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Synthesis and characterization of some dibutylbis{5-[(*E*)-2-(aryl)-1-diazenyl]-2-hydroxybenzoato}tin(IV) compounds. Toxicity studies of di- and tri-organotin complexes on the second instar of *Aedes aegypti* mosquito larvae

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The preparation and spectroscopic characterization of some complexes of the type $Bu_2Sn(LH)_2$ (*LH* = 5-[(*E*)-2-(aryl)-1-diazenyl]-2-hydroxybenzoate) are reported. On the basis of spectroscopic evidence (^1H, ^{13}C, ^{119}Sn NMR, IR and ^{119m}Sn Mössbauer) the compounds were judged to adopt the usual dicarboxylato structural type with a skew trapezoidal arrangement. This was further confirmed by X-ray crystallography in the case of $Bu_2Sn(L^5H)_2$ (L^5H = 5-[(*E*)-2-(4-chlorophenyl)-1-diazenyl]-2-hydroxybenzoate). Toxicity studies of the di- and tri-organotin compounds on the second larval instar of *Aedes aegypti* mosquito larvae are reported. Copyright © 2003 John Wiley & Sons, Ltd.

KEYWORDS: organotin; carboxylates; 5-[(*E*)-2-(aryl)-1-diazenyl]-2-hydroxybenzoic acids; NMR; Mössbauer; X-ray; toxicity; *Aedes aegypti* mosquito larvae

INTRODUCTION

Organotin carboxylates form an important series of compounds that find wide applications in chemistry and biology.[1–6] Diorganotin dicarboxylate compounds, in particular, are widely used as homogeneous catalysts for polyurethane and RTV silicone polymerization and for trans esterification reactions.[7,8] Owing to these applications, the structure and mechanisms of action of these diorganotin dicarboxylates remain a matter of great interest.[8–11] In recent years, several such compounds have shown potential as anti-neoplastic agents.[12–14]

As a further contribution to this active field, we report herein the preparation and the spectroscopic and crystal structural characterization of some di-*n*-butylbis (5-[(*E*)-2-(aryl)-1-diazenyl]-2-hydroxybenzoato)tin(IV) compounds (see Fig. 1 for the ligand framework), which have a monomeric hexa-coordinated skew-trapezoidal bipyramidal structure. We also report the toxicity studies of these organotin(IV) complexes on the second larval instar of *Aedes aegypti* mosquito.

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EXPERIMENTAL

Materials

Di-*n*-butyltin oxide (Fluka) was used as received. The ligands (L^1HH'–L^6HH') were prepared as described in earlier

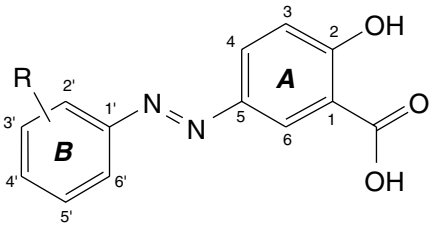

Figure 1. Ligands used in the present work. (Abbreviations: L^1HH': R = H; L^2HH': R = 2′-CH_3; L^3HH': R = 3′-CH_3; L^4HH': R = 4′-CH_3; L^5HH': R = 4′-Cl_3; L^6HH': R = 4′-NO_2, where H and H′ represent hydroxyl and carboxyl protons respectively.)

reports.[15–17] The solvents used in the reactions were of AR grade and dried using standard procedures, and the 95% ethanol was reagent grade.

Measurements

Carbon, hydrogen and nitrogen analyses were performed with a Perkin Elmer 2400 series II instrument. IR spectra in the range 4000–400 cm^{-1} were obtained on a BOMEM DA-8 FT-IR spectrophotometer with samples run as KBr discs. The ^1H and ^{13}C NMR spectra of the ligands were acquired on either a Varian Gemini 2000 spectrometer (operating at 300.13 MHz and 75.47 MHz respectively) or a Varian Inova spectrometer (operating at 599.91 MHz and 150.85 MHz respectively). For the organotin compounds, the ^1H, ^{13}C and ^{119}Sn NMR spectra were recorded on a Bruker ACF 300 spectrometer and measured at 300.13 MHz, 75.47 MHz and 111.92 MHz respectively. The ^1H, ^{13}C and ^{119}Sn chemical shifts were referred to Me_4Si set at 0.00 ppm, $CDCl_3$ set at 77.0 ppm and tetramethyltin set at 0.00 ppm respectively. ^{119}Sn Mössbauer spectra of the complexes in the solid state were recorded on an Elscient–Laben spectrometer equipped with an AERE cryostat at liquid-nitrogen temperature. The $Ca^{119m}SnO_3$ Mössbauer source (10 mCi; Radiochemical Centre, Amersham, UK) moved with constant acceleration and a triangular waveform. The velocity calibration was made using a ^{57}Co Mössbauer source (10 mCi). An iron foil enriched to 95% in ^{57}Fe (DuPont Pharma Italia, Florence, Italy), was used as the absorber.

X-ray crystallography

The intensity data for a red–orange block-shaped crystal of complex **5** was measured at 293 K on a Rigaku AFC6S diffractometer fitted with graphite monochromatized Mo Kα radiation (λ = 0.710 73 Å) using the omega scan technique. Empirical corrections for the effects of absorption were made from psi-scan curves.[18] All hydrogen atoms were given calculated positions. Neutral atom scattering factors were taken from the literature.[19] The structure was solved by direct

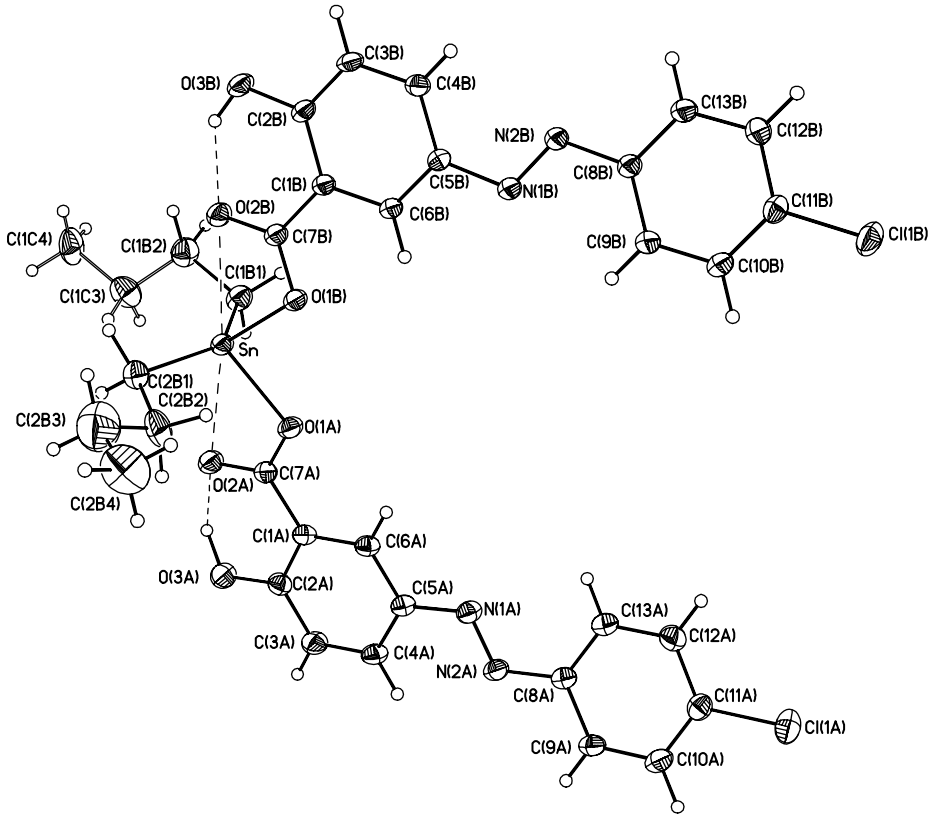

Figure 2. Molecular structure of $[^nBu_2Sn\{O_2CC_6H_4(OH\text{-}2)(N{=}NC_6H_4(Cl\text{-}4)\text{-}5)\}_2]$ (**5**).

methods and all computations were performed using the teXsan system of crystal structure solving programs.[20] All refinements were performed by full-matrix least-squares on F^2. The data were corrected for Lorentz and polarization effects. Crystallographic data, collection and refinement details are given in Table 5. Selected bond lengths and bond angles are listed in Table 6. The molecular structure, showing the crystallographic numbering scheme employed, is shown in Fig. 2, and the skew-trapezoidal configuration around the tin atom and the hydrogen bonding are more clearly illustrated in Fig. 3.

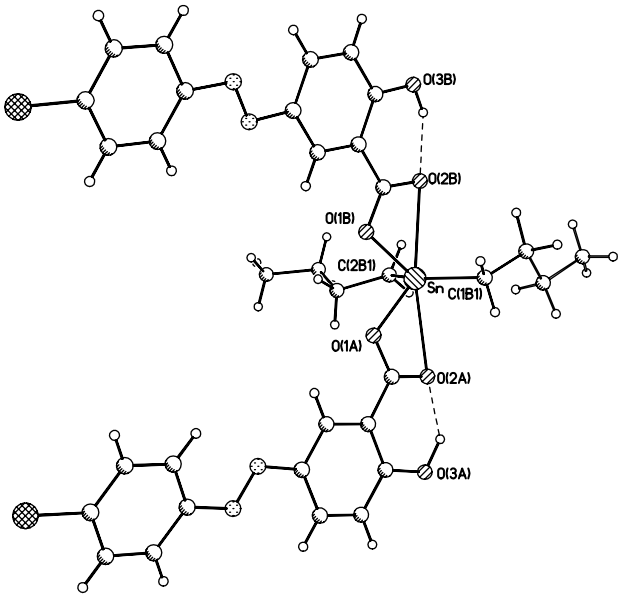

Figure 3. Perspective drawns of complex **5** showing hydrogen bonding.

Syntheses

Preparation of dibutylbis{5-[(E)-2-(aryl)-1-diazenyl]-2-hydroxybenzoato}tin(IV)

A typical procedure is described below, using $Bu_2Sn(L^5H)_2$ (**5**) as an example. Bu_2SnO (0.23 g, 0.90 mmol) and L^5HH' (0.50 g, 1.81 mmol) in 50 ml anhydrous benzene were refluxed for 3 h in a flask equipped with a Dean–Stark water separator and a water-cooled condenser. The solvent was gradually removed by a rotary evaporator until the red–orange solid product was obtained. The crude product was triturated, washed thoroughly with hexane and dried. The residue was then extracted into a large volume of hot chloroform and filtered. The filtrate was concentrated to half of the initial solvent volume and then methanol was added (chloroform : methanol; 4 : 1 v/v). Red–orange crystals were formed on standing at room temperature. The characterization data for the complexes are given in Table 1.

The other diorganotin complexes of 5-[(*E*)-2-(aryl)-1-diazenyl]-2-hydroxybenzoic acids were prepared analogously using Bu_2SnO and the appropriate ligand LHH′.

Biological tests

Preparation of the organotin stock solution

Stock solutions of the organotin compounds were prepared by dissolving the organotin in one of 95% ethanol, dimethyl sulfoxide (DMSO), or acetone, depending on the solubility of the compound, at concentrations between 400 and 600 ppm. The dissolution of the organotin compounds in the organic media was to facilitate the dispersion of the compounds in water.

Hatching of the mosquito eggs

Dried *Ae. aegypti* mosquito eggs were obtained from the laboratory of Dr Daniel Strickman, Entomology Department

Table 1. The physical and analytical data for the dibutyltin(IV) complexes

				Elemental analysis, found (calc.) (%)		
Complex[a]	Colour	Yield(%)	M.p. (°C)	C	H	N
1 $Bu_2Sn(L^1H)_2$	Orange	60	152–154	57.00 (57.09)	5.00 (5.07)	7.80 (7.83)
2 $Bu_2Sn(L^2H)_2$	Dark red	52	120–122	57.99 (58.16)	5.40 (5.42)	7.34 (7.54)
3 $Bu_2Sn(L^3H)_2$	Orange	93	123–125	58.29 (58.16)	5.50 (5.42)	7.63 (7.54)
4 $Bu_2Sn(L^4H)_2$	Yellow	49	174–176	58.39 (58.16)	5.41 (5.43)	7.44 (7.54)
5 $Bu_2Sn(L^5H)_2$	Red–orange	79	210–212	52.18 (52.07)	4.33 (4.37)	7.04 (7.14)
6 $Bu_2Sn(L^6H)_2$	Orange	82	219–220	50.83 (50.71)	4.38 (4.26)	10.40 (10.44)

[a] The complexes **8** Ph_3SnL^1H, **9** Ph_3SnL^2H, **10** Ph_3SnL^3H, **11** Ph_3SnL^5H, **12** Bu_3SnL^2H, **13** Bu_3SnL^4H, **14** Bu_3SnL^5H and **15** Bu_3SnL^6H are included elsewhere for convenience of discussion; for synthetic and structural details see Ref. 16.

at the Walter Reed Army Institute of Research, Washington, DC. Approximately 0.01 g of the *Ae. aegypti* eggs were placed in a stainless steel tray (30 cm × 20 cm × 5 cm) containing approximately 1 l of deionized water. After 24 h, finely ground-up dog food (0.2–0.5 g) was added as the nutrient. The container was kept at 25–29 °C with a humidity of 80%. The second instar stage was attained after 2–3 days.

Larval toxicity studies

The toxicity studies were performed in $100 \times 15\ mm^2$ disposable Petri dishes using ten *Ae. aegypti* larvae in the second instar stage. The *Ae. aegypti* larvae were transferred into the Petri dishes using a 100 µl micro-pipetter. An additional 15 ml of water was added. Aliquots of the organotin solution and deionized water were then added to the Petri dish containing the larvae to give the desired concentration of organotins. The total assay volume in each case was 20 ml. Both positive and negative controls were used in the assay. Each assay was done in triplicate. The larvae were exposed to the organotin compounds for 24 h and the mortality rates for the mosquito larvae were determined by visual counting. Mosquito larvae that showed a slight reflex to disturbance were considered alive. Probit analyses[21] were used to determine the LC_{50} values (concentration at which the test compounds killed 50% of the tested organisms).

Molecular modeling and quantitative structure–activity relationships

The Chem 3D program from Cambridge Soft Corp., Cambridge, MA, was used to model the structures of the compounds. The QSARIS program from SciVision, Burlington, MA, was used to generate the quantitative structure–activity relationships (QSARs).

RESULTS AND DISCUSSION

Treatment of Bu_2SnO with LHH′ (1:2) in benzene yielded the dibutylbis{5-[(*E*)-2-(aryl)-1-diazenyl]-2-hydroxybenzoato}tin(IV) complexes. A typical reaction is described in the Experimental section, and the physical and analytical data for the complexes are summarized in Table 1. The complexes are soluble in chloroform, dichloromethane, methanol, ethanol and DMSO.

In our earlier communications[15–17,22] we have reported that the ligands can coordinate to a tin atom via oxygen atom(s) of the carboxylate group in mono- or bi-dentate fashion depending on the nature of the Sn–R groups. On this basis, we discuss the spectroscopic results in relation to the structure of the complexes.

The IR spectra of the complexes display two bands at around 1625 cm^{-1} and 1415 cm^{-1} that are assigned to the ν_{asym}(OCO) and ν_{sym}(OCO) stretching vibrations respectively, in accord with the earlier reports.[15,16] The separation $\Delta\nu$ [ν_{asym}(OCO)−ν_{sym}(OCO)] is greater than 200 cm^{-1}, implying the presence of bidentate, chelating carboxylate groups[23] (see X-ray discussion).

The ^1H and ^{13}C NMR data of the ligands are reported in Refs 15 and 16. The signals were assigned by the use of COSY, HSQC and CIGAR-HMBC[24] experiments using gradient coherence selection. The conclusions drawn from the ligand assignments have been subsequently extrapolated to the complexes owing to the similarity in the data. The ^1H and ^{13}C chemical shift assignments (Tables 2 and 3 respectively) of the butyltin moiety are readily deducible from the multiplicity patterns and resonance intensities. The ^1H NMR integration values were completely consistent with the formulation of the products. The ^{119}Sn NMR spectra for the bis complexes in $CDCl_3$ solution (Table 3) displayed a single resonance in the range −113 to −120 ppm. The values are consistent with those reported for the diorganotin diacetates and dibenzoates,[25–27] i.e. the tin atom is six-coordinated with two bis-chelated carboxylate ligands.

The Mössbauer spectra of the other dibutyltin complexes have been recorded (Table 4) in order to obtain further insight into the structure in the solid state in the absence of crystallographic data.[28] The quadrupole splitting (QS, Δ) values for the complexes are around 3.50 mm s^{-1}, which is

Table 2. ^1H chemical shifts (ppm)[a] for the dibutyltin(IV) complexes

Complex	Ligand skeleton[b]										Sn–Bu skeleton[c]			
	H-3	H-4	H-6	H-2′	H-3′	H-4′	H-5′	H-6′	R	OH	1*	2*	3*	4*
1	7.13	8.15	8.67	7.93	7.53	7.49	7.53	7.93	—	11.0	1.94	1.79	1.45	0.93
2	7.11	8.11	8.66	—	7.32	7.32	7.26	7.65	2.73	11.0	1.95	1.80	1.45	0.95
3	7.12	8.13	8.66	7.73	—	7.27	7.40	7.73	2.45	10.9	1.94	1.80	1.45	0.93
4	7.12	8.12	8.63	7.32	7.84	—	7.84	7.32	2.45	10.9	1.94	1.78	1.44	0.93
5	7.06	7.99	8.44	7.59	7.85	—	7.85	7.59	—	nd	1.62	1.62	1.33	0.84
6	7.17	8.18	8.73	8.04	8.40	—	8.40	8.04	—	11.1	1.96	1.79	1.45	0.94

[a] In $CDCl_3$ except for complex **5**, which is in DMSO-d_6.
[b] Refer to Fig. 1 for numbering scheme. OH signal is broad singlet in all the cases except in complex **5**, which is not detected (nd) owing to the exchange by the presence of water in the DMSO-d_6.
[c] Numbering scheme for Sn–Bu skeleton: $\overset{4^*}{CH_3}-\overset{3^*}{CH_2}-\overset{2^*}{CH_2}-\overset{1^*}{CH_2}-Sn$.

Table 3. ^{13}C and ^{119}Sn NMR data (ppm)[a] for the dibutyltin(IV) complexes

Complex	Ligand skeleton														Sn–R skeleton				^{119}Sn NMR data
	C-1	C-2	C-3	C-4	C-5	C-6	C-1′	C-2′	C-3′	C-4′	C-5′	C-6′	R	CO_2	1*	2*	3*	4*	
1	112.7	163.8	118.4	128.5	145.6	122.8	152.6	122.8	129.1	130.7	129.1	122.8	—	177.3	26.6	26.5	26.6	13.4	−114.6
2	112.7	163.7	118.3	129.6	146.0	126.4	150.6	137.8	131.2	130.6	128.1	115.5	17.6	177.2	26.5	26.3	26.5	13.5	−113.8
3	112.7	163.4	118.3	128.9	145.6	128.4	152.7	122.8	138.9	131.5	129.1	120.5	21.4	177.2	26.6	26.3	26.6	13.5	−119.7
4	112.7	163.7	118.3	129.1	145.6	128.2	150.7	122.8	129.8	141.3	129.8	122.8	21.5	177.0	26.6	26.4	26.5	13.4	−116.0
5	113.8	162.8	116.2	125.9	142.3	125.2	148.7	121.9	127.4	133.4	127.4	121.9	—	170.8	25.0	23.9	25.0	11.7	—[b]
6	112.9	165.0	118.8	124.8	148.6	124.8	155.7	123.3	130.0	145.5	129.0	123.3	—	177.1	26.7	26.4	26.6	13.5	−114.1

[a] Refer to Fig. 1 and Table 2 for numbering schemes.
[b] Not recorded owing to the solubility problem in $CDCl_3$.

Table 4. ^{119}Sn Mössbauer parameters (mm s^{-1}) for some representative dibutyltin(IV) complexes[a]

Complex	δ	Δ	Γ_1	Γ_2	C–Sn–C (°)
2	1.49	3.56	0.79	0.79	147
4	1.48	3.49	0.82	0.88	144
5	1.43	3.43	0.88	0.88	144
6	1.45	3.45	0.92	0.90	144

[a] Γ_1 and Γ_2: line widths.

indicative of an octahedral configuration of the tin atom with *trans* alkyl groups.[29] This conclusion is in excellent agreement with the structures determined by X-ray crystallography (see below). The isomer shift (IS, δ) values are in the range 1.43–1.49 mm s^{-1}, which is typical for quadrivalent organotin derivatives, and the full width at half maximum ($\Gamma\pm$) of these resonance absorptions is in the range 0.80–1.00 mm s^{-1}, further suggesting the presence of a single tin centre in the complexes.[29] All the complexes display similar Mössbauer data, indicating that they are isostructural. Using the Parish relationship between QS parameter value and C–Sn–C bond angle,[30] the latter have been calculated. The calculated angles are 144° and 147° (Table 4), indicating a distortion from the ideal *trans*-R_2Sn octahedral structure.

The results of the X-ray crystallographic study on compound **5** are fully consistent with the other spectroscopic evidence presented above (Table 5). The compound has a monomeric six-coordinate structure. The carboxylate groups on the ligands act as bidentate chelating agents, giving a basal plane around the tin of four asymmetrically coordinated oxygen atoms, whereas the butyl groups are in the axial positions, but pinned back somewhat to produce a skew-trapezoidal bipyramidal structure. Such a configuration is commonly encountered with diorganotin carboxylates.[31] Compounds of this type exhibiting this structural motif have Sn–O(1) values $\leqslant$ 2.2 Å and Sn–O(2) values $\geqslant$ 2.5 Å. The corresponding bond lengths for compound **5** (Table 6) are 2.081(2) Å (Sn–O1A), 2.083(2) Å (Sn–O1B) and 2.706(2) Å (Sn–O2A), 2.638(2) Å (Sn–O2B). In addition, these compounds have the two organo substituents disposed over the longer Sn–O vectors with C–Sn–C angles in the range 130–150°. In compound **5**, the C–Sn–C angle is 139.45(13)°. It is noteworthy

Table 5. Crystallographic data for **5**

Empirical formula	$C_{34}H_{34}N_4O_6SnCl_2$
Formula weight	784.24
Crystal size (mm^3)	0.13 × 0.12 × 0.30
Colour and morphology	Red–orange, block
Crystal system	Triclinic
Space group	$P\bar{1}$
a (Å)	9.770(2)
b (Å)	12.087(2)
c (Å)	15.323(3)
α (°)	93.388(12)
β (°)	99.06(2)
γ (°)	104.070(12)
V ($Å^3$)	1724.3(5)
Z	2
D_{calc} (g cm^{-3})	1.511
Temperature (K)	293(2)
Absorption coefficient (mm^{-1}), $F(000)$	0.946, 796
θ range for data collection (°)	2.3–27.5
Reflections collected	8276
Independent reflections	7827 (R_{int} = 0.0166)
Absorption correction	None
Refinement method	Full-matrix least-squares on F^2
Data/restraints/parameters	7827/78/499
Goodness-of-fit on F^2	1.03
Final R indices ($I > 2\sigma(I)$)	R_1 = 0.039, wR_2 = 0.0952
R indices (all data)	R_1 = 0.054, wR_2 = 0.105
Largest diff. peak and hole (e/$Å^3$)	0.56 and −0.44

Table 6. Selected bond lengths (Å) and angles (°) for the dibutyltin complex **5**

Sn–O(1A)	2.081(2)		
Sn–O(1B)	2.083(2)		
Sn–O(2A)	2.706(2)	O(1A)–Sn–O(1B)	83.19(8)
Sn–O(2B)	2.638(2)	O(1A)–Sn–C(2B1)	105.33(13)
Sn–C(2B1)	2.118(4)	O(1B)–Sn–C(2B1)	104.18(13)
Sn–C(1B1)	2.130(4)	O(1A)–Sn–C(1B1)	104.54(12)
Cl(1A)–C(11A)	1.732(4)	O(1B)–Sn–C(1B1)	106.03(13)
Cl(1B)–C(11B)	1.730(3)	O(2A)–Sn–O(1A)	52.60(7)
O(1A)–C(7A)	1.277(4)	O(2A)–Sn–O(1B)	135.70(12)
O(2A)–C(7A)	1.248(4)	O(2A)–Sn–O(2B)	169.60(13)
O(3A)–C(2A)	1.349(4)	O(2B)–Sn–O(1A)	136.70(13)
O(1B)–C(7B)	1.283(3)	O(2B)–Sn–O(1B)	53.80(8)
O(2B)–C(7B)	1.257(4)	O(2A)–Sn–C(1B1)	87.30(9)
O(3B)–C(2B)	1.344(4)	O(2A)–Sn–C(2B1)	89.50(8)
N(1A)–N(2A)	1.246(3)	O(2B)–Sn–C(1B1)	85.20(7)
N(1A)–C(5A)	1.423(4)	O(2B)–Sn–C(2B1)	91.40(8)
N(2A)–C(8A)	1.416(4)	C(2B1)–Sn–C(1B1)	139.45(13)
N(1B)–N(2B)	1.249(3)	C(7A)–O(1A)–Sn	107.9(2)
N(1B)–C(5B)	1.424(4)	C(7B)–O(1B)–Sn	105.97(18)
N(2B)–C(8B)	1.432(4)		

that this value is close to those (144° and 147° (Table 4)) predicted (above) from the Mössbauer data using the Parish relationship. The asymmetry in the bonding of the carboxylate oxygen atoms to the tin atom may be partly explained on the basis of hydrogen bonding, which is observed between one carboxylate oxygen in each group and the adjacent phenolic proton from the same ligand molecule. The bond lengths for the hydrogen-bonding schemes shown in Figures 2 and 3 are O(3A)–H(3A) = 0.99 Å, H(3A)–O(2A) = 1.75 Å, O(3A)–O(2A) = 2.60 Å and O(3B)–H(3B) = 0.88 Å, H(3B)–O(2B) = 1.85 Å, O(3B)–O(2B) = 2.60 Å. The corresponding O–H···O angles are O(3A)–H(3A)···O(2A) = 142° and O(3B)–H(3B)···O(2B) = 144°. Thus, one of the carboxylate oxygen atoms in each of the coordinating groups is bound to the central tin atom and, at the same time, hydrogen bonded to a phenolic oxygen, thus weakening the Sn–O interaction. There are no intermolecular hydrogen-bonding interactions present.

Full tables of bond lengths and angles, tables of non-hydrogen and hydrogen atomic coordinates, and anisotropic thermal parameters for non-hydrogen atoms are available upon request from The Director, CCDC, 12 Union Road, Cambridge, CB2 1EZ, UK (fax: +44-1223-336033; e-mail: deposit@ccdc.cam.ac.uk or www: http://www.ccdc.cam.ac.uk), quoting the CCDC deposition number 181621.

Larval toxicity studies

The LC_{50} values and their standard deviations for the di- and tri-organotin compounds **1** and **8–15** screened against the second larval instar stage of the *Ae. aegypti* are reported in Table 7. It is well established that triorganotins possess higher biocidal activity than diorganotins,[32] and this is illustrated in the present study. All the triorganotins have activities of an order of magnitude higher than for the diorganotin derivative. The LC_{50} values for the triorganotin compounds tested ranged from 0.53 to 3.50 mg l^{-1}. These values are quite similar to those of an earlier study by Nguyen *et al.*,[33] in which they screened a host of triorganotins on the fourth larval instar stage of the *Ae. aegypti* mosquito. Their range of toxicity for the triorganotins tested was between 0.57 to 3.40 mg l^{-1}. Also, the data indicate that the butyl compounds were more effective than the phenyl derivatives, as was found by Nguyen *et al.*[33]

However, the toxicities towards the *Ae. aegypti* larvae are lower when compared to organophosphorus insecticides, as reported by Rawlins and Wan.[34] Their study involved screening several organophosphorus insecticides against 34 strains of *Ae. aegypti* larvae from 17 Caribbean countries.

Although the triorganotin compounds, in the present study, are not as effective as organophosphorus insecticides[34] in their larvicidal effects, their advantages lie in their biodegradability and lack of known resistance by this species of mosquitoes. It has been reported that many strains of *Ae. aegypti* have shown some resistance to several organophosphorus insecticides,[34,35] with that to Malathion being the highest.[34] It has also been established that highly toxic triorganotins biodegrade in the environment[32] to non-toxic inorganic tin species through the progressive removal of the organic groups attached to the tin atom. This is an important aspect, since some countries have banned the use of organophosphorus compounds for the control of mosquitoes due to their toxic side effects.[36] In light of these two drawbacks for organophosphorus insecticides and the overall effectiveness of the triorganotins against the *Ae. aegypti* larvae, this class of compounds can be considered a good candidate for the control of this species of mosquito larvae.

The development of a reliable correlation such as a QSAR between the toxicities of the compounds and some

Table 7. Toxicity of di- and tri-organotin complexes[a] against *Ae. aegypti* mosquito second larval instar

Complex	LC_{50} (ppm)
1	>10
8	2.17 ± 0.02
9	3.50 ± 0.16
10	1.95 ± 0.03
11	1.82 ± 0.01
12	1.23 ± 0.20
13	0.72 ± 0.04
14	0.53 ± 0.01
15	0.96 ± 0.01

[a] Refer to Table 1 for complex description.

descriptor(s) of the molecules would be of great value. It would allow both the prediction of untested compounds and the ability to design new molecules with more effective toxicities. QSARs have been shown to be useful in assessing environmental impacts of hazardous chemicals.[37] Using the LC_{50} values and the molecular connectivity χ indices of the molecules, a reasonable QSAR was obtainable with a correlation coefficient $r^2 = 0.82$. However, owing to the limited number of compounds used in generating the QSAR, care should be taken in its use.

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