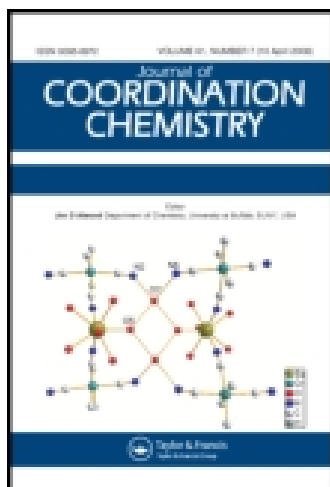


This article was downloaded by: [North West University]

On: 18 December 2014, At: 13:15

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Journal of Coordination Chemistry

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/gcoo20>

Synthesis, spectral, and antibacterial screening studies of chelating polymers of bisphenol-A-formaldehyde resin bearing barbituric acid

Nahid Nishat ^a, M. Zulfequar ^b, Asma ^a & Sumaiya Hasnain ^a

^a Department of Chemistry, Jamia Millia Islamia University, New Delhi 110025, India

^b Department of Physics, Jamia Millia Islamia University, New Delhi 110025, India

Published online: 30 Mar 2010.

To cite this article: Nahid Nishat, M. Zulfequar, Asma & Sumaiya Hasnain (2010) Synthesis, spectral, and antibacterial screening studies of chelating polymers of bisphenol-A-formaldehyde resin bearing barbituric acid, Journal of Coordination Chemistry, 63:7, 1273-1281, DOI: [10.1080/00958971003728296](https://doi.org/10.1080/00958971003728296)

To link to this article: <http://dx.doi.org/10.1080/00958971003728296>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms &

Synthesis, spectral, and antibacterial screening studies of chelating polymers of bisphenol-A–formaldehyde resin bearing barbituric acid

NAHID NISHAT*†, M. ZULFEQUAR‡, ASMA† and SUMAIYA HASNAIN†

†Department of Chemistry, Jamia Millia Islamia University, New Delhi 110025, India

‡Department of Physics, Jamia Millia Islamia University, New Delhi 110025, India

(Received 11 July 2009; in final form 9 November 2009)

A new polymeric ligand was synthesized by the reaction of bisphenol-A and formaldehyde in the basic medium, followed by condensation polymerization with barbituric acid in the acidic medium. Polymer metal complexes were prepared by reaction of this resin with Mn(II), Co(II), Ni(II), Cu(II), and Zn(II). The polymeric resin and its metal polychelates were characterized by elemental analysis, FT-IR, ^{13}C -NMR, and ^1H -NMR spectra. The geometry of the polymer metal complexes was evaluated by electronic spectra (UV-Vis) and magnetic moment measurement. Thermal stabilities show an increased thermal stability of the metal polychelates compared to the ligand. The antibacterial activities of all the synthesized polymers were investigated against *Bacillus subtilis*, *Staphylococcus aureus*, and *Escherichia coli*, showing good antibacterial activities against these bacteria. Cu(II) polychelate showed highest biocidal activity.

Keywords: Barbituric acid; Polymer metal complexes; Thermogravimetric analysis

1. Introduction

Metal containing polymers show many potential applications as functional materials with desirable chemical and physical properties, catalytic activities [1, 2], and models for bioinorganic systems [3]. After the discovery of barbituric acid by Adolf von Baeyer in 1864, it was concluded that barbituric acid is not pharmacologically active, but its derivatives could be used as drugs, valuable in medicine as soporifics, hypnotics, sedatives, and anesthetics [4]. Barbituric acid is nontoxic and thermally stable [5]. The presence of potential donors such as two amine nitrogens and three carbonyl oxygens makes barbiturates interesting and polyfunctional ligands [6], suitable candidates for pharmacologically active and useful ligands in coordination and polymer chemistry. This article reports the synthesis and characterization of bisphenol-A–formaldehyde resin according to the reported method, and its condensation polymerization to obtain the polymeric ligand (BFB) containing barbituric acid moiety. Mn(II), Co(II), Ni(II), Cu(II), and Zn(II) were added to BFB to obtain metal polychelates.

*Corresponding author. Email: nishat_nchem08@yahoo.com

The spectral, magnetic, thermal properties, the type of chelation of the ligand, and the geometry around the metal center are discussed. In addition, the antimicrobial activities are tested against several bacteria, *Bacillus subtilis*, *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative).

2. Experimental

2.1. Chemicals

The following materials were used as received: bisphenol-A (G.S. Chemicals), formaldehyde (37–41%) (S.D. Fine Chemicals), barbituric acid, sodium hydroxide pellets (Merck India), and metal(II) acetate (Qualigens Fine Chemicals, India). Solvents such as dimethyl sulfoxide (DMSO) and dimethyl formamide (DMF) (Qualigens Fine Chemicals) were of analytical grade and used without purification.

2.2. Preparation of bacterial strains

The antibacterial activities of the ligand and metal polychelates were screened *in vitro* against various bacteria in DMSO. The sample concentration was $20\text{ }\mu\text{g mL}^{-1}$. Antibacterial activity was screened against *B. subtilis*, *S. aureus* (Gram positive) and *E. coli* (Gram negative) bacteria by the shaking flask method [7] and the number of viable cells was counted utilizing the spread plate method [8]. One loop full of bacteria was inoculated in 10 mL of a nutrient broth (peptone, 5 g L^{-1} ; pH 6.8) and incubated at 37°C for 28 h in a test-tube shaker at 100 rpm. The nutrient agar (20 mL) was poured into sterile Petri plates and allowed to solidify at room temperature. After solidification, 0.1 mL of the bacterial culture was spread on the agar. A circular well was made at the center of each Petri plate with a sterilized steel borer. The test samples were prepared in DMSO at $20\text{ }\mu\text{g mL}^{-1}$, and 0.1 mL of each test solution was added to the well and incubated at 37°C for 24 h. After incubation, the zones of inhibition were measured in millimeters and represented as inactive, mildly active, moderately active, and highly active depending on the diameter and clarity of the zone of inhibition. Kanamycin was used as positive control and DMSO as negative control.

2.3. Instrumentations

Elemental analyses (C, H, and N) were carried out on an elemental analyzer system GmbH Vario ELIII with the percentage of metal obtained by complexometric titration with EDTA after decomposing with conc. HNO_3 at room temperature, the results are given in table 1. Magnetic susceptibility measurements were recorded on a Vibrating Sample Magnetometer model 155 at room temperature. FT-IR spectra were obtained on a Perkin Elmer IR spectrophotometer model 621 using KBR pellets. Proton NMR (^1H -NMR) and carbon (^{13}C -NMR) nuclear magnetic resonance spectra were recorded on a JEOL-GSX 300 MHz FX 1000 FT-NMR spectrometer using DMSO- d_6 and tetramethylsilane (TMS) as an internal standard. UV-Visible spectra were carried out on a Perkin Elmer Lambda EZ-201 spectrophotometer in DMSO.

Table 1. Elemental analysis data for BFB and BFB-M.

Compound abbreviation	Empirical formula	Yield (%)	Elemental analysis (%) ^a			
			Carbon	Hydrogen	Nitrogen	Metal
BFB	[C ₂₁ H ₂₀ N ₂ O ₅] _n	68	65.22 (66.30)	5.90 (5.29)	7.55 (7.36)	—
BFB-Mn(II)	[MnC ₂₁ H ₁₈ N ₂ O ₅ ·2H ₂ O] _n	74	53.77 (53.74)	4.63 (4.72)	5.87 (5.96)	11.64 (11.70)
BFB-Co(II)	[CoC ₂₁ H ₁₈ N ₂ O ₅ ·2H ₂ O] _n	71	53.51 (53.28)	4.35 (4.68)	5.83 (5.91)	12.36 (12.45)
BFB-Ni(II)	[NiC ₂₁ H ₁₈ N ₂ O ₅ ·2H ₂ O] _n	72	53.51 (53.31)	4.57 (4.68)	5.74 (5.92)	12.31 (12.40)
BFB-Cu(II)	[CuC ₂₁ H ₁₈ N ₂ O ₅] _n	68	57.29 (57.07)	4.00 (4.10)	6.26 (6.33)	14.34 (14.37)
BFB-Zn(II)	[ZnC ₂₁ H ₁₈ N ₂ O ₅] _n	72	57.09 (56.83)	4.01 (4.08)	6.21 (6.31)	14.64 (14.73)

^aObserved value (calculated).

Thermal behavior was determined using a Perkin Elmer (Pyris Diamond) Thermal Analyzer in nitrogen at 20°C min⁻¹. The solubilities of the polymeric ligand and polymer metal complexes were determined in both polar and non-polar solvents by the addition of 2 mg of sample to 10 mL of the solvent kept overnight.

2.4. Synthesis of polymeric ligand

Initially, salicyl alcohol was formed by the addition of bisphenol-A and formaldehyde in the molar ratio of 1 : 2 (2.28 g, 1.5 mL, respectively) in DMSO. Stirring and heating on a magnetic stirrer was continued in a three-necked round bottom flask equipped with a thermometer and a water condenser in the presence of NaOH at 60°C for 2.5 h. Thereafter, salicyl alcohol of bisphenol-A {4,4'-propane-2,2-diylbis[(2-hydroxymethyl)-phenol]} was obtained in good yield.

Barbituric acid (barbH₂) (0.01 mol, 1.28 g) was added to the formed salicyl alcohol in slightly acidic medium and stirred magnetically at 70°C giving a light orange sticky compound. It was precipitated in distilled water and washed several times with acetone and diethyl ether, giving an orange powdery material. After drying in an oven for 6–8 h at 40°C, polymeric ligand (BFB) was obtained. This polymeric ligand lost two protons, so it can be written as (barb). Anal. Calcd for BFB (%): C, 65.22; H, 5.90; N, 7.55. Found (%): C, 66.30; H, 5.29; N, 7.36.

2.5. Synthesis of metal polychelates

A series of polymer complexes of Mn(II), Co(II), Ni(II), Cu(II), and Zn(II) were prepared from BFB in 2 : 1 molar ratio. A typical procedure for preparation of BFB-Co(II) complex follows:

The polymeric ligand was dissolved in DMSO and heated at 60–70°C in a three-necked round bottom flask fitted to an ice-cooled condenser. Cobalt(II) acetate (1.24 g, 0.005 mol) dissolved in DMSO was added to this hot solution and maintained for 8–10 h at the same temperature. Stirring was continued until complete dissolution and a royal blue viscous solution was obtained. It was then precipitated with distilled H₂O, filtered and washed several times with distilled H₂O and diethyl ether, giving a dark blue precipitate which was oven dried at 45°C for 5–6 h to obtain the polychelate BFB-Co(II). Similar procedure was adopted for the preparation of polychelates

of Mn(II), Ni(II), Cu(II), and Zn(II). The percentage yield of the ligand (BFB) and its metal polychelates (BFB–M) are listed in table 1.

3. Results and discussion

3.1. Chemistry of polymeric ligand and polymer metal complex

Transition metal polychelate and polymeric ligand were prepared according to the synthetic route, as shown in scheme 1. The reaction of phenol with formaldehyde is followed by condensation. Formation of phenoxide is the initial step. Then, formaldehyde in its hydrated form gives salicyl alcohol. Condensation of barbituric acid occurs by the removal of water to form the ligand.

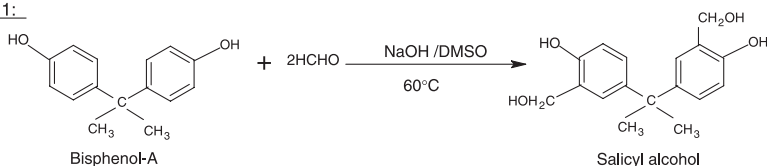
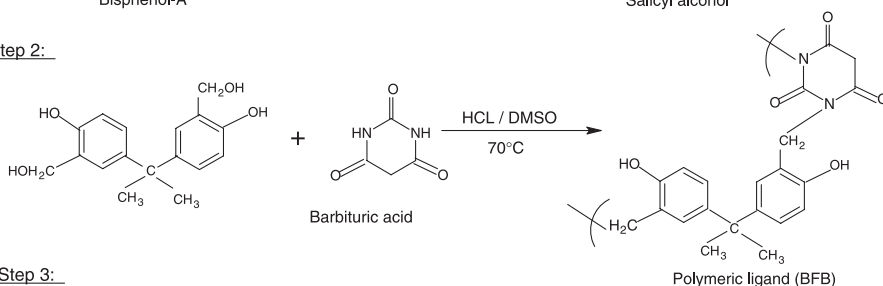
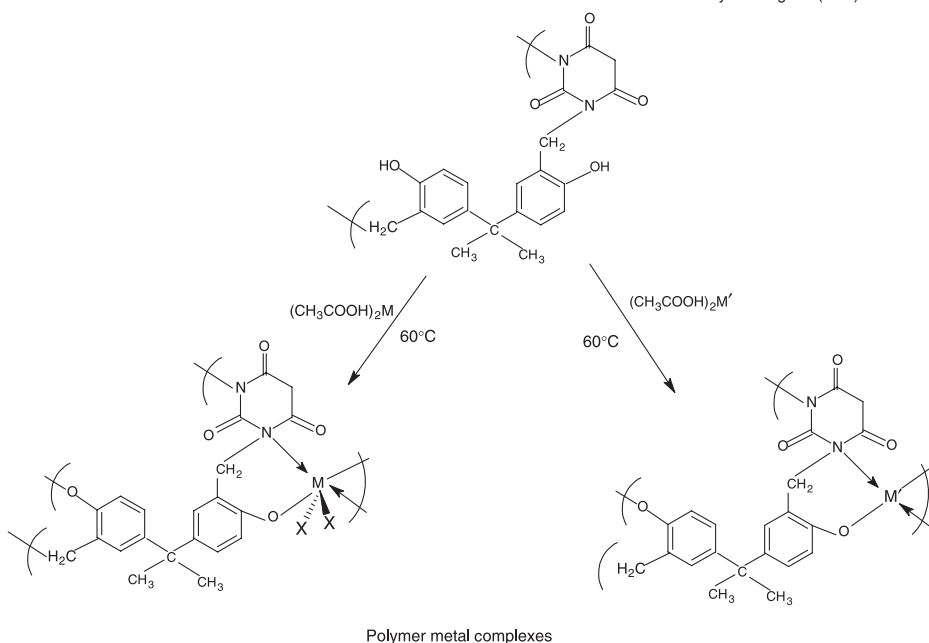
All polychelates including the ligand were colored and insoluble in distilled water, ethanol, methanol, benzene, and chloroform, but soluble in DMSO and DMF. Their insolubility indicates their polymeric behavior. Elemental analyses of all the polymers are in very good agreement with calculated values (table 1). The elemental analysis data also reveal that ligand-to-metal ratio is 2:1.

3.2. FT-IR spectral studies

Barbituric acid has two donors, nitrogen and oxygen, but the metals discussed here prefer nitrogen [9]. Similarity of FT-IR spectra of the complexes shows binding through deprotonated nitrogen for all the metals. The absorption at 3422 cm^{-1} from phenolic–OH stretching in the polymeric ligand (BFB) is a very broad band which disappears in the spectra of metal polychelates, suggesting the involvement of hydroxyl oxygen in bond formation [10]. In the ligand, a band at 1244 cm^{-1} corresponds to phenolic (C–OH) group vibration; in metal complexes, these bands shift to lower frequency by $10\text{--}14\text{ cm}^{-1}$, indicating the coordination of metal to oxygen [11]. Sharp signal at $1718\text{--}1721\text{ cm}^{-1}$ is due to C=O; no change in the frequency of C=O in the ligand and metal polychelate shows that the oxygen of barbituric acid is not involved in bond formation. Aromatic ring has C=C stretching vibrations at $1654\text{--}1620\text{ cm}^{-1}$. The isopropyl group of bisphenol-A shows peaks of almost equal intensity at 1363 cm^{-1} [12]. The peak at $1458\text{--}1452\text{ cm}^{-1}$ from C–N stretching is a strong evidence for the polymerization of bisphenol-A–formaldehyde resin with barbituric acid [13]. A band at $541\text{--}530\text{ cm}^{-1}$ indicates M–N bonding [14] while M–O appears at $618\text{--}610\text{ cm}^{-1}$ [15]. Medium-to-weak intensity bands are due to coordinated water at $952\text{--}950\text{ cm}^{-1}$ (rocking) and $774\text{--}770\text{ cm}^{-1}$ (wagging) in the spectra of Mn(II), Co(II), and Ni(II) polymer complexes but are not observed in the spectra of Cu(II) and Zn(II) polychelates. This difference suggests that water is present in Mn(II), Co(II), and Ni(II) polymer metal complexes.

3.3. NMR spectrum analyses

^1H -NMR spectra of BFB and its Zn(II) polychelate were carried out in DMSO at room temperature using TMS as internal standard (Supplementary material). Dimethyls of

Step 1:Step 2:Step 3:

where M = Mn(II), Co(II) and Ni(II)

M' = Cu(II) and Zn(II)

X = H₂O

Scheme 1. Proposed synthetic route to polymer metal complexes.

bisphenol-A are between 1.3 and 1.7 ppm in BFB and BFB-Zn(II) [16] while the resonance signals for the aromatic rings appear as multiplets at 6.6–6.9 ppm [17]. Phenolic OH is at 11.5 ppm [18] for BFB but is absent in the spectrum of BFB-Zn(II), indicating the coordination of phenolic oxygen. CH₂ at δ 4.1 and 4.4 ppm [19] in the ligand and metal polychelate, respectively, shows the polymerization of bisphenol-A-formaldehyde unit with barbituric acid.

The ¹³C-NMR spectra of BFB and its Zn(II) polychelate show carbonyl carbons (Ca, Cc) at 154.87 and 164.51 ppm, respectively [20]. Methylene of barbituric acid (Cb)

and formaldehyde (Cd) show peaks at 43.64 and 40.33 ppm, respectively [21]. Aromatic carbons show multiple overlapping peaks between 39.22 and 39.78 ppm, and at 114.56 and 127.29 ppm. The characteristic peak for the carbon to which hydroxyl is attached may have shifted to lower frequency after complexation but was not clearly visible in the spectrum due to several overlapped peaks. Methyl carbon of bisphenol-A (Cg) is at 31.88 ppm [22].

Thus, ¹H-NMR and ¹³C-NMR spectra reveal that the metal is attached through the phenolic oxygen of bisphenol-A and nitrogen of barbituric acid.

3.4. UV-Visible analysis

Electronic spectra were recorded in DMSO and various parameters 10 *D*_q (crystal field parameter), *B* (Racah interelectronic repulsion parameter), β (nephelauxetic ratio) and β° (covalency parameter) calculated (table 2). The nephelauxetic parameter, β, is obtained by using the relation β = *B*_{complex}/*B*_{free ion}, where *B*_{free ion} = 960, 1120, and 1080 for Mn(II), Co(II), and Ni(II), respectively.

The magnetic moment of BFB–Mn(II) is 5.72 B.M. corresponding to five unpaired electrons. The electronic spectrum has three absorptions at 15,562, 19,850, and 24,341 cm^{−1}, assigned to ⁴T_{1g}(G) ← ⁶A_{1g}(F), ⁴T_{2g}(G) ← ⁶A_{1g}(F), and ⁴E_g(G) ← ⁶A_{1g}(F), respectively. The assignments obtained by fitting the observed spectrum to the Tanabe–Sugano diagram suggest octahedral geometry [23]. The 10 *D*_q and *B* are 4126 and 825 cm^{−1} while β and β° values are 0.85 and 0.15, respectively.

The magnetic moment of polymer Co(II) complex was 4.41 B.M. and electronic transitions at 9632, 14,670, and 18,980 cm^{−1} correspond to ⁴T_{2g} ← ⁴T_{1g}, ⁴A_{2g}(P) ← ⁴T_{1g}, and ⁴T_{1g}(P) ← ⁴T_{1g}, respectively. The positions of bands indicate the octahedral geometry [24]. The value of *D*_q was calculated from the Orgel energy diagram. The spectral parameters are 10 *D*_q = 4694 cm^{−1}, *B* = 670.6 cm^{−1}, β = 0.59, and β° = 0.41, suggesting the covalent nature of the compound.

The magnetic moment of BFB–Ni(II) was 2.62 B.M. Bands at 8942, 16,880, and 21,443 cm^{−1} correspond to ³T_{2g} ← ³A_{2g}, ³T_{1g} ← ³A_{2g}, and ³T_{1g}(P) ← ³A_{2g} transitions, respectively, suggesting octahedral complex [25]. Spectral parameters for this

Table 2. Magnetic susceptibility, electronic spectra, and their ligand field parameters.

Abbreviation	Magnetic moment (μ _{eff})	Electronic transitions (cm ^{−1})	Assignment	Geometry	ε ^a	B	10 <i>D</i> _q	β	β°
BFB–Mn(II)	5.72	15,562	⁴ T _{1g} (G) ← ⁶ A _{1g} (F)	Octahedral	11	825	4126	0.85	0.15
		19,850	⁴ T _{2g} (G) ← ⁶ A _{1g} (F)		13				
		24,341	⁴ E _g (G) ← ⁶ A _{1g} (F)		16				
BFB–Co(II)	4.41	9632	⁴ T _{2g} ← ⁴ T _{1g}	Octahedral	10	670	4694	0.59	0.41
		14,670	⁴ A _{2g} (P) ← ⁴ T _{1g}		12				
		18,980	⁴ T _{1g} (P) ← ⁴ T _{1g}		14				
BFB–Ni(II)	2.62	8942	³ T _{2g} ← ³ A _{2g}	Octahedral	15	794	9530	0.73	0.27
		16,880	³ T _{1g} ← ³ A _{2g}		12				
		21,443	³ T _{1g} (P) ← ³ A _{2g}		13				
BFB–Cu(II)	1.75	14,685	² A _{1g} ← ² B _{1g} (F)	Square planar	14				
		21,872	Charge transfer		15				

μ_{eff}, effective magnetic moment in B.M.; ε^a, dm³ mol^{−1} cm^{−1}.

polychelate are $10Dq = 9530.1\text{ cm}^{-1}$, $B = 794.18\text{ cm}^{-1}$, $\beta = 0.73$, and $\beta = 0.27$, obtained from the Orgel diagram.

The BFB-Cu(II) has a magnetic moment of 1.75 B.M. and shows bands at 14,685 and $21,872\text{ cm}^{-1}$ assigned to ${}^2A_{1g} \leftarrow {}^2B_{1g}$ and charge transfer indicative of square planar geometry. The BFB-Zn(II) is diamagnetic and no d-d transitions are observed.

$B_{\text{free ion}}$ value in the metal complexes is reduced revealing that the complexation of the metal ion occurs. Thus, the electronic spectral study further supports the structure proposed for the polymeric ligand and its metal polychelates.

3.5. Thermogravimetric analysis

Degradation was carried out at a heating rate of $20^\circ\text{C min}^{-1}$ in nitrogen to 850°C . The weight loss fractions of resin were calculated and the TGA thermograms of BFB and BFB-M are depicted in the "Supplementary material". The polymers start decomposing at 100°C with 2–8% weight loss due to the elimination of water/solvent. For Mn(II), Co(II), and Ni(II) polychelates, the curve showed 10–20% weight loss corresponding to two coordinated waters in the temperature range of $100\text{--}150^\circ\text{C}$, while Cu(II) and Zn(II) polychelates do not show weight loss in this temperature range, indicating the absence of coordinated water and thus favoring four coordinate geometry for Cu(II) and Zn(II) polychelates. Above 200°C , a gradual mass loss was observed, but the rate of decomposition was quite rapid between 300°C and 600°C , which can be attributed to the decomposition of the chelate polymer followed by the formation of metal oxides (MnO, CoO, NiO, CuO, and ZnO). Greater stabilities of the polymer metal complexes than the ligand may be attributed to the formation of stable six-membered rings in all the polymeric complexes. The thermal stability of polymeric chelates was $\text{Cu} > \text{Ni} > \text{Zn} > \text{Co} > \text{Mn}$. The greater stability of BFB-Cu(II) compared with the other polychelates is in agreement with the spectrochemical series, where Cu(II) complexes are always more stable than other complexes.

3.6. Antimicrobial effects

Antibacterial activities show that the newly synthesized ligand and polymer metal complexes have biological activity (table 3 and figure 1). Polymer metal complexes of Cu(II) exhibited the highest activity against both Gram positive and Gram negative bacteria, the polymeric ligand was inactive to moderately active while other polychelate complexes were moderately active. Co(II) and Zn(II) polychelates were highly active against *S. aureus* but moderately active against *E. coli* and *B. subtilis*. Mn(II) polychelates were highly active against *E. coli* but moderately active against *B. subtilis* and *S. aureus*. Ni(II) polychelates exhibited high activity against *E. coli* while moderate activity against *S. aureus*. Metal containing polyesters with an antimicrobial activity have been published [26], and further increasing the biological activity including this work is still in progress.

The possible mode of biocidal action can be explained with the help of chelation theory [27, 28]. More activity of the Cu(II) polychelate can be attributed to its higher stability with N and O donors having strong interaction toward the central metal, by which its lipophilic nature was increased. The higher activity of Gram positive bacteria can be explained on the basis that there is a thick outer membrane made up of

Table 3. Antibacterial analysis (zones of inhibition in mm).

Compounds	<i>B. subtilis</i>	<i>S. aureus</i>	<i>E. coli</i>
BFB	3 ± 2	5 ± 1	4 ± 1
BFB–Mn(II)	14 ± 1	16 ± 1	20 ± 2
BFB–Co(II)	12 ± 1	19 ± 2	17 ± 1
BFB–Ni(II)	8 ± 2	12 ± 2	21 ± 2
BFB–Cu(II)	23 ± 2	16 ± 2	18 ± 3
BFB–Zn(II)	6 ± 3	22 ± 3	19 ± 2
Kanamycin	22 ± 1	23 ± 1	25 ± 2

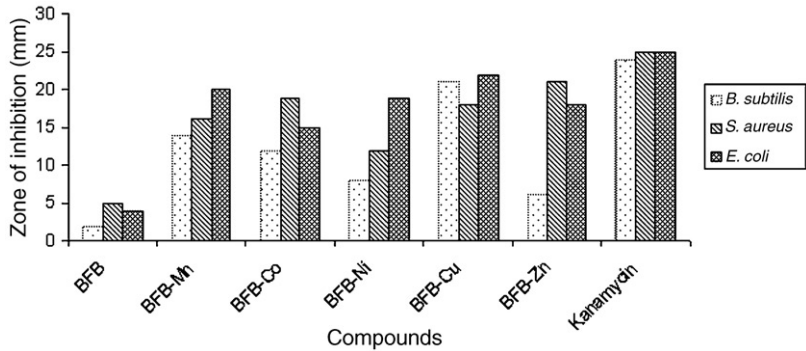


Figure 1. Antibacterial activity data.

lipopolysaccharide and protein in the Gram negative bacteria which inhibits or partially permits the penetration of polymer metal complexes into the bacterial cell, but such membrane is not present in the Gram positive bacteria; instead, a wall of peptidoglycan is present which easily permits the penetration of polymer metal complexes.

Various other biocidal activities of coordination polymers have been published [29, 30] with various mechanisms of the inhibition of bacteria. The new polymers containing metal complexes are not expected to have toxicities to humans; however, a toxicity study for these polymers should be carried out before their use *in vivo*. Although allergies may develop to formaldehyde, in general, this should not be a concern for formaldehyde-based polymers. As these polymers cause fewer allergic responses compared with the formaldehyde monomers, however, this issue should also be clarified before any internal use of these polymers.

4. Conclusions

The new polymeric ligand (BFB) has been synthesized by condensation polymerization and coordinated with several transition metals. The insolubility of the ligand and metal complexes indicate their polymeric nature. Cu(II) chelated polymer showed more antibacterial activity than other polymers. Further work will be done on some of the polychelates to enhance their properties and make them applicable in biomedical fields.

Acknowledgments

The authors express their sincere thanks to “The Third World Academy of Sciences Italy” for UV-Vis spectrophotometer EZ-201 (PerkinElmer) through research grant scheme No. 00-047 RG/CHE/AS.

References

- [1] K.C. Gupta, A.K. Sutar. *React. Funct. Polym.*, **68**, 12 (2008).
- [2] O.E. Woisetschlager, K. Sunkel, W. Weigand, W. Beck. *J. Organomet. Chem.*, **584**, 122 (1999).
- [3] M.S. Niasari. *J. Mol. Catal. A: Chem.*, **283**, 120 (2008).
- [4] H.A.A. Medien, A.A. Zahran. *Phosphorus, Sulfur Silicon*, **178**, 1069 (2003).
- [5] N.A. Mohamed, A.A. Yassin, Kh.D. Khalil, M.W. Sabaa. *Polym. Degrad. Stab.*, **70**, 121 (2000).
- [6] V.T. Yilmaz, F. Yilmaz, H. Karakaya, O. Buyukgungor, W.T.A. Harrison. *Polyhedron*, **25**, 2829 (2006).
- [7] W.S. Moon, J.C. Kim, K.H. Chung, E.S. Park, M.N. Kim, J.S. Yoon. *J. Appl. Polym. Sci.*, **90**, 1797 (2003).
- [8] J.J. Merianos, Surface Active Agents. In *Disinfection, Sterilization and Preservation*, S.S. Block (Ed.), 5th Edn, Lippincott Williams and Wilkins, Philadelphia (2001).
- [9] A. Bult, H.B. Klasen. *Spectrosc. Lett.*, **9**, 81 (1976).
- [10] N. Chantarasiri, T. Damrongkosit, W. Jangwong, D. Sridaeng, S. Suebphan. *Eur. Polym. J.*, **40**, 1867 (2004).
- [11] S. Saydam, E. Yilmaz. *Spectrochim. Acta, Part A*, **63**, 506 (2006).
- [12] R.M. Silverstein, G.C. Bassler, T.C. Morrill. *Spectroscopic Identification of Organic Compounds*, 5th Edn, John Wiley and Sons, New York (1991).
- [13] A. Chaudhary, R. Saroop, R. Singh. *Bol. Soc. Chil. Quim.*, **47**, 203 (2002).
- [14] H. Mart. *J. Macromol. Sci. Part A: Pure and Appl. Chem.*, **42**, 1197 (2005).
- [15] A. Manimaran, R. Prabhakaran, T. Deepa, K. Natarajan, C. Jayabalakrishnan. *Appl. Org. Chem.*, **22**, 353 (2008).
- [16] C. Soykan, I. Erol, S. Kirbag. *J. Appl. Polym. Sci.*, **90**, 3244 (2004).
- [17] H. Keypour, S. Salehzadeh, R.V. Parish. *Molecules*, **7**, 140 (2002).
- [18] A.W. Nashed, T.A. Elbokl, T.E. Khalil, W. Haase, M.F. Iskander. *J. Coord. Chem.*, **58**, 153 (2005).
- [19] D. Habibi, V. Izadkhah. *Phosphorus, Sulfur Silicon*, **179**, 1197 (2004).
- [20] M. Guzman-Chozas, I.M. Vicario-Romero, R. Guillen-Sans. *J. Am. Oil Chem. Soc.*, **75**, 1711 (1998).
- [21] E. Mendez, M.F. Cerda, J.S. Gancheff, J. Torres, C. Kremer, J. Castiglioni, M. Kieninger, O.N. Ventura. *J. Phys. Chem. C*, **111**, 3369 (2007).
- [22] D. Casarini, R.K. Harris, A.M. Kenwright. *J. Mol. Struct.*, **355**, 121 (1995).
- [23] M. John, J. Jose, B. Mathew. *J. Appl. Polym. Sci.*, **92**, 272 (2004).
- [24] F. Cotton, G. Wilkinson, C. Murillo, M. Bochmann. *Advanced Inorganic Chemistry*, 6th Edn, Wiley Interscience, New York (1999).
- [25] G.R. Nath, T. Radhakrishnan. *Synth. React. Inorg. Met.-Org. Nano Metal Chem.*, **35**, 491 (2005).
- [26] N. Nishat, S. Parveen, S. Dhyani, Asma. *J. Coord. Chem.*, **62**, 1091 (2009).
- [27] Z.S. Chohan, M. Arif, M. Sarfaraz. *Appl. Organomet. Chem.*, **21**, 294 (2007).
- [28] Z.S. Chohan, M. Arif, M.A. Akhtar, C.T. Supuran. *Bioinorg. Chem. Appl.*, **14**, 13 (2006).
- [29] L. Yu, Z. Tang, P. Yi, S. Liu, X. Li. *J. Coord. Chem.*, **62**, 903 (2009).
- [30] A.A. Abu-Hussen, W. Linert. *J. Coord. Chem.*, **62**, 1388 (2009).