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PCBs and DDTs in light-vented bulbuls from Guangdong Province, South China: Levels, geographical pattern and risk assessment

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HIGHLIGHTS

• Light-vented bulbul was used as a bioindicator to monitor PCBs and DDTs.
• Geographical patterns of PCBs and DDTs were investigated in Guangdong Province.
• The highest PCB concentration was observed at the e-waste recycling site.
• DDT in light-vented bulbuls was mainly derived from historical residues.
• A significant positive correlation was found between TEQ and PCB levels.

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ABSTRACT

Thirty-two light-vented bulbuls (*Pycnonotus sinensis*) were collected from six sampling sites in Guangdong Province, South China to investigate the geographical variation on the occurrence of polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane and its metabolites (DDTs). Concentrations of PCBs and DDTs in the pectoral muscle of light-vented bulbul ranged from 140 to 73,000 ng/g lipid weight (lw) and 12 to 4600 ng/g lw, respectively. PCB concentrations were significantly higher in birds from e-waste site compared to other sampling sites (mean, 18,000 vs 290 ng/g lw, $p < 0.0001$), implying that PCBs mainly came from e-waste recycling activities. No significant differences for DDT levels were observed among the sampling sites ($p = 0.092$). Differences in PCB homologue profiles among the sampling sites were found and can be probably ascribed to different local contamination sources. *p,p'*-DDE (>80%) was the most abundant component of DDTs in birds. Compositional pattern of DDTs suggested that historical residue was the main source of DDT. The toxic equivalent (TEQ) concentrations had significant positive correlations with PCB concentrations, indicating that elevated PCB levels may have adverse effects on light-vented bulbuls.

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1. Introduction

Persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane and its metabolites (DDTs), have attracted considerable attention for over 40 years because of their persistence, bioaccumulation, toxicity and susceptibility to long-range transport (Jones and de Voogt, 1999). PCBs and DDTs were added to the list of POPs by the Stockholm Convention in 2001. PCBs were historically used as dielectric and coolant fluids in a variety of industrial products such as transformers, capacitors, electric motors. DDT was extensively used as an agricultural insecticide throughout the 1940s and 1950s. It was estimated that 10,000 t of PCBs (Xing et al., 2005) and 400,000 t of DDTs (Guo et al., 2009) had been produced in China. The production of PCBs and DDT was banned in the 1980s. However, PCBs and DDTs are constantly released from a variety of industrial and agricultural activities into the environment. For example, intensive electronic waste (e-waste) recycling activities have illegally burgeoned in Guangdong Province, releasing large amounts of toxic chemicals into the environment. Remarkable PCB contamination was observed in waterbirds (960–1,400,000 ng/g lipid weight, lw) and fish (18–32,000 ng/g lw) from the e-waste site of Guangdong Province (Luo et al., 2009; Zhang et al., 2010).

Guangdong Province has become one of the most densely urbanized and economically dynamic regions of China since 1980. It is also one of

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the largest manufacturing bases in the world for various products such as electronic/electrical products, toys, garments, textiles, and plastic products (Sun et al., 2012). Meanwhile, Guangdong Province has experienced accelerated environmental deterioration in the past three decades due to rapidly developing industrial, municipal and agricultural activities. PCBs have been widely detected in air, soil, water, sediment and biota from this region (Fu et al., 2003). Unfortunately, extensive e-waste recycling activities have emerged in this region from the 1990s, which resulted in great amounts of PCBs released into the environment (Zhang et al., 2012). Elevated levels of PCBs have been frequently found in various environmental matrices from Guangdong Province (Chen et al., 2009a; Luo et al., 2009). High levels of DDTs have also been detected in water and sediment from Guangdong Province (Fu et al., 2003). New input sources of DDT were present and ascribed to local usage of dicofol and DDT-containing anti-fouling paints (Guan et al., 2009; Yu et al., 2011). Meanwhile, the occurrence of 1-chloro-2,2-bis(4-chlorophenyl)ethene (*p,p′*-DDMU), a secondary metabolite of *p,p′*-DDT, was widely detected in aquatic environmental matrices (Falandysz et al., 1999; Guo et al., 2009; Yu et al., 2011), but information in terrestrial ecosystems is still limited. Therefore, the geographical distribution in concentrations and patterns of these pollutants and their possible sources in Guangdong Province have attracted increasing attention.

Environmental monitoring is needed to evaluate the current levels and risks of different POPs in Guangdong Province. Birds have been successfully used as sentinel species to monitor the levels and effects of POPs in the environment because they are widespread, sensitive to environmental changes, and often high on the food chain (Dauwe et al., 2006; Van den Steen et al., 2010a,2010b; Custer et al., 2012; Sun et al., 2012; Eng et al., 2014). Predatory birds have been widely used as biomonitoring species for POPs (Chen et al., 2009b; Chen and Hale, 2010; Eulaers et al., 2011; Gómez-Ramírez et al., 2014), but most of these birds are less suitable to reflect the local contamination status because they are migratory and live in an extended area with low population densities (Dauwe et al., 2006, 2009). Thus, resident passerine bird species have been successfully used as biomonitoring tools to determine POPs contamination (Dauwe et al., 2009; Van den Steen et al., 2010b; Eens et al., 2013; Morrissey et al., 2013; Eng et al., 2014). In contrast with predatory birds, resident passerine bird species are particularly expected to reflect local pollution with POPs in small study areas because of their small-scale territories and limited foraging areas (Van den Steen et al., 2009, 2010b). Resident passerine bird species, such as great tit (*Parus major*) (Dauwe et al., 2006; Van den Steen et al., 2008, 2009), blue tit (*Cyanistes caeruleus*) (Van den Steen et al., 2010b), and European starling (*Sturnus vulgaris*) (Eens et al., 2013; Eng et al., 2014), have been reported to monitor local contamination with POPs in the environment.

Light-vented bulbul (*Pycnonotus sinensis*) is a polyphagous bird feeding predominantly on berries, soft fruits and vegetables (Wang et al., 2005). Light-vented bulbul is a common resident passerine bird species in Guangdong Province with relatively small home range and foraging areas and readily captured by man-made mist-nets (Wu et al., 2011), making it suitable for monitoring local contamination of OCs. In the present study, 32 light-vented bulbuls from six sampling sites, involving rural, suburban, urban, and e-waste areas, in Guangdong Province of South China were collected and analyzed for PCBs and DDTs. The objectives of this study were to investigate the geographic variation in the levels and profiles of PCBs and DDTs, explore their potential sources, and evaluate their potential effects on light-vented bulbuls.

2. Materials and methods

2.1. Sample collection

Thirty-two light-vented bulbuls were collected from six sampling sites in Guangdong Province, South China from September 2009 to March 2011. Six sampling sites were classified into four categories, rural, suburban, urban and e-waste areas. Liannan (LN) and Maoming (MM), located in the northwest and southeast of Guangdong Province, are two rural sampling sites which are characterized by agricultural activities. Zhaoqing (ZQ) and Heshan (HS), surrounded by the Pearl River Delta region, represent the suburban areas. An urban sampling site is situated in a typical urban area of Guangzhou (GZ) characterized by high population density and heavy industrial and commercial activities. An e-waste sampling site is Qingyuan (QY), where a large amount of e-waste (about 700,000 t) is processed annually using primitive techniques such as open incineration, acid dipping and manual disassembly. The sampling map and sample numbers of each site are given in Fig. 1 and Table 1, respectively. Birds were captured by mist nets of 12 m × 2.6 m × 3.6 cm (length × height × mesh). Eight nets were operated simultaneously at each sampling site for 3–4 consecutive days between 6:30 and 17:30 on days without rain for each period. Nets were checked at intervals of 1 h. Birds were immediately transported to the laboratory and euthanized with N_2. The necessary permit for this study was obtained from the Forestry Bureau of Guangdong Province of China. Pectoral muscles were excised from each bird and stored at −20 °C until chemical analysis.

2.2. Chemical analysis

The extraction procedure for PCBs and DDTs was described in a previous study (Luo et al., 2009). Briefly, approximately 5 g of muscle tissue was homogenized with anhydrous sodium sulfate, spiked with surrogate standards (PCB 30, 65, and 204) and Soxhlet extracted with 50% acetone in hexane for 48 h. The lipid content was gravimetrically determined from an aliquot of the extract. The remainder of the extract used for chemical analysis was subjected to gel permeation chromatography for lipid removal. Eluate from 90 to 280 mL containing PCBs and DDTs was collected and concentrated to 1 mL, further cleaned up on a multilayer column packed with 8 cm acidified silica, 8 cm neutral silica and 1 cm anhydrous sodium sulfate from bottom to top, and eluted with 30 mL hexane/dichloromethane ($v/v = 1{:}1$). The eluate was concentrated to near dryness under N_2 and reconstituted in 100 μL of isooctane. Internal standards (PCB 24, 82, and 198) were spiked before instrumental analysis.

Thirty-four PCB congeners (PCB 28/31, 52, 60, 66, 74, 99, 101, 105, 115/87, 118, 128, 130, 137, 138, 146, 149/139, 153, 156, 158, 164/163, 171, 172, 175, 180, 183, 187, 190, 191, 194, 195, 203, 205, 206, 209), DDT (*p,p′*-DDT and *o,p′*-DDT) and its metabolites (*p,p′*-DDD, *p,p′*-DDE, *p,p′*-DDM, *p,p′*-DDMU, *o,p′*-DDE, *o,p′*-DDD) were analyzed in all samples. PCBs and DDTs were quantified by an Agilent 7890 gas chromatograph coupled with an Agilent 5975C mass spectrometer (GC/MS) using electron impact (EI) in the selective ion-monitoring (SIM) mode and separated by a DB-5MS (60 m × 0.25 mm × 0.25 μm, J&W Scientific) capillary column. The initial oven temperature was set at 120 °C, then increased to 180 °C at a rate of 6 °C/min, further increased to 240 °C at a rate of 1 °C/min, and finally raised to 290 °C at a rate of 10 °C/min (held for 15 min). 1 μL of sample was injected in the pulsed splitless mode. The ion source, quadrupole and interface temperatures were set at 230 °C, 150 °C, and 290 °C, respectively. Detailed information on GC/MS and monitored ions were given elsewhere (Hu et al., 2008).

2.3. Quality assurance and quality control (QA/QC)

Instrumental QC included regular injection of solvent blanks and standard solutions. Procedural blanks, triplicate spiked blanks (20 individual PCB congeners, PCB 8, 18, 28, 44, 52, 66, 77, 101, 105, 118, 126, 128, 138, 153, 170, 180, 187, 195, 206 and 209), and triplicate spiked matrices were analyzed to ensure method QC. Procedural blanks were processed consistently for each batch of 11 samples. Trace levels of PCB 153 and 128 were detected in the procedural blanks (<8% of those in the samples with the lowest levels) and the mean

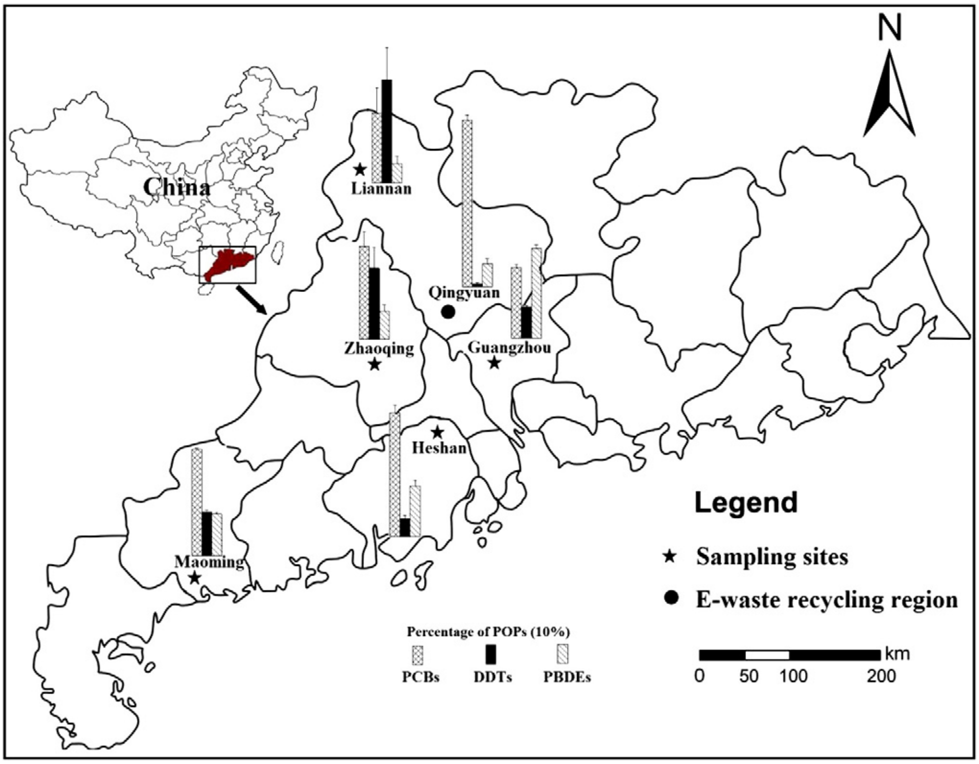

Fig. 1. Percentage of PCBs, DDTs and PBDEs in birds from six sampling sites in Guangdong Province, South China. PBDEs data were cited from Sun et al. (2012).

concentrations were subtracted from samples. The average recoveries of 20 PCB congeners ranged from 60% to 110% and 63% to 107% for the spiked blanks and matrices, respectively. The relative standard deviations of triplicate samples were less than 14%. The mean recoveries of surrogate standard in all samples were 83.9 ± 9.5% (mean ± standard deviation), 92.3 ± 8.6%, and 82.4 ± 6.7% for PCB 30, 65, and 204, respectively. Reported concentrations were not corrected by surrogate recoveries. For PCB 153 and 128, method detection limits (MDLs) were set as three times the standard deviation of the target value in blanks. For the undetected compounds in blanks, MDLs were defined as signals of 5 times the noise levels. Based on the mean lw of the samples, MDLs for PCBs and DDTs ranged from 0.04 to 4.54 ng/g lw and 0.02 to 2.72 ng/g lw, respectively.

2.4. Data analysis

Concentrations were expressed on a lw basis. Data analysis was performed using SPSS 16.0 (SPSS Inc., Illinois, USA). Concentrations were not normally distributed and $\log_{10}$ transformed before statistical analysis. One-way analysis of variance (ANOVA) was used to determine the differences in PCB and DDT concentrations among the six sampling sites in Guangdong Province. Simple linear correlation analysis was used to investigate the relationships between TEQ and ∑PCBs, *p,p′*-DDMU and *p,p′*-DDE, and *p,p′*-DDMU and *p,p′*-DDD concentrations, respectively. The level of significance was set at $p < 0.05$.

3. Results and discussion

3.1. PCB and DDT levels

Concentrations of PCBs in light-vented bulbul from six sampling sites in Guangdong Province are shown in Tables 1 and S1 (Supporting information). PCB concentrations (34 PCB congeners) ranged from a minimum of 140 ng/g lw in LN to a maximum of 73,000 ng/g lw in QY. A one-way ANOVA revealed that significant differences in PCB concentrations were found among the six sampling sites ($F_{5,31}$ = 32.79, $p < 0.0001$). Concentrations in light-vented bulbul from QY were significantly higher compared to the other five sampling sites ($p < 0.0001$). In general, the geographic distribution of PCB concentrations prevailed in the following decreased order: e-waste site > suburban ≥urban > rural (Table 1). The highest PCB concentration was observed in the e-waste recycling area, suggesting that e-waste is

Table 1
Median and range concentrations (ng/g lw) of PCBs and DDTs in birds from different sampling sites in Guangdong Province.

Locations	Category	N	Lipid (%)	PCBs[b]	DDTs[c]	*p,p′*-DDMU	(DDE + DDD)/DDTs
LN	Rural	4	3.93 ± 0.15[a]	160 (140–240)	260 (82–4600)	2.9 (nd[d]–4.4)	0.96 (0.89–1.0)
MM	Rural	4	2.70 ± 0.11	160 (150–180)	67 (53–82)	1.8 (1.1–2.5)	0.85 (0.82–0.92)
ZQ	Suburban	7	3.60 ± 0.33	370 (180–520)	90 (39–1600)	nd (nd–80)	0.96 (0.94–0.98)
HS	Suburban	5	3.22 ± 0.35	260 (200–870)	69 (12–89)	1.2 (nd–4.3)	0.98 (0.93–1.0)
GZ	Urban	6	2.69 ± 0.27	250 (220–460)	120 (88–170)	nd	1.0 (0.97–1.0)
QY	E-waste site	6	2.77 ± 0.30	7300 (3200–73,000)	170 (46–600)	nd (nd–17)	0.99 (0.92–1.0)

[a] Mean ± SE.
[b] Sum of PCB 28/31, 52, 60, 66, 74, 99, 101, 105, 115/87, 118, 128, 130, 137, 138, 146, 149/139, 153, 156, 158, 164/163, 171, 172, 175, 180, 183, 187, 190, 191, 194, 195, 203, 205, 206, and 209.
[c] Sum of *p,p′*-DDE, *p,p′*-DDD, *p,p′*-DDT, *p,p′*-DDM, *p,p′*-DDMU, *o,p′*-DDE, *o,p′*-DDD, and *o,p′*-DDT.
[d] Not detectable.

one of the important sources of PCBs in the study site. Previous studies have also reported that much higher PCB concentrations were detected in aquatic biota such as waterbirds, fish, and hydrobiidae at the same sampling site (Luo et al., 2009; Zhang et al., 2010, 2011). These results indicate that higher PCB levels in biota from Guangdong Province could be linked to high density of e-waste recycling activities in this region. In Guangdong Province, approximately 145 million electronic devices (including television sets, computers, and electric fans) were dismantled using crude recycling methods (burning/acid dissolution, etc.) in 2002 alone (Martin et al., 2004). Intensive e-waste recycling activities accelerate the release of PCBs into the environment and may result in serious environmental problems and/or pose a potential risk to human/wildlife. In fact, high PCB concentrations were often found near/at the e-waste recycling area (Robinson, 2009; Fu et al., 2011). PCB levels were significantly higher at the urban/suburban areas compared to the rural areas, which is similar to other previous studies. Van den Steen et al. (2009, 2010b) reported large-scale geographical variation of PCB levels in European environment using eggs of great tit and blue tit as biomonitoring tools and found that both great tit and blue tit eggs from the urban locations had significantly higher concentrations of PCBs compared to the rural locations. Similarly, Eens et al. (2013) also found that PCB concentrations in starling eggs from the urban locations were significantly higher than those from the rural locations. The geographic pattern of PCB levels in the present study confirmed that PCBs are linked to industrialization and urbanization in Guangdong Province.

Concentrations of DDTs (DDT and its metabolites) in light-vented bulbul from six sampling sites of Guangdong Province are presented in Table 1. The highest (4600 ng/g lw) and the lowest (12 ng/g lw) DDT levels were detected in birds from LN and HS, respectively (Table 1). The median concentrations of DDTs after excluding MM sampling site had the decreasing order rural > e-waste site > urban > suburban (Table 1). However, no significant differences for DDT concentrations were observed among the sampling sites ($F_{5,31} = 2.15$, $p = 0.092$). The reason for this observation might be partly attributed to small sample sizes. LN, located in the northwest of Guangdong Province, is an economically undeveloped county characterized by intensive agricultural activities. The highest median concentration from LN might result from intensive agricultural activities or wide historical usage of DDT. QY had been characterized by the intensive agricultural activities in the earlier age and e-waste recycling activities have become prevalent in this sampling site from the 1990s. Therefore, relatively high levels of DDTs were expectantly found at this sampling site. The occurrence of DDTs in biota from QY has also been reported in the previous studies. DDTs were detected in five waterbird species with concentrations ranging from 73 to 6900 ng/g lw (Luo et al., 2009). DDTs were also found in four fish species with concentrations ranging from not detectable (nd) to 850 ng/g lw (Zhang et al., 2010).

p,p′-DDMU was detected in 47% of the samples with concentrations ranging from nd to 80 ng/g lw (Table 1), which were one or four orders of magnitude lower than those in muscle of white-tailed sea eagle (*Haliaeetus albicilla*, 330–110,000 ng/g lw) from the Baltic South Coast (Falandysz et al., 1999). *p,p′*-DDMU was also reported in fish, sediment, soil, air, and rainwater from Guangdong Province (Guo et al., 2009). These results show that *p,p′*-DDMU is highly ubiquitous in the environment of Guangdong Province. Correlation analysis revealed that *p,p′*-DDMU levels were significantly correlated with both concentrations of *p,p′*-DDE ($r^2 = 0.35$, $p = 0.01$) and *p,p′*-DDD ($r^2 = 0.43$, $p = 0.02$) (Fig. 2), suggesting that *p,p′*-DDMU in birds might be derived from in vivo dehydrochlorination from *p,p′*-DDE and/or *p,p′*-DDD. Given the occurrence of *p,p′*-DDMU in abiotic samples from Guangdong Province (Guo et al., 2009), bioaccumulation from environment might be another explanation for this observation. Thus, future research on the source of *p,p′*-DDMU in birds is needed.

3.2. Composition profiles of POPs

Deca-BDE is still the largest used brominated flame retardants in China. Penta- and octa-BDEs were banned and added to the list of emerging POPs by the Stockholm Convention in 2009. Polybrominated diphenyl ether (PBDE) data in light-vented bulbul reported in our previous study (Sun et al., 2012) were used to discuss the composition profile of emerging (PBDEs) and traditional POPs (PCBs and DDTs) at different sampling sites. Distinct composition pattern of POPs were observed among the different sampling sites (Fig. 1). PCBs were the predominant contaminants in light-vented bulbuls from QY, HS, ZQ and MM, with contributions of 86.2%, 64.2%, 48.2% and 55.4%, respectively. Birds from the e-waste site had a rather higher proportion of PCBs compared to those from other sampling sites, indicating that PCBs in bird samples were likely derived from e-waste recycling activities. This predominance of PCBs was also reported in waterbird species and fish from the same e-waste site (Luo et al., 2009; Zhang et al., 2010). The proportion of PCBs in birds from HS, ZQ and MM was also higher than those of PBDEs and DDTs. POPs in birds from GZ were dominated by PBDEs (46.6%), followed by PCBs (36.8%) and DDTs (16.6%). As the capital of Guangdong Province, GZ is a highly urbanized and industrialized city. Emission from household products and industry activities may explain a relatively high proportion of PBDEs in GZ (Sun et al., 2012). In samples

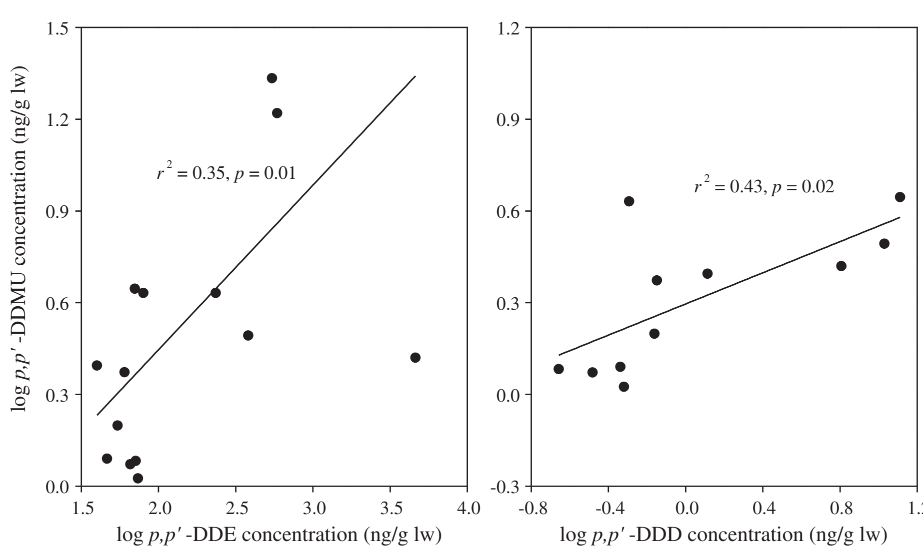

Fig. 2. Correlations of concentrations of *p,p′*-DDE and *p,p′*-DDD plotted against *p,p′*-DDMU in birds from Guangdong Province, South China.

from LN, the contribution of DDTs to POPs (53.5%) was higher than that of PCBs (36.3%) and PBDEs (10.2%). LN is located at the north of Guangdong Province and characterized by intensive agricultural activities. The earlier use of DDT is probably responsible for the above result.

The patterns for PCB homologue profiles in birds from six sampling sites are shown in Fig. 3. Penta-, hexa-, hepta- and octa-PCBs were the main homologue profiles at all sampling sites and contributed more than 90% to total PCBs. Among the 34 PCB congeners that were mentioned above, the most abundant congener was PCB 153 (8.5%), followed by PCB 118 (7.1%), 138 (6.3%), and 180 (5.0%). These congeners are known to be slowly cleared in birds due to the presence of chlorine substitutions at *meta-para* positions on the phenyl rings (Drouillard et al., 2001). Distinct homologue profiles of PCB were found among the sampling sites and classified into three groups (Fig. 3). Birds from QY is the first group, in which hexa-PCBs (42.1%) are the predominant PCB component, followed by penta- (22.0%) and hepta-PCBs (14.6%), with lesser contributions from tetra- (9.2%) and octa-PCBs (6.6%). This pattern was similar to the previous study on aquatic bird species collected from the same sampling site (Luo et al., 2009). Samples from GZ, HS, and ZQ are the second group, where PCB homologue profiles in birds prevailed in the following order hexa- > hepta- > penta- > octa- > tetra-PCBs. Samples from LN and MM are the third group, in which hepta- and hexa-PCBs are the dominant homologue profiles, contributing about 50% to total PCBs, followed by octa- > penta- > tetra-PCBs. It has been reported that PCB congener patterns in technical mixtures from developed countries were different from those in #1 and #2 PCB produced in China with a production of 9000 and 1000 t, respectively (Zhang et al., 2009). E-wastes in China were imported from North America and Europe. Thus, the different pattern among the sampling sites is probably due to local contamination sources.

Among DDTs, *p,p*′-DDE was the most abundant compound at all sampling sites and accounted for more than 90% of total DDTs except in MM (81%) (Fig. 4). Similar results have previously reported that *p,p*′-DDE contributed more than 85% to DDTs in eggs of great tit and blue tit from different European countries (Van den Steen et al., 2009, 2010a,2010b), and starling from Europe, North America and Australia (Eens et al., 2013). The ratios of (DDE + DDD)/DDTs have been used to indicate whether fresh input of DDT is prevailing and (DDE + DDD)/DDTs >0.5 can be thought that DDTs come from historical use instead of fresh input (Yu et al., 2011). In this study, the ratios of (DDE + DDD)/DDTs ranged from 0.85 to 1.0, with an average value of 0.95 (Table 1), indicating that historical residue is likely the main source of DDT in birds from Guangdong Province. The highly bioaccumulative *p,p*′-DDE along with the low concentrations and detectable frequency of *p,p*′-DDT (25%) also suggested that DDTs in birds were mainly derived from historical residue rather than recent input.

3.3. Risk assessment

Toxic equivalency factors (TEFs) for birds, proposed by the World Health Organization (WHO), were used to calculate the toxic equivalent (TEQ) concentrations of non- and mono-*ortho*-PCB congeners which can cause dioxin-like effects by binding affinity to the aryl hydrocarbon receptor (Van den Berg et al., 1998). Non-*ortho*-PCB congeners were below MDLs in most samples and are not discussed in the present study. Among mono-*ortho*-PCB congeners (PCB 105, 118, 123, 156, 157 and 169), PCB 105 was the major contributor to TEQ concentrations (53.8%), followed by PCB 156 and PCB 118. This pattern was similar to other studies on predatory birds from northern China (Chen et al., 2009b) and aquatic birds from Russia and Switzerland (Zimmermann et al., 1997; Kunisue et al., 2002). The levels of TEQ in light-vented bulbul ranged from 0.25 to 912 pg/g lw. The birds from QY had the highest TEQ level (mean, 254 pg/g lw). The TEQ concentrations had a significant positive relationship with PCB concentrations ($r^2 = 0.97$, $p < 0.0001$, Fig. 5). After excluding the samples from QY, a significant linear correlation also existed ($r^2 = 0.94$, $p < 0.0001$). A meta-analysis of data from a previous bird study also found a significant positive relationship between TEQ and PCB concentrations across diverse bird species (Chen et al., 2009b). These results suggest that high PCB concentrations may cause adverse effects on bird species. The induction of hepatic cytochrome P450A (CYP1A) in avian species by dioxin-like PCBs with comparable structural and biochemical properties to dioxins may lead to embryo lethality and toxic side effects (Kennedy et al., 1996; Manning et al., 2013). Reduced nest provisioning behavior and decreased chick survival were observed in European starlings and tree swallows (*Tachycineta bicolor*) from PCB-contaminated sites in southern Illinois (Arenal et al., 2004) and the Hudson River, New York, USA (Custer et al., 2012).

Population declines in several bird species have been reported in Europe and North America due to bioaccumulation of DDTs, especially DDE (Douthwaite and Tingle, 1992; Ludwig, 1996). The major reason for the declines is that DDE can induce avian reproductive failure by

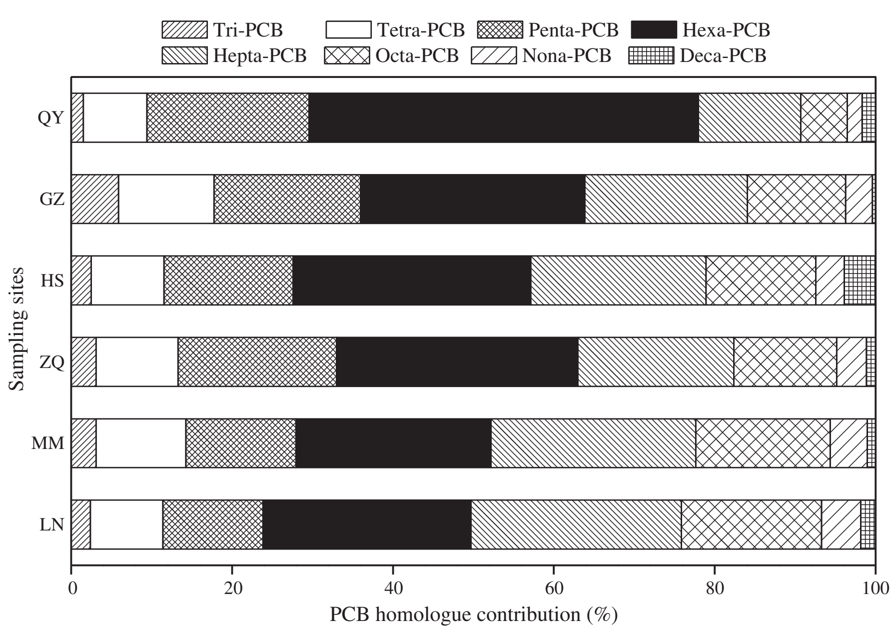

Fig. 3. PCB homologue profiles in birds from six sampling sites in Guangdong Province, South China.

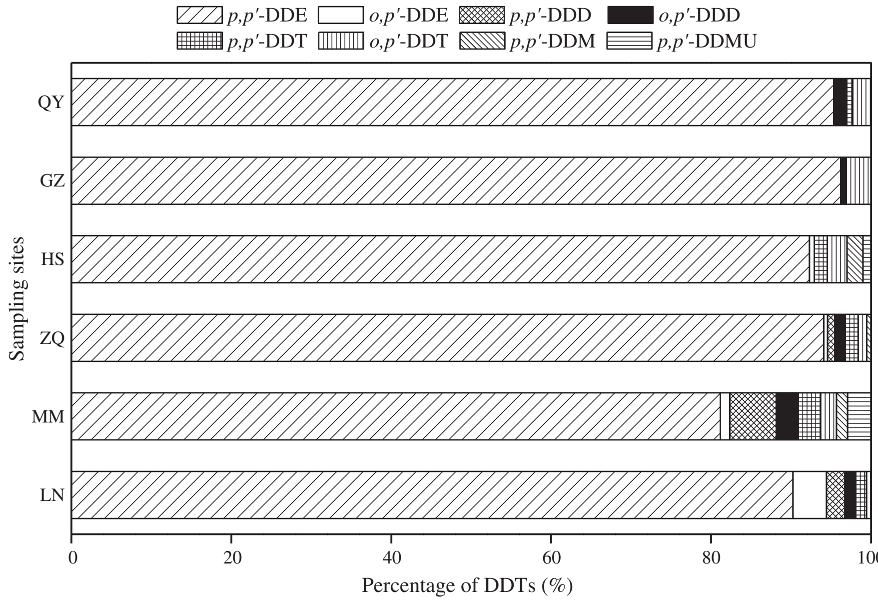

Fig. 4. Composition profiles of DDTs in birds from six sampling sites in Guangdong Province, South China.

reducing eggshell thickness (Grier, 1982). In the present study, DDE concentrations (sum of *p,p′*-DDE and *o,p′*-DDE), between 0.39 and 176 ng/g ww (wet weight), may not cause reproductive effect on light-vented bulbul based on the no-observed-effect-level (NOEL) of predatory birds (3000–3700 ng/g ww) (Helander et al., 2002; Chen et al., 2009b) and aquatic birds (1000–2800 ng/g ww) (Connell et al., 2003; Lam et al., 2008; Wang et al., 2011). But the NOEL for risk evaluation must be cautiously used in this study because of the different species and tissues that were measured. Thus, further study on the NOEL of DDE available for passerine bird species is needed.

4. Conclusions

Levels and geographical distribution of PCBs and DDTs were investigated in Guangdong Province using light-vented bulbuls as a biomonitoring tool. Geographic distribution of PCB levels increased in the following order rural < urban ≤ suburban < e-waste site, suggesting that e-waste is a major source of PCBs. Due to extensive e-waste recycling activities in Guangdong Province, adverse effects of PCBs on birds should be concerned. No significant differences for DDT concentrations were observed among the sampling sites. PCB homologue profiles differed among the sampling sites, probably due to different pollution sources. Ratios of (DDE + DDD)/DDTs in birds suggested that DDT was mainly derived from historical residues. A significant positive correlation was observed between TEQ and PCB concentrations, suggesting that elevated PCB levels may pose a potential risk to light-vented bulbuls in the study area.

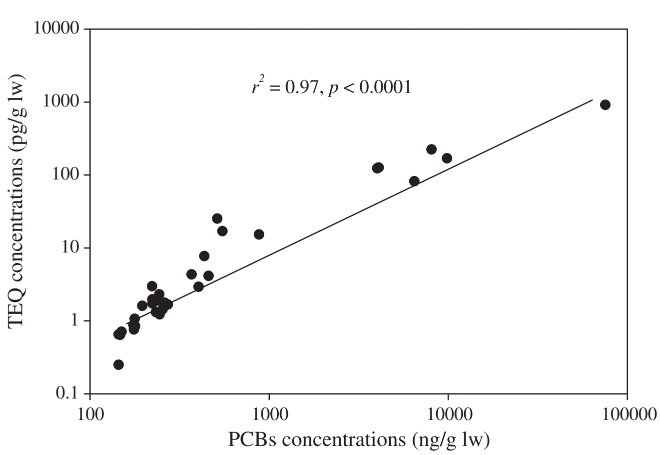

Fig. 5. Correlations between PCB and TEQ concentrations in birds from Guangdong Province, South China.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2014.05.066.

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