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Synthesis, Characterization and Biological Activities of Organotin(IV) Complexes with Vitamin K_3-2-hydrazinopyridine: X-ray crystal structure of vitamin K_3-2-hydrazinopyridine [VHzP]

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ABSTRACT

Six new organotin(IV) complexes were synthesized by direct reaction of $RSnCl_3$ (R= Me, Bu and Ph) or R_2SnCl_2 (R= Me, Bu and Ph) and vitamin K_3-2-hydrazinopyridine [VHzP, (**1**)] in Schlenk round bottom flask under nitrogen atmosphere. All organotin(IV) complexes (**2-7**) have been characterized by elemental analyses, molar conductivity, UV-Visible, IR and ^{1}H NMR spectral studies. The organotin(IV) complexes (**2-7**) are non-electrolytic in nature. The crystal structure of ligand (**1**) has also been determined by X-ray crystallography diffraction analysis. The ligand (**1**) and its organotin(IV) complexes (**2-7**) have also been tested for their toxicity and anti-termitic potential and found to be moderately active against *Artemia salina* and *Coptotermes* sp.

Keywords: Vitamin K_3-2-hydrazinopyridine; organotin(IV) complexes; toxicity; anti-termitic.

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INTRODUCTION

Vitamin K_3 (Fig. 1) is a chemical compound which also known as menadione or 2-methyl-1,4-naphthoquinone. Its water soluble derivative, menadione sodium bisulfite has shown significant antitumor activity *in vitro* [1].

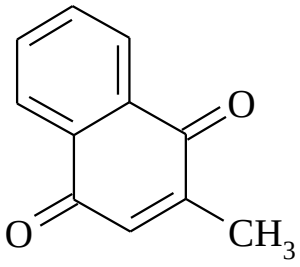

Fig. 1: Structure of 2-methyl-1,4-naphthoquinone (vitamin K_3)

Sodium bisulfate of vitamin K_3-thiosemicarbazone (Fig. 2) and its transition metal complexes have been synthesized by Li *et al.* [2]. From the research, the authors found that Ni(II) complex showed very good antibacterial activity against *Staphylococcus aureus* while Cu(II) complex showed good antibacterial activity against *Escherichia coli*. Preliminary *in-vitro* screening of vitamin K_3-thiosemicarbazone complexes with gold(I) showed that the gold(I) complex has significant anti-cancer activity against cisplatin-resistant cell line A2780cis [1].

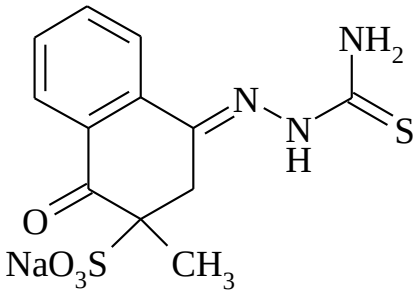

Fig. 2: Menadione sodium bisulfite thiosemicarbazone ligand

In recent years, Grgurić-Šipka *et al*. (2008) have conducted a research to study the cytotoxic activity of new organoruthenium(II) complexes; one of the ligand used, namely vitamin K_3-thiosemicarbazone [3]. The organoruthenium(II) complexes showed toxic effect and might have the capability to suppress autoimmune disease.

From the literature review, report on organotin(IV) complexes containing vitamin K_3 derivatives had not been found. Therefore, the authors are interested to synthesize, characterize and study the biological activities of organotin(IV) complexes of vitamin K_3 derivatives against *Artemia salina* and *Coptotermes* sp.

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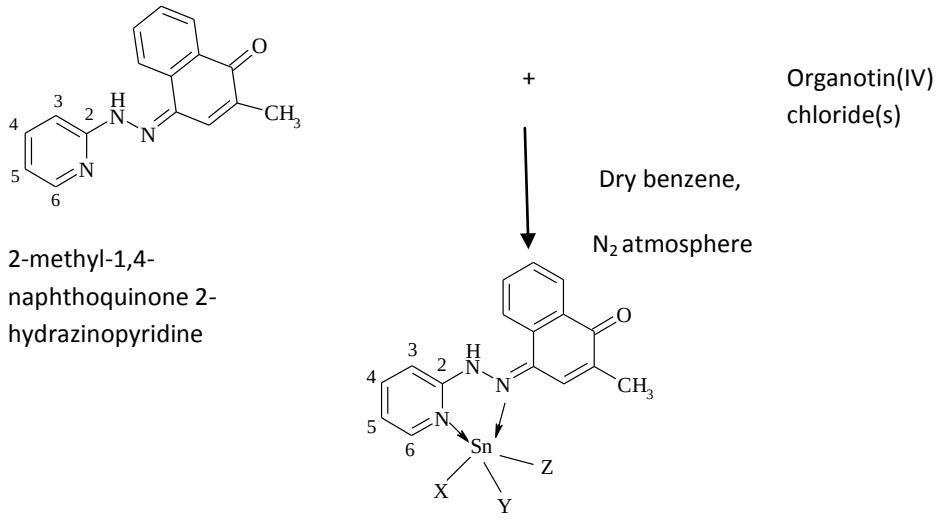
RESULTS AND DISCUSSION

The vitamin K_3-2-hydrazinopyridine [VHzP, (**1**)] was synthesized by the condensation reaction of vitamin K_3 with 2-hydrazinopyridine in the mixture of 95% ethanol and 5% acetic acid in 1:1 mole ratio. Six new organotin(IV) complexes (**2-7**) were synthesized by direct reaction of organotin(IV) chloride(s) with ligand (**1**) under nitrogen atmosphere. The organotin(IV) complexes were prepared as shown in Scheme 1. All the newly synthesized organotin(IV) complexes are coloured solids and soluble in DMSO, DMF and THF. The molar conductivity of the organotin(IV) complexes in DMF solvent are in the range 9.66-30.26 Ω^{-1} cm^2mol^{-1} showing that the complexes are non-electrolytic in nature [4]. The physical properties and elemental analyses of ligand (**1**) and its organotin(IV) complexes (**2-7**) are shown in Table 1. The UV-Visible, IR and ^{1}H NMR data are in the experimental section. The analytical data are in good agreement with the proposed geometry of the synthesized organotin(IV) complexes.



Scheme 1: The general synthesis of organotin(IV) complexes (**2-7**)

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Table 1: Physical and analytical data of ligand (**1**) and its organotin(IV) complexes (**2-7**)

Compounds	Colour	m.p (°C)	Found (Calc.)%		
			C	H	N
VHzP (**1**)	Dark red	196-198	72.96 (72.99)	4.95 (4.98)	16.00 (15.96)
[$MeSnCl_2$(VHzP)] (**2**)	Dark green	229-231	41.73 (41.76)	3.30 (3.28)	8.58 (8.60)
[$BuSnCl_2$(VHzP)] (**3**)	Light green	224-226	43.93 (43.91)	4.00 (4.03)	7.68 (7.69)
[$PhSnCl_2$(VHzP)] (**4**)	Dark green	276-278	46.55 (46.52)	3.15 (3.17)	7.37 (7.40)
[Me_2SnCl(VHzP)] (**5**)	Dark red	223-224	46.95 (46.96)	4.20 (4.22)	9.31 (9.33)
[Bu_2SnCl(VHzP)] (**6**)	Dark red	200-202	53.91 (53.93)	5.79 (5.81)	7.84 (7.86)
[Ph_2SnCl(VHzP)] (**7**)	Dark green	212-214	58.52 (58.54)	3.98 (4.00)	7.30 (7.32)

Electronic absorption spectra

Electronic spectra of the vitamin K_3-2-hydrazinopyridine [VHzP, (**1**)] ligand and its organotin(IV) complexes (**2-7**) were recorded in DMF (10^{-4} M) at room temperature ranged from 270 to 750 nm, respectively. Free ligand (**1**) exhibited two intense peaks at 289 and 440 nm which can be assigned to the π-π* transition of benzene and imino group, respectively [5]. UV-visible spectra of all the organotin(IV) complexes showed two intensive peaks at 290 nm and 450-520 nm, respectively. The peak at 290 nm was suggested to be the π-π* transition of benzene which did not participated in coordination while the peak appeared at 450-520 nm showed the existence of ligand-metal charge transfer (LMCT) which indicated the bonding of the ligand (**1**) to the tin(IV) ion [6].

Infrared Spectra

Several characteristic bands were observed in the free ligand (**1**) at 3168, 1638, 1599, 991 and 762 cm^{-1} which attributed to ν(N-H), ν(C=O), ν(C=N+C=C), ν(N-N) and ν(pyridine-N in plane), respectively.

Upon complexation, the stretching vibration of the azomethine nitrogen ν(C=N) in the complexes are 9-10 cm^{-1} higher, compared to the free ligand (**1**). This observation indicated the involvement of azomethine nitrogen in coordination with tin(IV) ion [7]. The ν(N-N) value also went to higher frequency in the complexes compared to the free ligand, which is also supported the complexation of azomethine nitrogen atom to the tin(IV) atom. In the spectrum of the free ligand (**1**), a very strong band at 762 cm^{-1} is attributed to the ν(pyridine in plane). This band is shifted to higher frequencies in the range of 765-773 cm^{-1} in the complexes (**2-7**). This observation supported that pyridyl ring nitrogen is coordinated to tin(IV). This may due to the electron density reduction after complexation. The ν(C=O) band is not much different from the free ligand, supported that no complexation occurred between tin(IV) and oxygen atom of the carbonyl group.

A new band was observed in all the organotin(IV) complexes in the range of 443-466 cm^{-1} for ν(Sn-N), indicating the coordination of the ligand to the tin(IV) *via* azomethine nitrogen atom and pyridine-N atoms. The appearance of the ν(Sn-C) band also proved that all the organic group still attached to the central tin(IV) atom during complexation reaction.

^{1}H NMR spectra

The ^{1}H NMR data of the free ligand (**1**) and its organotin(IV) complexes (**2-7**) are given in the experimental section. The free ligand (**1**) showed resonance signals at 11.80, 8.03, 7.52-7.71, 8.30-8.42 and 7.80-7.83, 7.01-7.04 and 2.11 ppm due to NH, py-H_6, py-H_3-H_5, aromatic ring, CH-aromatic and CH_3 protons, respectively.

The NH resonance signal for the complexes (**2-7**) shifted to the downfield region (12.03-15.04 ppm) compared to the NH resonance signal of the free ligand. The shifting of the resonance signal supported the complexation of NH-C=N nitrogen atom to the tin(IV) atom.

There are multiplet signals at 7.03-8.42 ppm in the ligand spectrum due to the overlapping of aromatic ring protons and pyridine ring protons, respectively. The position of the py-H_6 signal shifted to downfield by 8.04-8.76 ppm compared to the free ligand (**1**) in all the complexes (**2-7**), suggesting the involvement of pyridyl ring nitrogen atom in the coordination to tin(IV). Other signals for aromatic and pyridyl ring protons were also shifted to the downfield region but the signals could not be identified properly due to severe overlap between aromatic and pyridyl ring protons. A sharp signal at 7.03-7.24 ppm is observed in the complexes (**2-7**) due to the CH proton of aromatic ring, showing downfield shift in comparison to its original position of the free ligand, indicating the coordination of the CH-C=N nitrogen atom to tin(IV).

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The CH_3 resonance signal for complexes (**2-7**) shifted to the downfield region (2.12-2.25 ppm) compared to the CH_3 resonance signal of the free ligand also supported the complexation of CH-C=N nitrogen atom to the tin(IV) atom.

In complexes (**2**) and (**5**), sharp resonance signal appeared as singlet at 0.94 and 1.05 ppm, respectively. The signal attributed to methyl group attached to tin(IV) atom. Two resonance signals were appeared at 1.95 and 2.15 ppm for the complex (**3**) which assigned to CH_3 and $(-CH_2-)_3$ chain of the *n*-Bu group attached to tin(IV) atom. Multiplet in the region 1.30-1.60 ppm can be observed in the compound (**6**) spectrum corresponded to two butyl group that attached to tin(IV) core. Complexes (**4**) and (**7**) exhibited multiplet signals in the region of 7.23-7.78 ppm, were attributed to Sn-Ph protons.

*Crystal Structure of Vitamin K_3-2-hydrazinopyridine, [VHzP, (**1**)]*

The molecular structure along with atom numbering for [VHzP, (**1**)] ligand is shown in Fig. 3. The crystal data and structure refinement for the compound are summarized in Table 2. The bond distances and angles for the ligand (**1**) are given in Table 3.

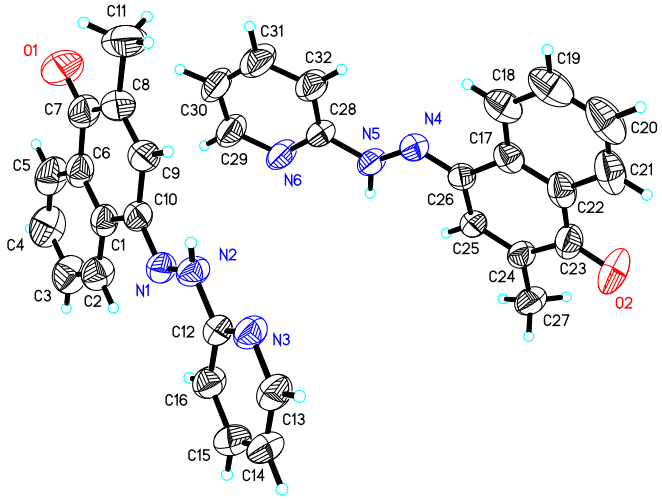

Fig. 3: Molecular structure of [VHzP, (**1**)]

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Table 2: Crystallographic data of ligand (**1**)

Empirical formula	$C_{16}H_{13}N_3O_2$
Formula weight	263.30
Temperature (K)	298(2) K
Wavelength (Å)	0.71073
Crystal system	Triclinic
Space group	$P\bar{1}$
Unit cell dimensions	
a (Å)	8.130 (2)
b (Å)	12.619(3)
c (Å)	13.500(4)
ß (^{o})	83.61
Volume ($Å^3$)	1322.6 (6)
Calculated density (mg/m^3)	1.322
Crystal size (mm)	0.50 x 0.50 x 0.33
Goodness-of-fit on F^2	1.020
Final R indices [I>2σ(I)]	R_1= 0.0515, wR_2= 0.1504
R indices (all data)	R_1= 0.0828, wR_2= 0.1504

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Table 3: Selected bond lengths (Å) and bond angles (°) for ligand (**1**)

Bond lengths (Å)			
O(2)-C(23)	1.2271(19)	C(29)-C(30)	1.356(2)
N(4)-C(26)	1.2989(17)	C(29)-H(29)	0.9300
N(4)-N(5)	1.3395(16)	C(30)-C(31)	1.373(3)
N(5)-C(28)	1.3841(18)	C(30)-H(30)	0.9300
N(5)-H(5A)	0.8767(9)	C(31)-C(32)	1.367(2)
N(6)-C(28)	1.3254(19)	C(31)-H(31)	0.9300
N(6)-C(29)	1.339(2)	C(32)-H(32)	0.9300
Bond angles (^{o})			
C(22)-C(17)-C(18)	118.91(15)	N(6)-C(28)-N(5)	114.29(12)
C(22)-C(17)-C(26)	119.56(14)	N(6)-C(28)-C(32)	122.73(14)
C(18)-C(17)-C(26)	121.52(14)	N(5)-C(28)-C(32)	122.98(14)
C(19)-C(18)-C(17)	120.24(19)	O(2)-C(23)-C(24)	120.53(17)
C(17)-C(18)-H(18)	119.9	O(2)-C(23)-C(22)	121.74(16)
N(4)-C(26)-C(25)	126.08(13)	N(6)-C(29)-C(30)	124.27(17)
N(4)-C(26)-C(17)	116.08(13)	N(6)-C(29)-H(29)	117.9

On the basis of the different spectral studies, it is suggested the bonding through >C=N and pyridyl ring nitrogen atoms to Sn(IV). Finally, octahedral geometries around the tin atom has been proposed as shown in Fig. 4.

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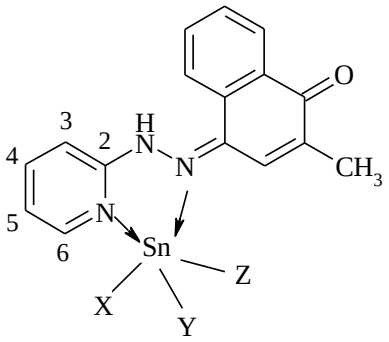

X= Cl; Y= Me, Bu or Ph; Z= Me, Bu, Ph or Cl

Fig. 4: Proposed structure of organotin(IV) complexes (**2-7**)

Biological activities

*Toxicity of ligand (**1**) and its organotin(IV) complexes (**2-7**)*

The toxicity of ligand (**1**) and its organotin(IV) complexes are shown in Table 4. Results showed that compound (**2**) has the highest LC_{50} value. Among all the compounds, [Ph_2SnCl(VHzP)] (**7**) has the highest toxicity towards *Artemia salina* with LC_{50} of 66.07 ppm (Table 4 and Fig. 5).

The result showed that the toxicity activity is depend on the R group (alkyl or phenyl group) present in the organotin(IV) complexes. Compounds with the bulky R group showed higher toxicity against *Artemia salina* compared to the smaller size of R group. This may due to the ability of the bulky group to dissociate to form ionic compound, thus increase the permeability of the compounds into cells [8].

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Table 4: The LC_{50} of ligand (1) and its complexes (**2-7**)

Complexes		LC_{50} (ppm)
VHzP	(**1**)	107.15
$[MeSnCl_2(VHzP)]$	(**2**)	331.13
$[BuSnCl_2(VHzP)]$	(**3**)	302.00
$[PhSnCl_2(VHzP)]$	(**4**)	109.65
$[Me_2SnCl(VHzP)]$	(**5**)	251.19
$[Bu_2SnCl(VHzP)]$	(**6**)	89.13
$[Ph_2SnCl(VHzP)]$	(**7**)	66.07

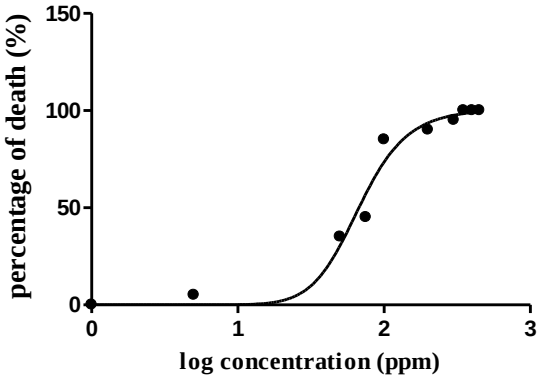

Fig. 5: Toxicity test of $[Ph_2SnCl(VHzP)]$ (**7**)

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Anti-termitic test of ligand (1) and its organotin(IV) complexes ***(2-7)***

From the anti-termitic data, concentration affects the mortality rate (Fig. 6). Among all the compounds, [Ph_2SnCl(VHzP)] (**7**) has good termiticidal activity because within 5-7 days, it can kill all the termites tested. This results also might due to the effect of R group attached to the organotin(IV) complexes. Complexes with larger R group attached to the tin(IV) atom showed good activity compared to the smaller size R group.

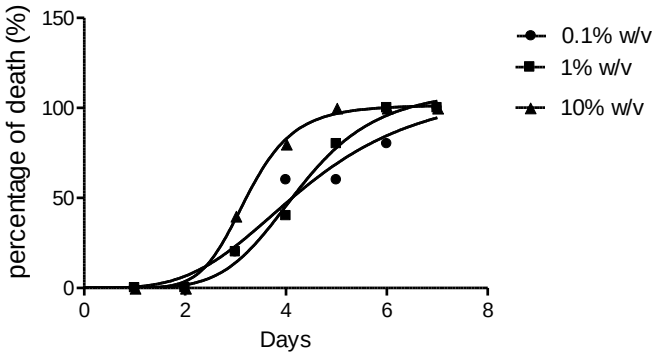

Fig. 6: Anti-termitic test of [Ph_2SnCl(VHzP)] (**7**)

Experimental methods

*Preparation of Vitamin K_3-2-hydrazinopyridine ligand [VHzP, (**1**)]*

A mixture of vitamin K_3 (0.86 g, 0.005 mole) which was dissolved in 5% w/w acetic acid and 2-hydrazinopyridine (0.55 g, 0.005 mole) dissolved in 95% ethanol were heated under reflux for 4-6 hours. The reaction mixture was allowed to cool to room temperature for one hour. The reddish precipitate was filtered off and washed several times by using absolute ethanol. The reddish solid obtained was purified by recrystallization from hot absolute ethanol and dried in vacou over P_2O_5. Single crystals suitable for X-ray diffraction studies were obtained by slow evaporation of chloroform solution at room temperature. Yield: 0.90 g, 63.8%. M.p: 196-198 °C. UV-Visible (DMF) λ_{max}(nm): 289, 440. IR (ν_{max} cm^{-1}) (KBr): 3168 (NH), 1638 (C=O), 1599 (C=N+C=C), 991 (N-N), 762 (pyridine in plane). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 11.80 (s, 1H, NH), 8.03 (d, 1H, py-H_6), 7.52-7.71 (m, 3H, py-H_3- H_5), 8.30-8.42 and 7.80-7.83 (m, 4H, aromatic-H) 7.01-7.04 (q, 1H, CH-aromatic), 2.11 (s, 3H, CH_3) ppm.

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Preparation of organotin(IV) complexes

Synthesis of [$MeSnCl_2$(VHzP)] ***(2)***

Ligand (**1**) (0.526 g, 0.002 mole) was added in absolute benzene (20 mL) and heated till all the ligand dissolved in Schlenk round bottom flask. Methyltin(IV) chloride (0.478 g, 0.002 mole) which was dissolved readily in benzene was added dropwise into the ligand solution. The resulting mixture was refluxed continuously for 4 hours and cooled to room temperature. The precipitate was filtered off and dark green powder was obtained and dried in vacuo over silica gel overnight. Yield: 0.65 g, 67%. M.p: 229-231 °C. Molar conductance (DMF) Ω^{-1} cm^2 mol^{-1}: 21.8. UV-Visible (DMF) λ_{max}(nm): 289, 444. IR (ν_{max} cm^{-1}) (KBr): 3187(NH), 1639(C=O), 1608 (C=N+C=C), 1005 (N-N), 767 (pyridine in plane), 543 (Sn-C), 466 (Sn-N). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 13.67 (s, 1H, NH), 8.66 (d, 1H, py-H_6), 8.04-8.06 and 8.32-8.40 (m, 4H, aromatic-H), 7.59-8.06 (m, 3H, py-H_3-H_5), 7.15-7.19 (q, 1H, CH-aromatic), 2.15 (s, 3H, CH_3), 0.94 (s, 3H, Sn-CH_3) ppm.

The other complexes (**3-7**) were synthesized by using the same procedure as [$MeSnCl_2$(VHzP)] (**2**) with appropriate organotin(IV) chloride(s).

*Synthesis of [$BuSnCl_2$(VHzP)] (**3**)*

Yield: 0.839 g, 77%. M.p: 276-278 °C Molar conductance (DMF) Ω^{-1} cm^2 mol^{-1}: 30.26. UV-Visible (DMF) λ_{max}(nm): 289, 454. IR (ν_{max} cm^{-1}) (KBr): 3219 (NH), 1639 (C=O), 1608 (C=N+C=C), 1001 (N-N), 765 (pyridine in plane), 544 (Sn-C), 460 (Sn-N). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 12.03 (s, 1H, NH), 8.75 (d, 1H, py-H_6), 8.33-8.50 and 8.03-8.17 (m, 4H, aromatic-H), 7.61-7.86 (m, 3H, py-H_3-H_5), 7.22-7.24 (q, 1H, CH-aromatic), 2.15 (s, 3H, CH_3), 1.95 - 2.08 (m, 9H, Sn-*n*Bu) ppm.

*Synthesis of [$PhSnCl_2$(VHzP)] (**4**)*

Yield: 0.735 g, 65%. M.p: 276-278 °C. Molar conductance (DMF) Ω^{-1} cm^2 mol^{-1}: 14.65. UV-Visible (DMF) λ_{max}(nm): 289, 448. IR (ν_{max} cm^{-1}) (KBr): 3239 (NH), 1639 (C=O), 1609 (C=N+C=C), 1002 (N-N), 773 (pyridine in plane), 543 (Sn-C), 453 (Sn-N). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 12.30 (s, 1H, NH), 8.76 (d, 1H, py-H_6), 7.62-8.39 (m, overlapping of aromatic-H, pyridine-H and phenyl ring protons of phenyl ring attached to the center tin(IV) atom, aromatic-H),7.02-7.03 (q, 1H, CH-aromatic), 2.15 (s, 3H, CH_3) ppm.

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*Synthesis of [$Me_2SnCl(VHzP)$] (**5**)*

Yield: 0.848 g, 88%. M.p: 223-225 °C. Molar conductance (DMF) Ω^{-1} cm^2 mol^{-1}: 29.1. UV-Visible (DMF) λ_{max}(nm): 294, 521. IR (ν_{max} cm^{-1}) (KBr): 3105 (NH), 1640 (C=O), 1608 (C=N+C=C), 996 (N-N), 767 (pyridine in plane), 544 (Sn-C), 456 (Sn-N). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 15.00 (s, 1H, NH), 8.20 (d, 1H, py-H_6), 7.87-7.92 and 8.31-8.34 (m, 4H, aromatic-H), 7.50-7.80 (m, 3H, py-H_3- H_5), 7.12-7.14 (q, 4H, CH-aromatic), 2.25 (s, 3H, CH_3), 1.05 (s, 3H, Sn-CH_3) ppm.

*Synthesis of [$Bu_2SnCl(VHzP)$] (**6**)*

Yield: 0.736 g, 65%. Mp: 200-202 °C. Molar conductance (DMF) Ω^{-1} cm^2 mol^{-1}: 9.66. UV-Visible (DMF) λ_{max}(nm): 296, 521. IR (ν_{max} cm^{-1}) (KBr): 3059 (NH), 1639 (C=O), 1608(C=N+ C=C), 997 (N-N), 766 (pyridine in plane), 522 (Sn-C), 443 (Sn-N). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 15.04 (s, 1H, NH), 8.05 (d,1H, py-H_6), 8.30-8.44 and 7.80-7.84 (m, 4H, aromatic-H), 7.53-7.72 (m, 3H, py-H_3-H_5), 7.02-7.04 (q, 1H, CH-aromatic), 2.12 (s, 3H, CH_3), 1.51-1.66 (*m*, 4H, Sn-$CH_2CH_2CH_2CH_3$), 1.30-1.31 (*m*, 2H, Sn-$CH_2CH_2CH_2CH_3$), 0.87-0.89 (*t*, 3H, Sn-$CH_2CH_2CH_2CH_3$) ppm.

*Synthesis of [$Ph_2SnCl(VHzP)$] (**7**)*

Yield: 0.667 g, 55%. M.p: 212-214 °C. Molar conductance (DMF) Ω^{-1} cm^2 mol^{-1}: 9.71. UV-Visible (DMF) λ_{max}(nm): 291, 444. IR (ν_{max} cm^{-1}) (KBr): 3149 (NH), 1639 (C=O), 1604 (C=N +C=C), 996 (N-N), 767 (pyridine in plane), 544 (Sn-C), 460 (Sn-N). ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 12.03 (s, 1H, NH), 8.31 (d, 1H, py-H_6), 7.36-7.80 (m, overlapping of aromatic-H, pyridine-H and phenyl ring protons), 7.03 (q, 1H, CH-aromatic), 2.12 (s, 3H, CH_3) ppm.

Biological activities

Artemia toxicity

Brine shrimp lethality is a preliminary test for screening the antitumor potential of organotin(IV) complexes.

The brine shrimp bioassay of ligand (**1**) and the organotin(IV) complexes (**2-7**) were done generally followed the method of McLaughlin (1998) with some modifications [9]. The sea water was collected from the coastal area in Pantai Puteri, Kuching, Sarawak and filtered with Whatman filter paper grade 1, autoclaved and adjusted to 20 psu. A pinch of brine shrimp eggs were hatched in 100 mL treated sea water and the process was carried out at ambient temperature for 24 hours. Aeration and light was provided along the hatching process.

A stock solution with concentration 5000 ppm of the ligand (**1**) and its organotin(IV) complexes (**2-7**) were prepared using ethanol as solvent. The stock solutions were then diluted into different concentrations which were 1, 2, 5, 50, 75, 100, 200, 300, 350, 400 and 450 ppm, and were put into small plastic mugs up to 5 mL each. Ethanol used as negative control for this toxicity test.

After 24 hours, the hatched nauplii were transferred into each filled mug. The mortality of the shrimps were observed after the next 24 hours. The mortality were computed and corrected for the natural death observed in the negative control using Abbott's formula [10].

$$p = \frac{p_i - C}{l - C}$$

Where p_i denotes the observed mortality in the sample solutions; C is the natural mortality observed from the negative control; l is the number of individual in each replicates. The percentage of mortalities could be calculated by multiply p with 100%. All the results obtained in percentage were plotted in allosteric sigmoidal graph by using GraphPad Prism and the LC_{50} could be obtained through the graph.

Anti-termitic test

Termites species which identified as *Coptotermes* sp. was collected from UNIMAS East Campus. The termite colony along with the wood pieces were brought back to laboratory and placed in a container under ambient temperature and condition. Water was sprinkled once a while to cultivate humid condition for the termite.

The termiticidal activity was done according to Sakasegawa (2003) with some modifications [11]. Filter papers (Advantec No. 1) was cut in 25 mm diameter size and placed in small, covered plastic container. The paper was treated with ligand (**1**) and complexes (**2-7**) solution which were prepared in 0.1, 1 and 10% w/v concentration using ethanol as solvent and let to dry. Filter papers treated with only ethanol were served as negative control and the test was carried out with three replicates each. Six termites which consist of one soldier and five workers were added to all containers. The mortality of workers was observed for every 24 hours within 14 days. The mortalities of termites were corrected using Abbot's formula [10].

X-ray crystallography

The measurement were performed at 273(2) or 298(2) K on Siemen SMART CCD diffraction using graphite-monochromated Mo-Kα radiation (λ= 0.71073 Å). Orientation matrix and unit cell parameters were obtained from the setting angles of 25-centeres reflection. The structure was solved using direct method and refined by full-matrix least-square method on F^2 using the SHELXTL software package [12]. All non-H atoms were anisotropically refined. The

hydrogen atoms were located in a difference Fourier map and then were fixed geometrically and treated as riding atom on the parent C atoms, with C-H distances = 0.97 Å.

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REFERENCES

[1] Casas JS, Castellano EE, Couce, MD, Ellena, J, Sánchez, A, Sordo, J, Taboada C. J Inorg Biochem 2006; 100: 1858-1860.
[2] Li Q, Tang H, Wang M, Wang L, Xia, C. J Inorg Biochem 1999; 78: 167-174.
[3] Grgurić-Šipka S, Alshtewi MAM, Jeremić, D, Kaluderovic GN, Gómez Ruiz, S, Žižak Ž, Juranić Z, Sabo TJ. J Serb Chem Soc 2008; 73 (6): 619-630.
[4] Geary WG. Coord Chem Rev 1971; 7: 81-122.
[5] Affan MA, Liew YZ, Ahmad FB, Shamsuddin MB, Yamin BM. Ind J Chem 2007; 46A: 1063-1068.
[6] Sharaby CM. Spectrochim Act A 2007; 66: 1271-1278.
[7] Abou-Melha KS, Faruk H. J Iran Chem Soc 2007; 5(1): 122-134.
[8] Affan MA, Fasihuddin BA, Liew YZ, Foo SW, Ismail J. J Sci Res 2009; 1(2):306-316.
[9] McLaughlin JL, Rogers LL. Drug Information Journal 1998; 32:513-524.
[10] Hartl M, Humpf HU. Food Chem Toxi 2000; 38: 1097-1102.
[11] Sakasegawa M, Hori K, Yatagai M. J Wood Sci 2003; 49: 181-187.
[12] Sheldrick GM. SHELXTL V5.1, Software Reference Manual, Bruker AXS; Madison Inc WI, USA. 1997.