were used to prepare respective ligand-metal complexes. The Fe (III), Ru (III), and Cu (II) complexes were prepared refluxing 1:2 metal-ligand ratio, while 1:1 ratio was refluxed in anhydrous methanol for 3 h to get Co (II), Ni (II), Pd (II), Zn (II), Cd (II), and Hg (II) complexes. The precipitated solid was filtered; washed successively with water, hot methanol, and ether; and dried under vacuum over fused calcium chloride ($CaCl_2$) [11, 12] (Fig. 3).

3.2 Biology

3.2.1 Antioxidant activity

3.2.1.1 DPPH radical scavenging assay Compounds in micro-molar (μM) concentration (10, 50, 100, 200, and 500) were prepared using DMSO as solvent. One milliliter test solution was added into a volumetric flask (10 mL) containing 4 mL of 0.1 millimole (mM) DPPH. The final volume was adjusted to 10 mL with DMSO. The resulting solution was shaken vigorously and incubated at 28 °C in dark for 20 min. Any change in absorbance was measured at 517 nanometers (nm) using UV-vis spectrophotometer. Decrease in absorbance (A) and DPPH scavenging property (in %) were calculated using following formula:

Radical scavenging activity (%) = $[(A_o - A_1)/A_o \times 100]$ where A_o is the absorbance of control (DPPH) and A_1 is the absorbance of test compounds. The inhibitory concentration (IC_{50}) values were calculated using linear regression algorithm and expressed in μM [13].

Table 1 Composition of bacterial culture medium

Ingredients	Quantity
Peptone	10 g
Beef extract	10 g
NaCl	5 g
Agar	20 g
Distilled water	To 1000 mL

Table 2 Composition of fungal culture medium (Asthana and Hawker's medium)

Ingredients	Quantity
D-glucose	5 g
KNO_3	3.5 g
KH_2PO_4	1.75 g
$MgSO_4$	0.75 g
Agar	20 g
Distilled water	To 1000 mL

3.2.2 Antimicrobial activities

3.2.2.1 Antibacterial screening The antibacterial screening of newly synthesized ligand and its metal complexes were done by agar well diffusion method using 24-h old culture of *Staphylococcus aureus* (MTCC 7443), *Bacillus subtilis* (MTCC441), *Escherichia coli* (MTCC 40), and *Salmonella typhi* (MTCC 3231) in sterilized agar media as per literature (Table 1). The test compounds were dissolved in DMSO to get the concentration of 5g/mL. Twenty milliliters of sterilized agar media was poured into each pre-sterilized Petri dish. Excess of the suspension was decanted and the plates were incubated at 37 °C for 1 h. About 60 mL of 24-h old culture suspension was poured and neatly swabbed with pre-sterilized cotton swabs. Wells were prepared using 6-mm sterile cork-borer to which 80 microliters (mL) of test solutions (5g/mL) was added. The plates were incubated further for 24 h at 37 °C. After 24 h of incubation, the zone of inhibition (ZI) in millimeter (mm) was measured and compared with streptomycin sulfate (5g/mL). Each experiment was repeated in triplicate [14, 15].

3.2.2.2 Antifungal screening Antifungal screening of ligand (TMABS) and its metal complexes was carried out against *Aspergillus niger* (MTCC-1344) and *Penicillium rubrum* in sterilized agar media (Table 2) by agar well diffusion method. In brief, suspension of fungal strains (in 3 mL of saline solution) mixed with 20 mL of sterile agar media was poured into Petri plates. The Petri plates were dried at 37 °C for 1 h. Wells were made on these seeded agar plates using 6-mm sterile cork borer. One hundred milliliters of test solutions (5g/mL in DMSO) was added to each well. The Petri dishes were prepared in triplicate and maintained at 25 °C for 72 h. The ZI (in mm) was measured and compared with fluconazole [15, 16].

4 Results

4.1 Synthesis and spectral data

See Additional file 1 for thermal and electronic spectral characterization.

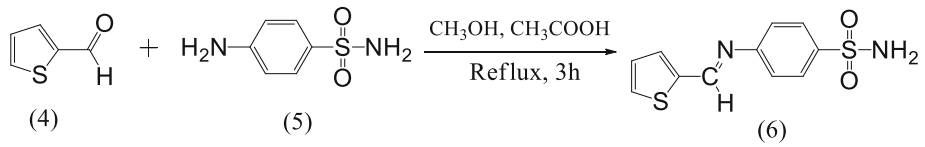

Fig. 2 Synthetic route for the preparation of TMABS (4-((thiophen-2-ylmethylene)amino)benzenesulfonamide) [1]

4.1.1 Synthesis of 4-((thiophen-2-ylmethylene)amino)benzenesulfonamide [TMABS]

Prepared by adopting the procedure mentioned in Section 3.1: yield 82%, yellow solid, *molecular formula* $C_{11}H_{10}N_2O_2S_2$, Mp 140–142 °C, R_f value 0.65 (n-hexane/ethylacetate: 6/4, (v/v)). *m/z:* 267.1 (266.34).

IR (KBr, cm^{-1}): 1590 (-HC=N), 1578 (-C=C, ar.), 1362 (-SO_2, a*sy.*), 1197 (-SO_2, *sym.*), 763 (-C-S).

Microanalysis

Obtained: C, 49.50%; H, 3.58%; N, 10.45%.

Calculated: C, 49.61%; H, 3.78%; N, 10.52%.

4.1.2 Synthesis of 4-((thiophen-2-ylmethylene)amino)benzenesulfonamide-metal complexes

4.1.2.1 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Fe complex

Obtained by adopting the procedure mentioned in Section 3.2: yield 81%, brown solid, *molecular formula* $[Fe(C_{11}H_{10}N_2O_2S_2)_2Cl_2]Cl$, *molar conductance* 47 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* (μ_{eff}) 5.86 B.M.

IR (KBr, cm^{-1}): 1607, (-HC=N), 1583 (-C=C, ar.), 1376 (-SO_2, a*sy.*), 1203 (-SO_2, *sym.*), 755 (-C-S).

Microanalysis

Obtained: C, 37.60%; H, 2.82%; N, 8.00%.

Calculated: C, 38.03%; H, 2.90%; N, 8.06%.

4.1.2.2 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Ru complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 80%, brown solid, *molecular formula* $[Ru\ (C_{11}H_{10}N_2O_2S_2)_2\ Cl_2]Cl$, *molar conductance* 54 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* (μ_{eff}) 1.80 B.M.

IR (KBr, cm^{-1}): 1601 (-HC=N), 1580 (-C=C-, ar.), 1370 (-SO_2, a*sy.*), 1197 (-SO_2, *sym.*), 753 (-C-S).

Microanalysis

Obtained: C, 35.22%; H, 2.70%; N, 7.42%.

Calculated: C, 35.70%; H, 2.72%; N, 7.57%.

4.1.2.3 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Co complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 70%, rose red solid, *molecular formula* $[Co(C_{11}H_{10}N_2O_2S_2)]Cl_2$, *molar conductance* 9 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* (μ_{eff}) 4.88 B.M.

IR (KBr, cm^{-1}): 1600 (-HC=N), 1595 (-C=C-, ar.), 1373 (-SO_2, a*sy.*), 751 (-C-S).

Microanalysis

Obtained: C, 39.68%; H, 3.00%; N, 8.28%.

Calculated: C, 39.88%; H, 3.04%; N, 8.46%.

4.1.2.4 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Ni complex

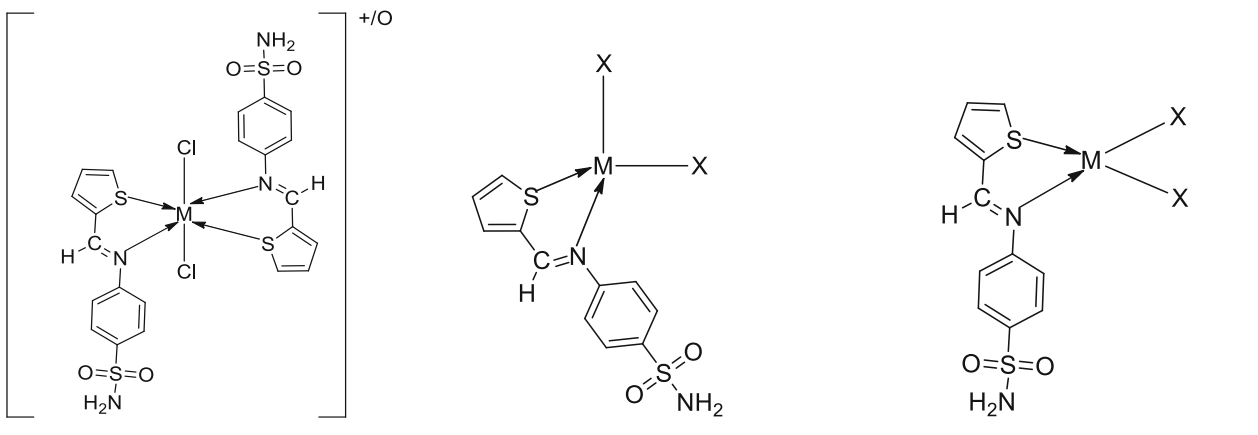

Fig. 3 General structures of synthesized metal complexes

Synthesized by adopting the procedure mentioned in Section 3.2: yield 70%, gray solid, *molecular formula* $[Ni(C_{11}H_{10}\ N_2O_2S_2)](OAc)_2$, m*olar conductance* 11 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* (μ_{eff}) 2.34 B.M.

IR (KBr, cm^{-1}): 1609 (-HC=N), 1579 (-C=C-, ar.), 1362 (-SO_2, a*sy.*), 1198 (-SO_2, *sym.*), 750 (-C-S).

Microanalysis

Obtained: C, 43.88%; H, 3.60%; N, 7.78%.

Calculated: C, 44.02%; H, 3.69%; N, 7.90%.

4.1.2.5 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Cu complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 80%, pale green solid, *molecular formula:* $[Cu(C_{11}H_{10}N_2O_2S_2)_2]Cl_2$, *molar conductance* 14 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* (μ_{eff}) 1.78 B.M.

IR (KBr, cm^{-1}): 1608 (-HC=N), 1579 (-C=C-, ar.), 1366 (-SO_2, a*sy.*), 1198 (-SO_2, *sym.*), 746 (-C-S).

Microanalysis

Obtained: C, 39.22%; H, 2.96%; N, 8.28%.

Calculated: C, 39.61%; H, 3.02%; N, 8.40%.

4.1.2.6 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Pd complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 75%, dark green solid, *molecular formula* $[Pd(C_{11}H_{10}N_2O_2S_2)]Cl_2$, *molar conductance* 12 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* (μ_{eff}, B.M) nil.

IR (KBr, cm^{-1}): 1600 (-HC=N), 1580 (-C=C-, ar.), 1376 (-SO_2, a*sy.*), 1179 (-SO_2, *sym.*), 750 (-C-S).

Microanalysis

Obtained: C, 36.94%; H, 2.80%; N, 7.72%.

Calculated: C, 37.22%; H, 2.84%; N, 7.89%.

4.1.2.7 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Zn complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 70%, light yellow solid, *molecular formula* $[Zn(C_{11}H_{10}N_2O_2S_2)](OAc)_2$, molar conductance 13 $\Omega^{-1}cm^2mol^{-1}$, magnetic susceptibility (μ_{eff}, B.M) nil.

IR (KBr, cm^{-1}): 1608 (-HC=N), 1579 (-C=C-, ar.), 1376 (-SO_2, a*sy.*), 1198 (-SO_2, *sym.*), 748 (-C-S).

Microanalysis

Obtained: C, 43.44; H, 3.44%; N, 7.70%.

Calculated: C, 43.60%; H, 3.66%; N, 7.82%.

4.1.2.8 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Cd complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 75%, yellow solid, *molecular formula* $[Cd(C_{11}H_{10}N_2O_2S_2)](OAc)_2$, *molar conductance* 12 $\Omega^{-1}cm^2mol^{-1}$, magnetic susceptibility (μ_{eff}, B.M) nil.

IR (KBr, cm^{-1}): 1604 (-HC=N), 1581 (-C=C-, ar.), 1372 (-SO_2, a*sy.*), 1197 (-SO_2, *sym.*), 750 (-C-S).

Microanalysis

Obtained: C, 40.40%; H, 3.28%; N, 7.22%.

Calculated: C, 40.92%; H, 3.43%; N, 7.34%.

4.1.2.9 4-((Thiophen-2-ylmethylene)amino)benzenesulfonamide-Hg complex

Synthesized by adopting the procedure mentioned in Section 3.2: yield 82%, white solid, *molecular formula* $[Hg(C_{11}H_{10}N_2O_2S_2)]Cl_2$, *molar conductance* 10 $\Omega^{-1}cm^2mol^{-1}$, *magnetic susceptibility* ($\mu_{eff,}$ B.M) nil.

IR (KBr, cm^{-1}): 1614 (-HC=N), 1582 (-C=C-, ar.), 1366 (-SO_2, a*sy.*), 1197 (-SO_2, *sym.*), 751 (-C-S).

Microanalysis

Obtained: C, 32.52%; H, 2.48%; N, 6.90%.

Calculated: C, 32.86%; H, 2.51%; N, 6.97%.

4.2 Biological study

The TMABS and its metal complexes were screened for antioxidant and antimicrobial properties. Table 3 represents antioxidant results while the antimicrobial properties are summarized in Figs. 4, 5, and 6 and Tables 4 and 5.

5 Discussion

The metal complexes of TMABS were stable, non-hygroscopic, and decomposed gradually at the higher temperature (at room temperature) without melting. The complexes were sparingly soluble in methanol, freely in DMSO, and insoluble in water. Elemental analysis report show Fe (III), Ru (III), and Cu (II) with 2:1 while, Co (II), Ni (II), Pd (II), Zn (II), Cd (II), and Hg (II) complexes with 1:1 metal-ligand stoichiometric ratio. All metal complexes behaved non-electrolyte in DMF except, Fe (III) and Ru (III) [17]. The magnetic study reports find Fe (III), Ru (III), Co (II), and Cu (II) complexes paramagnetic while Ni (II), Pd (II), Zn (II), Cd (II), and Hg (II) complexes as diamagnetic in nature.

Table 3 Radical scavenging property of ligand and their metal complexes

Sl. No.	Compound	Scavenging activity (IC_{50} μM)
1	TMABS	155.3±0.1
2	Fe-TMABS	68.5±0.5
3	Ru-TMABS	55.2±0.3
4	Co-TMABS	9.5±0.1
5	Ni-TMABS	78±0.2
6	Cu-TMABS	10±0.2
7	Pd-TMABS	10±0.7
8	Zn-TMABS	123±0.2
9	Cd-TMABS	255±0.6
10	Hg-TMABS	278±0.1
11	BHA	12±0.1

Each value represents mean ± SD (n = 3)

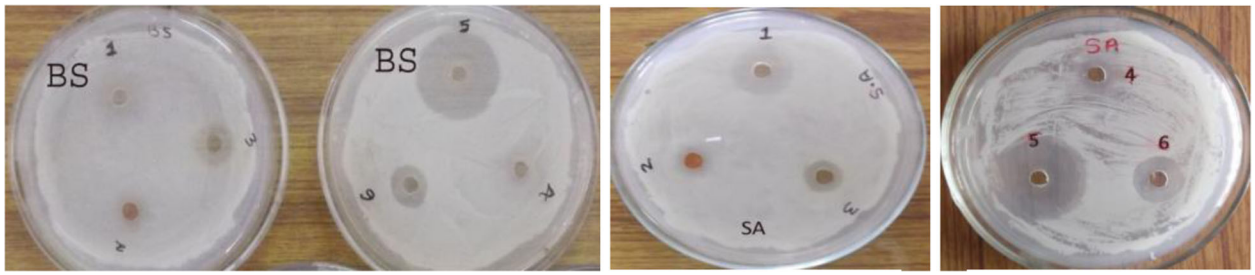

Fig. 4 Antimicrobial activity of TMABS against *Bacillus subtilis (BS)* and *Staphylococcus aureus (SA)*

Biological data suggest them good antioxidant and mild antimicrobial in nature.

5.1 Thermal data

Thermograms of Ru (III), Ni (II), Cu (II), Pd (II), and Zn (II) complexes show them stable at 28 °C. However, the loss in weight with decomposition at elevated temperature was observed. The Ru (III) complex decomposed at 250, Ni (II) at 170, Cu (II) at 286, Pd (II) at 301, and the Zn (II) complex decomposed at 315 °C in a gradual manner.

5.2 IR spectral data

The IR spectra of TMABS and its respective metal complexes showed transmittance peaks for azomethine group (-CH=N-) between 1614 and 1590 cm^{-1}. Lower shift in the position of -CH=N- peaks of metal complexes compared to TMABS ligand indicates the coordination of azomethine nitrogen with metal ions [18]. Further, the transmittance peaks of TMABS-SO_2 at 1197 (sym.) and 1362 cm^{-1} (asy.) remained unchanged in complexes (1203–1197 cm^{-1}), indicating free nature of SO_2 [19]. The shift of TMABS -C-S- peak from 763 to 760 to 746 cm^{-1} indicates its involvement in coordination with metal ions [20]. Based on IR spectral data, it can be concluded that the ligand TMABS is neutral, bidentate in nature and coordinating with respective metal ions *via* its azomethine nitrogen and thiophene sulfur.

5.3 Electronic spectral data

The TMABS-Fe (III) complex had shown three bands at 12,500, 15,600, and 20,000 cm^{-1} representing $^6A_{1g}\rightarrow{}^4T_{1g}$ (G), $^6A_{1g}\rightarrow{}^4T_{2g}$ (G), and $^6A_{1g}\rightarrow{}^4E_g$ (G) transitions of high spin octahedral geometry.

The Ru (III) complex revealed bands in the range of 11,640–22,600 cm^{-1} for $^2T_{2g}\rightarrow{}^4T_{1g}$, $^2T_{2g}\rightarrow{}^4T_{2g}$, and $^2T_{2g}\rightarrow{}^2A_{2g}$, transition of octahedral geometry [21].

The Co (II) complex had shown three bands at 12,080, 15,680, and 19,650 cm^{-1} assigned to the transitions $^4A_2$ (F)$\rightarrow{}^4T_2$ (F), $^4A_2$ (F)$\rightarrow{}^4T_1$ (F), and $^4A_2$ (F)$\rightarrow{}^4T_1$(P) of tetrahedral geometry [22].

The Ni (II) complex had shown bands in the range of 15,150–21,800 cm^{-1}. The Cu (II) complex had revealed another broad peak in the region 15,000–21,500 cm^{-1} that could be assigned to the transitions $^2B_{1g}\rightarrow{}^2B_{2g}$ and $^2B_{1g}\rightarrow{}^2E_g$ of a square-planar geometry [23].

The Pd (II) complex had shown three peaks around 16,100, 18,200, and 23,800 cm^{-1} which could be assigned for the transitions $^1A_{1g}\rightarrow{}^1A_{2g}$, $^1A_{1g}\rightarrow{}^1B_{1g}$, and $^1A_{1g}\rightarrow{}^1E_g$ of square-planar geometry [24].

The Zn (II), Cd (II), and Hg (II) complexes did not show any *d-d* band in their electronic spectra. Based on analytical, conductance, and infrared spectral data, the tetrahedral geometry is assigned. It is the most preferred geometry for a tetra-coordinated d^{10} type system.

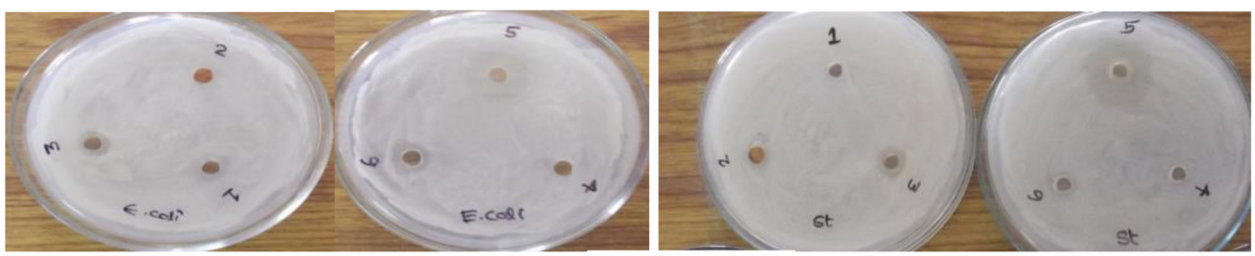

Fig. 5 Antimicrobial activity of TMABS against *Escherichia coli (E. coli)* and *Salmonella typhi (ST)*

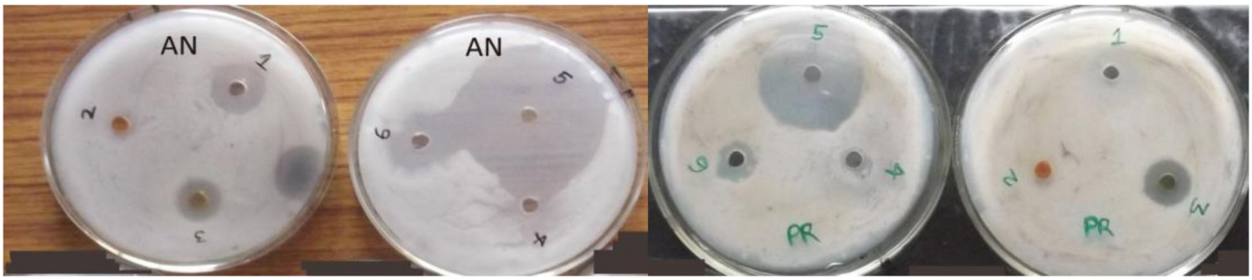

Fig. 6 Antimicrobial activity of TMABS against *Aspergillus niger* (AN) and *Penicillium rubrum* (PR) (note: (1) TMABS, (2) Fe-TMABS, (3) Ru-TMABS, (4) Cu-TMABS, (5) respective reference standards, and (6) represents Hg-TMABS in Figs. 4, 5, and 6)

Based on electronic spectral and other data, the Fe (III), Ru (III), and Cu (II) complexes were assigned octahedral; Ni (II) and Pd (II) complexes were assigned to square planar; and the Co (II), Zn (II), Cd (II), and Hg (II) complexes a tetrahedral geometry.

5.4 ESR spectrum

The ESR spectrum of Cu (II) complex was anisotropic in nature with $g_{||} > g_{\perp}$ indicating the presence of unpaired electron in $d_{x^2-y^2}$ orbital giving $^2B_{1g}$ as the ground state [25].

5.5 Antioxidant property

The antioxidant property of the ligand and their metal complexes were evaluated by DPPH method. Among screened complexes, the Co-TMABS, Cu-TMABS, and, Pd-TMABS showed maximum radical scavenging property with IC_{50} value 9.5±0.1, 13±00.2, and 10±07 μM respectively, as in Table 3.

5.6 Antimicrobial properties

Ligand (TMABS) and its metal complexes were screened for their antioxidant and antimicrobial properties by agar well diffusion method against *Bacillus subtilis*, *Staphylococcus aureus* (Gram +ve), *Escherichia coli*, *Salmonella typhi* (Gram -ve), and fungal strains *Penicillium rubrum* and *Aspergillus niger*. The ZI (in mm) in Tables 4 and 5 showed Hg (II) and Ru (II) complexes are better antimicrobial agents compared to others with 10–18 and 18–28 mm ZI against bacterial and fungal cells respectively. However, none of the synthesized molecules showed antimicrobial properties better than the reference streptomycin sulfate (22–28 mm ZI) and fluconazole (38–52 mm ZI).

6 Conclusions

Based on the foregoing discussion, it was concluded that the ligand TMABS acts in a neutral bidentate manner coordinating with metal ions through its azomethine nitrogen and thiophene sulfur. The Fe (III), Ru (III), and Cu (II) complexes were found

Table 4 Antibacterial activity of TMABS and its complexes

		Zone of inhibition (mm)			
		Gram positive Bacteria		Gram negative Bacteria	
Sl. No.	Compounds	*B. subtilis*	*S. aureus*	*E. coli*	*S. typhi*
1	TMABS	12	20	--	--
2	Fe-TMABS	10	10	--	--
3	Ru-TMABS	14	14	12	12
4	Co-TMABS	--	--	--	--
5	Ni-TMABS	--	--	--	--
6	Cu-TMABS	10	10	--	--
7	Pd-TMABS	--	--	--	--
8	Zn-TMABS	--	--	--	--
9	Cd-TMABS	--	--	--	--
10	Hg-TMABS	12	18	14	10
11	Streptomycin sulfate	28	32	22	26

Table 5 Antifungal activities of TMABS and its complexes

		Zone of inhibition (mm)	
		Fungi	
Sl. No.	Compound	*P. rubrum*	*A. niger*
1	TMABS	14	20
2	Fe-TMABS	--	10
3	Ru-TMABS	18	20
4	Co-TMABS	12	10
5	Ni-TMABS	05	08
6	Cu-TMABS	10	10
7	Pd-TMABS	12	10
8	Zn-TMABS	10	12
9	Cd-TMABS	08	09
10	Hg-TMABS	18	28
11	Fluconazole	38	52

octahedral, while Ni (II) and Pd (II) complexes as square planar and Co (II), Zn (II), Cd (II), and Hg (II) complexes tetrahedral in geometry. With IC_{50} of 9.5 ± 0.1 and 10.0 ± 0.7 μM, the Co, Cu, and Pd complexes appeared better antioxidant than the ligand TMABS (155.3±0.1 μM). The zone of inhibition (ZI) of Hg (28 mm) and Ru complexes (20 mm) were similar to the ligand TMABS (20 mm) against *Aspergillus niger* (MTCC-1344). None of the synthesized derivatives showed improved antimicrobial properties over streptomycin sulfate and fluconazole.

Abbreviations

A: Absorbance; asy: Asymmetric; BHA: Butylated hydroxyanisole; BM: Bohr magnetons; cm: Centimeter; DMSO: Dimethyl sulfoxide; DMF: Dimethylformamide; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; ESR: Electron spin resonance; FTIR: Fourier transform infrared; g: Gram; h: Hour (s); IR: Infrared; LCMS: Liquid chromatography-mass spectrometry; TLC: Thin layer chromatography; L: Liter; LNT: Liquid nitrogen temperature; M: Mole; mL: Milliliter; mM: Millimole; mm: Millimeter; m/z: Mass to charge ratio; Rf: Retardation factor; sym.: Symmetric; TAI: Thermal analysis instrument; TMABS: ((*E*)-4-((thiophen-2-ylmethylene)amino)benzenesulfonamide); UV: Ultra-violet; v: Volume; -ve: Negative; +ve: Positive; Vis: Visible; ZI: Zone of inhibition

7 Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43088-021-00113-y.

Additional file 1. Spectral details.

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Authors' contributions

All authors have read and approved the manuscript. EVS: Designed and performed the experiment. JR: Performed the experiment. SSK: Contributed to reagents and chemicals. MB: Wrote the paper. SK: Wrote and compiled the paper.

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Competing interests

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