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Atmospheric Deposition Modeling of Polychlorinated Dibenzo-*p*-dioxins, Dibenzofurans and Polychlorinated Biphenyls in the Ambient Air of Southern Taiwan. Part I. Dry Depositions

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ABSTRACT

Atmospheric deposition, including dry and wet deposition, is a primary pathway for the transfer of POPs to terrestrial and aquatic ecosystems. In this study (that is, the part I.), the characteristics of PCDD/Fs and PCBs in the ambient air of Tainan City were simulated by the PM_{10} versus PCDD/Fs concentration regression analysis, gas-particle partition modeling, and the simulation of dry deposition. Dry deposition fluxes are obtained from the combination of the PCDD/F and PCB concentrations, meteorological information, dry deposition velocities, and scavenging ratios. The dry deposition fluxes of PCDD/F-TEQ_{2005} increase with decreasing temperature, while increase with a higher degree of chlorine numbers on PCDD/F homologues. In this study (that is, the part I.), the average PCDD/F dry deposition fluxes in spring, summer, fall and winter were 69.3, 28.2, 129 and 246 pg WHO-TEQ/m^2-month during 2012, respectively. As for 2013, the average PCDD/F dry deposition fluxes in spring, summer, fall and winter were 67.0, 29.8, 102 and 377 pg WHO-TEQ/m^2-month, respectively. The average PCB dry deposition fluxes in spring, summer, fall and winter were 2.16, 1.99, 5.70 and 11.9 pg WHO-TEQ/m^2-month during 2012, respectively. As for 2013, the average PCB dry deposition fluxes in spring, summer, fall and winter were 2.11, 1.27, 4.49 and 8.88 pg WHO-TEQ/m^2-month, respectively. The minimum simulated value occurred in summer, while the maximum dry deposition fluxes, which were about 4–5 times higher than the minimum values, occurred in winter. The lower values observed in summer may be caused by the atmospheric diffusion of SVOCs and high rainfall intensity.

Keywords: Polychlorinated dibenzo-*p*-dioxins; Dibenzofurans; Polychlorinated biphenyls; Dry deposition; Atmosphere.

INTRODUCTION

Concentration levels of persistent organic pollutant (POPs) in different environmental matrices had become a global concern due to their environmental characteristics of persistence, bioaccumulation, toxicity and global dispersion. Polychlorinated dibenzo-*p*-dioxin (PCDD), polychlorinated dibenzofuran (PCDF) and polychlorinated biphenyls (PCB) are semi-volatile compounds. Both of PCDD/Fs and PCBs have high boiling points, high degree of chemical stability (Aristizábal *et al.*, 2011; Wang *et al.*, 2003). PCDD/Fs are almost formed as undesired byproducts from anthropogenic and nature processes such as thermal processing of waste, internal combustion engines of vehicles when chlorine, oxygen, hydrogen and carbon are present (Quaß *et al.*, 2004; Altarawneh *et al.*, 2009; Relvas *et al.*, 2013). PCBs have been used in closed systems, such as hydraulic fluids and insulating fluid in electrical transformers and capacitors (Heinzow *et al.*, 2007). Approximately two-third of the PCBs was used for various open applications where PCBs functioned either as softener, surfactant, flame retardant,

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lubricator or dispersant in different materials and products (Berg *et al.*, 1998; Kerst *et al.*, 2003; Anderson *et al.*, 2004; Heinzow *et al.*, 2007). Since some pollution incidents broke out in Taiwan during 20 and 21 century, PCDD/Fs as well as PCBs became the most important issues owing to their fat-soluble characteristic which could put threat to human health (Lee *et al.*, 1996a; Lee *et al.*, 2009).

The cycle of PCDD/Fs and PCBs contamination lasted for many years and people who were affected by it presumably throughout their whole life or for a relevant part of it. Consequently, we need to pay close attention to the concentration levels of PCDD, PCDF and PCB in the ambient air, including dry and wet depositions, which were thought to be major path way for the transfer of persistent organic pollutants (Agrell *et al.*, 2002; Lee *et al.*, 1996b; Tasdemir *et al.*, 2005). Since PCDD/Fs and PCBs are both semi-volatile organic pollutants, they demonstrate two different phases in the ambient air, one is gaseous phase and the other is compounds bound to particles (Aristizábal *et al.*, 2011). Once PCDD/Fs and PCBs are emitted into the ambient air, they could be transported by dry and wet depositions, especially particulate phase, into terrestrial environments, water systems, and even food chains.

A recent surge of research on PCDD/Fs and PCBs has given us new information and challenges in Asia (Mi *et al.*, 2012; Jen *et al.*, 2013; Sun *et al.*, 2013a, b; Watcharavitoon *et al.*, 2013). This study (the part I.) focuses on modeling the characteristics of PCDD/F and PCB in the atmosphere of southern Taiwan. By using the data collected seasonally in different types of areas including one industrial area, two urban areas as well as one rural area during 2010 and 2011 (Mi *et al.*, 2012), the concentrations of PCDD/F and PCB could be determined through PM_{10} concentrations. Gaseous and particulate concentrations were both obtained by means of simulation. Total fluxes (dry + wet) of PCDD/Fs and PCBs were developed by using meteorological information, gas-particle partitioning, scavenging ratios, etc. The simulated results from this study could provide helpful information to build up more complete inventory for understanding the level of PCDD/Fs and PCBs near Tainan city, or formulating stricter regulations about PCDD/Fs and PCBs.

METHODS

Sampling of PCDD/Fs and PCBs from the Atmosphere

The ambient air in Tainan City of four different sites were sampled for two seasons. Each ambient air sample was collected using PS-1 sampler (Graseby Anderson, GA, USA) according to the revised U.S. EPA Reference Method T09A. The sampling flow rate was about 0.225 m^3/min. In the first season, each sample was collected continuously on seven consecutive days yielding a sampling volume about 4000 m^3. Nevertheless, in order to obtain more accurate samples, sampling period was doubled to get higher sampling volume (sampling volume ~ 9000 m^3). The PS-1 sampler was equipped with quartz-fiber filter for sampling particle-phase SVOCs, and followed by a glass cartridge containing PUF for sampling gas-phase SVOCs, respectively.

In this study, total four atmospheric sampling sites (Fig. 1) and sampling periods in Tainan were presented in Mi *et al.* (2012). Based on the data given by Mi *et al.* (2012) combined with meteorological information provided by Air Quality Monitoring Stations, the concentration of PCDD/Fs and PCBs could be simulated.

Gas-Particle Partitioning Simulation Model

PCDD/Fs and PCBs are groups of semi-volatile organic compounds (SVOCs) as well as persistent organic pollutants (POPs) (Atkinson, 1996). They are stable in the environment, undergo long range transport over regional or even global scales in the atmosphere and can be accumulated in organisms via food chain (Bidleman, 1988). This means atmosphere is a major pathway to transport PCDD/Fs and PCBs. Atmospheric deposition is a significant process affecting the global sinks of natural and anthropogenic POPs (Quaß *et al.*, 2004), thus gas-particle partitioning of PCDD/Fs and PCBs in the atmosphere will affect such deposition process (Lohmann and Jones, 1998). Gas-phase POPs are depleted from the atmosphere owing to photochemical degradation reactions (Pankow, 1994), while particle-bound deposition accounts for most of the PCDD/F and PCB flux to the ecosystem (Lohmann and Jones, 1998). As a result, knowledge of the partitioning of SVOCs in the atmosphere is essential for comprehending with their subsequent fate in the environment (Lohmann and Jones, 1998).

Gaseous and particulate concentrations are estimated by multiplying gas-particle partitioning and the total concentration of SVOCs together. The gas-particle partitioning is simulated by Eq. (1). The Eq. (1) has been used to describe the gas-particle partitioning constant (Yamasaki *et al.*, 1982; Pankow, 1991; Pankow and Bidleman, 1991, 1992; Pankow, 1994), and as follows:

$$K_p = (F/TSP)/A \quad (1)$$

K_p: gas-particle partitioning constant $(pg/m^3)^{-1}$,
TSP: concentration of total suspended particulate material (pg/m^3), TSP was calculated by TSP/PM_{10} ratio 1.24 (Sheu *et al.*, 1996)
F: particulate concentration of SVOCs (pg/m^3),
A: gaseous concentration of SVOCs (pg/m^3).

Plotting log K_p against the logarithm of the subcooled liquid vapor pressure (PL_o), gives:

$$\text{Log } K_p = m_r \times \log (P_L^o) + b_r \quad (2)$$

P_L^o: subcooled liquid vapor pressure (Torr),
m_r: slope of a plot of log Kp versus log P_L^o,
b_r: y-intercept in a plot of log K_p versus log P_L^o (Lohmann and Jones, 1998).

Chao *et al.* (2004) reported a complete datasets on the gas-particle partitioning of PCDD/Fs in Taiwan. The study gave parameters for Eq (2), $m_r = -1.29$ and $b_r = -7.2$ with $R^2 = 0.94$ (Chao *et al.*, 2004). Those parameters are used for evaluating both PCDD/F and PCB gas-particle partitioning constant (K_p) in this study.

Eitzer and Hites (1989) have correlated P_L^o of PCDD/Fs with gas chromatographic retention indexes (GC-RI) on a

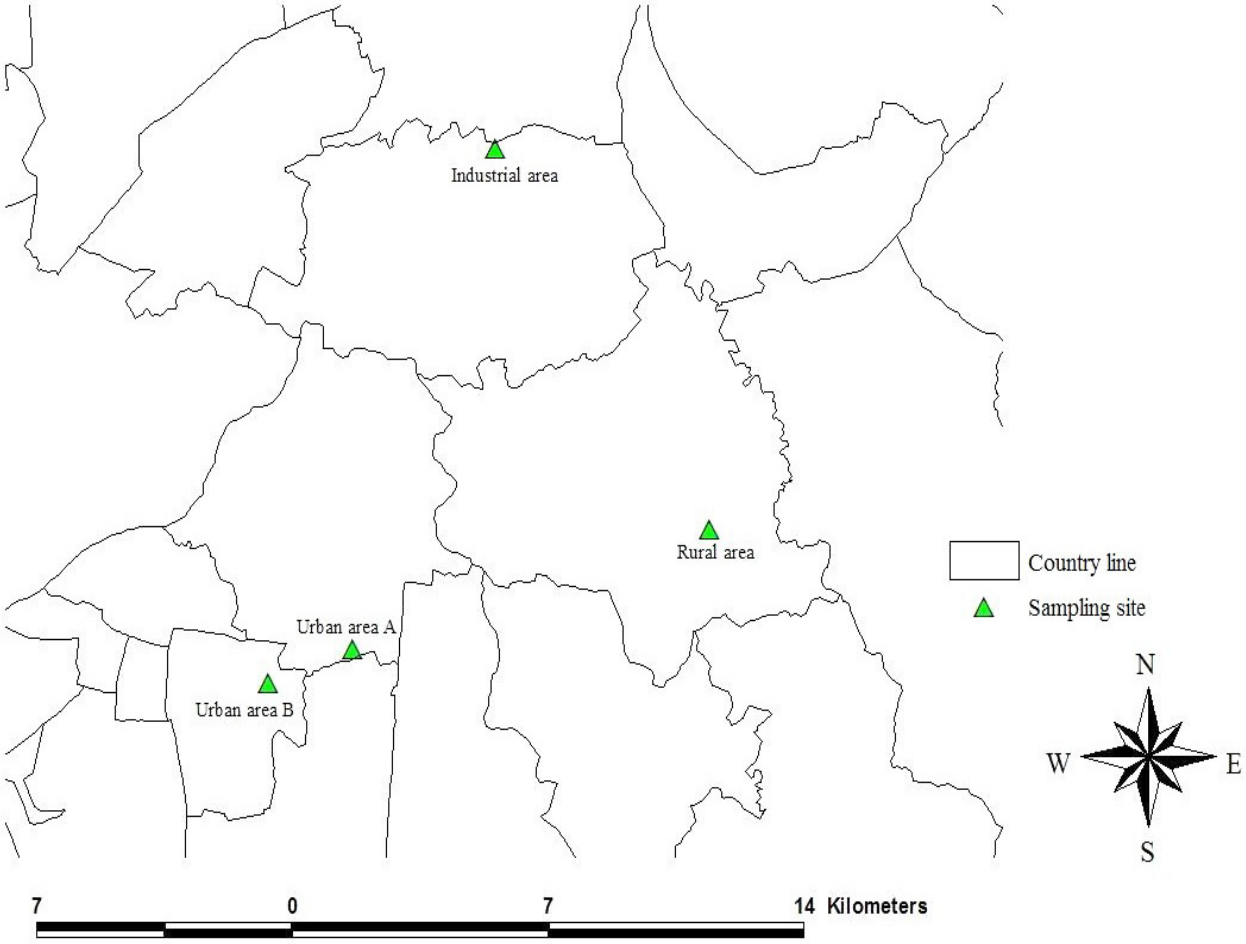

Fig. 1. Sampling sites of the ambient air in southern Taiwan.

non-polar (DB-5) GC-column using *p,p'*-DDT as a reference standard (Eitzer and Hites, 1989), and the correlation has been redeveloped by Hung *et al.* (2002):

$$\text{Log}\,(P_L^o) = -3.14 \times (RI/T) + 1.67 \times 10^{-3} \times (RI) - (1320/T) + 8.087 \quad (3)$$

RI: gas chromatographic retention indexes (GC-RI), referred to Donnelly and Hale (Hale *et al.*, 1985; Donnelly *et al.*, 1987),
T: ambient temperature (K).

Furthermore, parameters for simulating the subcooled liquid vapor pressure (P_L^o, Pa) of 180 PCB congeners as a function of temperature and ortho-chlorine substitution were given by Falconer and Bidleman (1994), which present in equation below.

$$\text{Log}\,(P_L^o) = (m_L/T) + b_L \quad (4)$$

Parameters such as m_L and b_L were determined from gas chromatographic retention data for 32 PCB congeners. The slopes (m_L) altered regularly with homolog (same numbers of total substituted chlorines) and with the number of ortho-chlorines. From the data and information given by Falconer and Bidleman (1994), m_L and b_L values of other 148 PCB congeners whose vapor pressures had been reported at a fixed temperature were evaluated.

Dry Deposition Process

There are three principal steps of the dry deposition process, aerodynamic transport, boundary layer transport and interactions with the receptor surface (Pankow, 1987). The aerodynamic transport process involves pollutant transport from the free atmosphere down to the quasi-laminar sublayer immediately adjacent to the surface. Movement across the sublayer comprises boundary layer transport as well as physical and chemical interactions between pollutant and the surface material compose the boundary layer transport process (Davidson and Wu, 1987).

The atmospheric dry deposition flux of SVOCs is a combination of both gas- and particle-phase flux, which is given by

$$F_{d,T} = F_g + F_p \quad (5)$$

$$C_T \times V_{d,T} = C_g \times V_{d,g} + C_p \times V_{d,p} \quad (6)$$

$F_{d,T}$: the dry deposition flux of SVOCs from both gaseous and particulate phases,
F_g: the dry deposition flux contributed by the gas-phase

SVOCs,
F_p: the dry deposition flux contributed by the particle-phase SVOCs,
C_T: the concentration of total SVOCs in the ambient air,
$V_{d,T}$: the dry deposition velocity of total SVOCs,
C_g: the simulated concentration of gas-phase SVOCs in the ambient air,
$V_{d,g}$: the dry deposition velocity of gas-phase SVOCs,
C_p: the simulated concentration of particle-phase SVOCs in the ambient air,
$V_{d,p}$: the dry deposition velocity of particle-phase SVOCs.

Shih *et al.* (2006) and Lee *et al.* (1996a) reported the mean dry deposition velocities of PCDD/Fs and PCBs, which were 0.42 and 0.28 (cm/sec), respectively (Lee *et al.*, 1996a; Shih *et al.*, 2006). Dry deposition of gas-phase PCDD/Fs and PCBs are predominantly by diffusion. Owing to the lack of measured data for PCDD/Fs and PCBs, 0.010 (cm/s) is selected to simulate PCDD/F and PCB dry deposition flux contributed by their gaseous phase. The value was reported by Sheu *et al.* (1996) used as the dry deposition velocity of gaseous polycyclic aromatic hydrocarbon (PAH), applied by Lee *et al.* (1996b).

Dry deposition of particle-phase PCDD/Fs and PCBs are predominantly by the gravitational settling. Therefore, the PCDD/F total dry deposition velocity 0.42 (cm/s) combine with gaseous phase deposition velocity 0.01 (cm/s) to calculate deposition velocity of particulate phase. Then use the PCDD/F simulated deposition velocity of particulate phase as the PCB simulated deposition velocity of particulate phase, because we assumed PCDD/Fs and PCBs bounded to particle that have the same average settling velocity, which can be simulated by Eq. (6).

RESULTS AND DISCUSSION

Meteorological Information

The pollutant transmission in the atmosphere would be affected by the meteorological conditions, such as wind speed, rainfall intensity, PM_{10} concentration and the atmospheric stability. The meteorological information for Tainan City during 2012 to 2013 was obtained from the nearby Air Quality Monitoring Stations, which were Tainan, Annan, and Shanhua Air Quality Monitoring Stations.

The required meteorological information is verified and all applied meteorological information is the averaging of data provided by a fore-stated three Air Quality Monitoring Stations. The average temperature monthly during 2012 and 2013 were 17.6–29.5°C and 17.2–29.3°C, respectively. The maximum rainfall intensity per month during 2012 and 2013 were 869 mm in June and 916 mm in August, respectively. By month, the average PM_{10} concentrations and wind speed were 34.8–105 μg/m^3 and 1.74–2.77 m/sec during 2012 and 2013.

Simulated Concentrations of PCDD/Fs and PCBs in the Ambient Air

The detail simulated PCDD/F concentrations in the atmosphere of Tainan City, Taiwan are presented in Tseng (2014). The main results indicate that the maximum and minimum total PCDD/F concentrations in 2012 were 1.30 pg/Nm^3 (March) and 0.532 pg/Nm^3 (July), respectively. The maximum and minimum concentrations in 2013 were 1.49 pg/Nm^3 (November) and 0.528 pg/Nm^3 (August), respectively. The maximum and minimum total PCDD/F WHO-TEQ_{2005} concentrations in 2012 were 0.0645 pg WHO-TEQ/Nm^3 (March) and 0.0253 pg WHO-TEQ/Nm^3 (July), respectively. The maximum and minimum concentrations in 2013 were 0.0709 pg WHO-TEQ/Nm^3 (November) and 0.0251 pg WHO-TEQ/Nm^3 (August), respectively.

The PCDDs/PCDFs mass ratios (0.576–0.745) during 2012 and 2013 were all lower than 1, which indicated that PCDFs were the dominant contribution of the PCDD/F atmospheric concentrations. On the other hand, the PCDDs/PCDFs WHO-TEQ_{2005} ratios (0.383–0.387) during 2012 and 2013 were all less than 1, which indicated that PCDFs also dominated the total toxicity. All simulated concentrations were much lower than the PCDD/F regulated standard of air quality in Japan (0.6 pg WHO-TEQ/Nm^3). The PCDD/F WHO-TEQ_{2005} concentrations (0.0251–0.0709 WHO-TEQ/Nm^3) in this study were in low range of the concentrations in comparison with other countries, such as Maderira, Portugal (0.130 pg I-TEQ/Nm^3) (Oh *et al.*, 2006) and Bucheon, Korea (0.22–1.16 pg I-TEQ/Nm^3) (Coutinho *et al.*, 2007). As can be seen from the atmospheric concentrations of summer and winter, the total mean WHO-TEQ_{2005} concentration in winter (0.0508 and 0.0626 pg WHO-TEQ/Nm^3 in 2012 and 2013, respectively) was approximately 2 times the magnitude in summer (0.0278 and 0.0283 pg I-TEQ/Nm^3 in 2012 and 2013, respectively), which has been found in previous studies (Shih *et al.*, 2006; Lee *et al.*, 2009; Wang *et al.*, 2010).

It has been reported that the atmospheric PCDD/F concentrations differ from among seasons because of several loss processes including photolysis, chemical reactions, wet and dry deposition, and scavenging by vegetation (Duarte-Davidson *et al.*, 1997). Among all PCDD/F congeners, the higher chlorinated substituted congeners such as OCDD, OCDF, 1,2,3,4,6,7,8-HpCDD and 1,2,3,4,6,7,8-HpCDF dominated the atmospheric concentrations, similar results also shown in Wang *et al.* (2003), Shih *et al.* (2008) and Lin *et al.* (2010b).

The simulated PCB concentrations in the atmosphere of Tainan are also presented in Tseng (2014). The main results indicate that the mean total PCB concentrations in atmosphere of Tainan City in spring (March, April and May) during 2012 and 2013 were 1.94–3.43 pg/Nm^3 and 1.82–3.21 pg/Nm^3, respectively. In terms of WHO-TEQ_{2005}, theWHO-TEQ_{2005} concentrations were 0.00328–0.00580 pg WHO-TEQ/Nm^3 and 0.00307–0.00542 pg WHO-TEQ/Nm^3, respectively. The mean total PCB concentrations in atmosphere of Tainan City in summer (June, July and August) during 2012 and 2013 were 1.40–1.66 pg/Nm^3 and 1.39–1.86 pg/Nm^3, respectively. In terms of WHO-TEQ_{2005}, the WHO-TEQ_{2005} concentrations were 0.00307–0.00363 pg WHO-TEQ/Nm^3 and 0.00305–0.00407 pg WHO-TEQ/Nm^3, respectively. The mean total PCB concentrations in atmosphere of Tainan City in fall (September, October and November) during2012 and 2013 were 2.38–3.21 pg/Nm^3 and 2.29–3.94 pg/Nm^3, respectively. In terms of WHO-TEQ_{2005}, the WHO-TEQ_{2005} concentrations

were 0.00520–0.00703 pg WHO-TEQ/Nm^3 and 0.00502–0.00861 pg WHO-TEQ/Nm^3, respectively. The mean total PCB concentrations in atmosphere of Tainan City in winter (January, February and December) during 2012 and 2013 were 2.66–2.78 pg/Nm^3 and 3.22–3.40 pg/Nm^3, respectively. In terms of WHO-TEQ_{2005}, the WHO-TEQ_{2005} concentrations were 0.00499–0.00469 pg WHO-TEQ/Nm^3 and 0.00543–0.00574 pg WHO-TEQ/Nm^3, respectively.

The maximum and minimum total PCB concentrations in 2012 were 3.43 pg/Nm^3 (March) and 1.40 pg/Nm^3 (July), respectively. The maximum and minimum concentrations in 2013 were 3.94 pg/Nm^3 (November) and 1.39 pg/Nm^3 (August), respectively.

The maximum and minimum total PCB WHO-TEQ_{2005} concentrations in 2012 were 0.00580 pg WHO-TEQ/Nm^3 (March) and 0.00307 pg WHO-TEQ/Nm^3 (July), respectively. The maximum and minimum concentrations in 2013 were 0.00861 pg WHO-TEQ/Nm^3 (November) and 0.00305 pg WHO-TEQ/Nm^3 (August), respectively. When comparing with the PCDD/F concentrations, the atmospheric PCB WHO-TEQ concentrations were 10 times lower than the PCDD/Fs, which indicated the toxicity in the ambient air was mainly dominated by PCDD/Fs. In this study, the result shows the simulated total (PCDD/Fs plus PCBs) atmospheric concentrations of Tainan city. The maximum total concentrations in the ambient air during 2012 and 2013 are 0.0703 pg/Nm^3 (March) and 0.0795 pg/Nm^3 (November), respectively.

Gas-Particle Partitioning

Atmosphere is a significant transport pathway influencing the global deposition of natural and anthropogenic POPs (Pacyna *et al.*, 2003; Quaß *et al.*, 2004), thus gas-particle partitioning of PCDD/Fs and PCBs in the atmosphere will affect such process (Lohmann and Jones, 1998). The methods to evaluate gas-particle partitioning, the subcooled liquid vapor pressure and gas-particle partitioning constant were presented in foregoing section.

The required meteorological information for the subcooled liquid vapor pressure (P_L^o) and gas-particle partitioning constant (K_p) are presented in Tseng (2014). The total suspended particulate (TSP) concentrations were evaluated by the fraction, TSP: PM_{10} = 1.24:1, which was cited from Sheu *et al.* (1996). On the basis of the meteorological information, the evaluated P_L^o and K_p of PCDD/Fs and PCBs in the atmosphere during 2012 and 2013 can be simulated. From the data of both PCDD/Fs and PCBs, the simulated value of P_L^o decline with the increase of substituted chlorine numbers; nevertheless, the value of K_p shows increase trend, which is opposed to the former. Consequently, the PCDD/F and PCB congeners that possess more chlorine atoms will have higher fraction of particle-phase at identical temperature and TSP concentration.

The gas-particle partitioning in the ambient air of PCDD/Fs and PCBs are also be calculated. According to the results of contribution fraction of particle phase, the PCDD/F and PCB congeners with higher chlorine numbers occupied a higher particle fraction. Compare the particulate fraction of PCDDs and PCDFs, PCDD homologues is apt to attaching to particles than the equivalent PCDFs, which might owing to the vapor pressure of PCDFs are slightly less than PCDDs (Rordorf, 1989). Comparable results can also be found in previous studies (Lohmann and Jones, 1998; Chao *et al.*, 2004; Lin *et al.*, 2010a). Different from the PCDD/F gas-particle partitioning, the predominance of gaseous PCBs in the atmosphere is well-known and it has been pointed out in several other studies (Mandalakis and Stephanou, 2004 and Tasdemir *et al.*, 2005).

Furthermore, the particulate fractions of PCDD/Fs and PCBs decline with the increase of ambient temperature. Previous study reported that vapor pressure is the predominant factor which affect the partition between gas and particle phase of semi-volatile organic compounds (Pankow, 1987). The study also reported the ambient temperature would be a significant factor influencing the gas-particle partitioning. Take PCB-189 for example, the particulate fraction in January 2012 (temperature 12.2–27.3°C) is 88.5%; however, the fraction decrease to 31.6% in July 2012 (temperature 32.4–25.6°C). The result also reveals PCB-189 dominated by gas phase in summer (from June to Aug.), but particulate phase dominant in a lower temperature season, such as in winter (from Dec. to Feb.).

Dry Deposition of PCDD/Fs and PCBs

The atmospheric dry deposition fluxes of SVOCs are the combination of both gas- and particle-phase flux, and the method to calculate dry deposition fluxes of SVOCs were demonstrated in previous section of the article. Dry depositions of gas-phase PCDD/Fs and PCBs are predominantly by diffusion. Owing to the lack of measured data for PCDD/Fs and PCBs, 0.01 (cm/s) is selected as the dry deposition velocity for both gaseous phase PCDD/Fs and PCBs. The above value was reported by Sheu *et al.* (1996) used as the dry deposition velocity of gaseous polycyclic aromatic hydrocarbon (PAH), applied by Lee *et al.* (1996b). Shih *et al.* (2006) and Lee *et al.* (1996a) reported the mean dry deposition velocities of total PCDD/Fs and total PCBs, which were 0.420 and 0.280 (cm/sec), respectively (Lee *et al.*, 1996a; Shih *et al.*, 2006).

Dry deposition of particle-phase PCDD/Fs and PCBs are predominantly by the gravitational settling. Therefore, the dry deposition velocity (0.42 cm/s) of total PCDD/Fs combine with gaseous phase deposition velocity 0.01 (cm/s) to calculate deposition velocity of particulate phase. Then, by using the calculated total PCDD/F dry deposition velocity in particulate phase (Eq. (6)) as that is particulate-phase total PCBs ($V_{d,p}$ of total-PCBs). This can be explained that both PCDD/Fs and PCBs were bounded to the same particulates that have the same average settling velocity.

The required information for evaluating PCDD/F and PCB dry deposition fluxes is presented in Tseng (2014). The maximum and minimum simulated dry deposition velocities of particle-phase PCDD/Fs and PCBs during 2012 are 0.718 and 0.489 cm/s in July and January, respectively. For 2013, the maximum and minimum simulated dry deposition velocities of particle-phase PCDD/Fs and PCBs are 0.705 and 0.479 cm/s in August and January, respectively.

Tables 1 to 8 list the simulated PCDD/F and PCB dry

Table 1. Simulated PCDD/F dry deposition fluxes in the ambient air of Tainan City during January 2012 to June 2012 (pg/m^2-month).

PCDD/Fs	Jan.			Feb.			March			April			May			June		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
2,3,7,8-TeCDD	0.174	0.154	88.7	0.179	0.158	88.5	0.175	0.149	84.9	0.0648	0.0447	69.0	0.0407	0.0244	60.0	0.0309	0.0169	54.5
1,2,3,7,8-PeCDD	1.52	1.48	97.8	1.57	1.53	97.8	1.63	1.58	96.9	0.618	0.570	92.2	0.365	0.324	88.7	0.248	0.214	86.2
1,2,3,4,7,8-HxCDD	2.18	2.18	99.6	2.28	2.27	99.6	2.69	2.68	99.4	1.48	1.45	98.4	0.980	0.956	97.5	0.706	0.684	96.9
1,2,3,6,7,8-HxCDD	4.36	4.34	99.6	4.55	4.53	99.6	5.40	5.36	99.4	3.01	2.96	98.4	2.01	1.96	97.6	1.53	1.48	97.0
1,2,3,7,8,9-HxCDD	3.98	3.96	99.7	4.15	4.13	99.7	4.96	4.93	99.5	2.84	2.80	98.6	1.92	1.88	97.9	1.34	1.31	97.4
1,2,3,4,6,7,8-HpCDD	36.3	36.3	99.9	38.0	38.0	99.9	48.0	47.9	99.9	35.8	35.7	99.7	28.7	28.6	99.6	21.6	21.4	99.4
OCDD	101	101	100	106	106	100	136	136	100	110	110	99.9	95.2	95.2	99.9	104	104	99.9
2,3,7,8-TeCDF	1.32	1.11	83.8	1.36	1.14	83.5	1.35	1.06	78.8	0.527	0.316	59.9	0.343	0.172	50.2	0.228	0.102	44.7
1,2,3,7,8-PeCDF	4.76	4.56	95.8	4.91	4.70	95.7	4.88	4.59	94.0	1.74	1.49	85.9	1.03	0.827	80.3	0.666	0.509	76.5
2,3,4,7,8-PeCDF	7.94	7.69	96.9	8.20	7.94	96.9	8.29	7.92	95.6	3.02	2.70	89.3	1.78	1.51	84.8	1.28	1.05	81.6
1,2,3,4,7,8-HxCDF	16.2	16.1	99.2	16.9	16.7	99.2	19.0	18.8	98.9	8.97	8.70	97.0	5.59	5.34	95.5	3.75	3.54	94.4
1,2,3,6,7,8-HxCDF	15.2	15.0	99.3	15.8	15.6	99.3	17.9	17.7	98.9	8.53	8.28	97.2	5.33	5.11	95.7	3.63	3.44	94.7
1,2,3,7,8,9-HxCDF	1.54	1.53	99.6	1.61	1.60	99.6	1.89	1.88	99.3	1.02	1.00	98.2	0.669	0.651	97.3	0.468	0.452	96.6
2,3,4,6,7,8-HxCDF	18.7	18.6	99.5	19.5	19.4	99.4	22.6	22.5	99.2	11.6	11.4	97.8	7.46	7.22	96.7	5.38	5.16	95.9
1,2,3,4,6,7,8-HpCDF	77.0	76.9	99.9	80.5	80.4	99.9	99.7	99.5	99.8	67.2	66.8	99.4	50.0	49.5	99.0	32.4	32.0	98.8
1,2,3,4,7,8,9-HpCDF	12.9	12.9	99.9	13.5	13.5	99.9	17.0	17.0	99.9	12.6	12.6	99.7	10.1	10.0	99.5	7.54	7.49	99.4
OCDF	60.0	60.0	100	62.8	62.8	100	80.3	80.3	100	64.5	64.5	99.9	55.3	55.2	99.9	43.0	43.0	99.8
PCDDs	150	149	99.9	157	156	99.9	198	198	99.9	154	153	99.8	129	129	99.7	130	129	99.7
PCDFs	216	214	99.5	225	224	99.5	273	271	99.3	180	178	98.8	138	136	98.6	98.4	96.7	98.3
PCDDs/PCDFs ratio	0.694	0.697	-	0.696	0.699	-	0.727	0.731	-	0.856	0.864	-	0.940	0.951	-	1.32	1.34	-
Total PCDD/Fs	**365**	**364**	**99.7**	**381**	**380**	**99.7**	**471**	**469**	**99.6**	**334**	**331**	**99.3**	**267**	**264**	**99.1**	**228**	**226**	**99.1**
PCDDs (WHO-TEQ)	3.14	3.08	98.1	3.26	3.20	98.2	3.63	3.54	97.5	1.81	1.73	95.6	1.21	1.14	94.2	0.883	0.823	93.2
PCDFs (WHO-TEQ)	8.74	8.60	98.4	9.08	8.93	98.3	10.1	9.89	97.9	4.84	4.63	95.7	3.12	2.94	94.2	2.16	2.01	93.1
PCDDs/PCDFs WHO-TEQ ratio	0.359	0.358	-	0.359	0.358	-	0.359	0.358	-	0.373	0.373	-	0.389	0.389	-	0.408	0.410	-
Total PCDD/Fs (WHO-TEQ)	**11.9**	**11.7**	**98.4**	**12.3**	**12.1**	**98.4**	**13.7**	**13.4**	**97.9**	**6.65**	**6.36**	**95.7**	**4.33**	**4.08**	**94.1**	**3.05**	**2.83**	**92.9**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 2. Simulated PCDD/F dry deposition fluxes in the ambient air of Tainan City during July 2012 to December 2012 (pg/m^2-month).

PCDD/Fs	July			Aug.			Sep.			Oct.			Nov.			Dec.		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
2,3,7,8-TeCDD	0.0232	0.0113	48.6	0.0286	0.0154	53.7	0.0525	0.0326	62.0	0.106	0.0798	75.3	0.105	0.0819	77.8	0.138	0.118	85.1
1,2,3,7,8-PeCDD	0.174	0.145	83.1	0.228	0.196	85.9	0.447	0.401	89.5	0.963	0.908	94.2	0.961	0.914	95.0	1.29	1.25	97.0
1,2,3,4,7,8-HxCDD	0.512	0.492	96.0	0.653	0.632	96.8	1.19	1.16	97.7	2.09	2.06	98.8	1.97	1.95	99.0	2.11	2.10	99.4
1,2,3,6,7,8-HxCDD	1.11	1.07	96.2	1.41	1.37	96.9	2.56	2.50	97.8	4.44	4.39	98.9	4.18	4.14	99.0	4.23	4.21	99.5
1,2,3,7,8,9-HxCDD	0.983	0.950	96.6	1.24	1.21	97.3	2.23	2.18	98.0	3.79	3.75	99.0	3.55	3.52	99.2	3.88	3.86	99.5
1,2,3,4,6,7,8-HpCDD	17.7	17.6	99.3	20.3	20.2	99.4	31.4	31.2	99.6	42.2	42.1	99.8	37.7	37.7	99.8	37.3	37.2	99.9
OCDD	92.4	92.3	99.9	98.8	98.7	99.9	142	142	99.9	174	174	100	153	153	100	105	105	100
2,3,7,8-TeCDF	0.175	0.0683	38.9	0.212	0.093	43.8	0.378	0.198	52.4	0.725	0.486	67.1	0.712	0.498	70.0	1.06	0.84	79.1
1,2,3,7,8-PeCDF	0.476	0.342	71.8	0.613	0.465	75.8	1.19	0.971	81.5	2.59	2.31	89.3	2.6	2.36	90.7	3.88	3.65	94.2
2,3,4,7,8-PeCDF	0.908	0.705	77.6	1.18	0.957	81.1	2.31	1.98	85.8	5.03	4.63	92.0	5.04	4.69	93.1	6.59	6.31	95.8
1,2,3,4,7,8-HxCDF	2.65	2.47	93.0	3.45	3.26	94.3	6.58	6.30	95.9	12.8	12.5	97.8	12.3	12.1	98.1	15.0	14.9	98.9
1,2,3,6,7,8-HxCDF	2.58	2.40	93.3	3.35	3.17	94.5	6.36	6.11	96.0	12.3	12.0	97.9	11.8	11.6	98.2	14.1	14.0	99.0
1,2,3,7,8,9-HxCDF	0.338	0.324	95.7	0.433	0.418	96.5	0.793	0.773	97.5	1.41	1.39	98.7	1.33	1.32	98.9	1.48	1.47	99.4
2,3,4,6,7,8-HxCDF	3.85	3.65	94.8	4.97	4.76	95.8	9.25	8.97	97.0	17.0	16.7	98.4	16.2	16	98.7	17.8	17.7	99.2
1,2,3,4,6,7,8-HpCDF	25.1	24.7	98.4	30.2	29.9	98.7	50.2	49.7	99.1	74.6	74.2	99.5	67.9	67.6	99.6	77.7	77.5	99.8
1,2,3,4,7,8,9-HpCDF	6.17	6.12	99.2	7.08	7.04	99.4	11.0	11.0	99.6	14.9	14.9	99.8	13.4	13.3	99.8	13.2	13.2	99.9
OCDF	37.7	37.6	99.8	40.7	40.7	99.8	59.0	59.0	99.9	73.3	73.2	99.9	64.7	64.6	100	62.2	62.2	100
PCDDs	113	113	99.7	123	122	99.7	180	179	99.8	227	227	99.8	202	201	99.9	154	154	99.9
PCDFs	80	78.4	98.1	92.3	90.7	98.3	147	145	98.6	215	212	99.0	196	194	99.1	213	212	99.4
PCDDs/PCDFs ratio	1.41	1.44	-	1.33	1.35	-	1.22	1.24	-	1.06	1.07	-	1.03	1.04	-	0.722	0.726	-
Total PCDD/Fs	**193**	**191**	**99.0**	**215**	**213**	**99.1**	**327**	**324**	**99.2**	**442**	**439**	**99.4**	**398**	**396**	**99.5**	**367**	**365**	**99.6**
PCDDs (WHO-TEQ)	0.633	0.611	92.2	0.820	0.763	93.0	1.45	1.37	94.5	2.58	2.48	96.1	2.46	2.38	96.7	2.86	2.79	97.6
PCDFs (WHO-TEQ)	1.57	1.43	91.1	2.00	1.85	92.5	3.69	3.48	94.3	6.92	6.68	96.5	6.67	6.47	97.0	7.97	7.81	98.0
PCDDs/PCDFs WHO-TEQ ratio	0.422	0.426	-	0.410	0.412	-	0.394	0.394	-	0.372	0.371	-	0.369	0.368	-	0.359	0.358	-
Total PCDD/Fs (WHO-TEQ)	**2.23**	**2.04**	**91.5**	**2.82**	**2.61**	**92.7**	**5.15**	**4.86**	**94.3**	**9.49**	**9.16**	**96.5**	**9.13**	**8.84**	**96.9**	**10.8**	**10.6**	**97.9**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 3. Simulated PCDD/F dry deposition fluxes in the ambient air of Tainan City during January 2013 to June 2013 (pg/m^2-month).

PCDD/Fs	Jan.			Feb.			March			April			May			June		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
2,3,7,8-TeCDD	0.251	0.228	90.9	0.202	0.176	87.3	0.149	0.123	83.1	0.0985	0.0764	77.5	0.0393	0.0241	61.3	0.0351	0.0194	55.2
1,2,3,7,8-PeCDD	2.04	2.00	98.3	1.80	1.76	97.5	1.41	1.36	96.5	0.961	0.912	94.9	0.358	0.320	89.3	0.282	0.244	86.5
1,2,3,4,7,8-HxCDD	2.69	2.68	99.7	2.75	2.73	99.5	2.46	2.44	99.3	1.95	1.93	99.0	0.949	0.927	97.7	0.799	0.774	96.9
1,2,3,6,7,8-HxCDD	5.36	5.35	99.7	5.49	5.47	99.5	4.94	4.91	99.3	3.93	3.89	99.0	1.94	1.90	97.8	1.73	1.68	97.1
1,2,3,7,8,9-HxCDD	4.87	4.86	99.7	5.02	5.00	99.6	4.55	4.53	99.4	3.66	3.63	99.1	1.85	1.82	98.0	1.52	1.48	97.4
1,2,3,4,6,7,8-HpCDD	43.3	43.3	100	46.9	46.9	99.9	45.2	45.2	99.9	39.7	39.7	99.8	26.9	26.8	99.6	24.2	24.0	99.4
OCDD	120	120	100	131	131	100	129	129	100	116	116	100	87.8	87.7	99.9	117	116	99.9
2,3,7,8-TeCDF	1.91	1.66	86.8	1.54	1.27	82.0	1.15	0.880	76.6	0.776	0.541	69.6	0.329	0.17	51.5	0.259	0.118	45.4
1,2,3,7,8-PeCDF	6.66	6.43	96.7	5.56	5.29	95.1	4.16	3.88	93.2	2.75	2.49	90.5	1.01	0.816	81.2	0.759	0.583	76.9
2,3,4,7,8-PeCDF	10.9	10.6	97.6	9.34	9.01	96.4	7.11	6.76	95.0	4.75	4.42	92.9	1.74	1.49	85.5	1.46	1.20	82.0
1,2,3,4,7,8-HxCDF	20.5	20.4	99.4	20.0	19.8	99.1	17.1	16.9	98.7	12.7	12.5	98.1	5.45	5.22	95.8	4.25	4.02	94.5
1,2,3,6,7,8-HxCDF	19.1	19.0	99.4	18.7	18.6	99.1	16.1	15.9	98.8	12.0	11.8	98.2	5.20	5.00	960	4.12	3.91	94.8
1,2,3,7,8,9-HxCDF	1.90	1.90	99.7	1.93	1.92	99.5	1.72	1.71	99.2	1.35	1.34	98.9	0.649	0.633	97.5	0.53	0.512	96.7
2,3,4,6,7,8-HxCDF	23.3	23.2	99.6	23.4	23.2	99.4	20.5	20.3	99.1	15.8	15.6	98.6	7.26	7.03	970	6.10	5.85	96.0
1,2,3,4,6,7,8-HpCDF	92.7	92.6	99.9	98.7	98.5	99.8	93.2	92.9	99.7	79.2	78.9	99.6	47.5	47.0	99.1	36.5	36.0	98.8
1,2,3,4,7,8,9-HpCDF	15.4	15.4	99.9	16.6	16.6	99.9	16.0	16.0	99.9	14.0	14.0	99.8	9.44	9.39	99.6	8.45	8.40	99.4
OCDF	71.2	71.2	100	77.9	77.8	100	76.2	76.2	100	68.4	68.4	100	51.1	51.0	99.9	48.1	48.0	99.8
PCDDs	178	178	99.9	193	193	99.9	187	187	99.9	166	166	99.8	120	120	99.7	145	145	99.7
PCDFs	264	262	99.5	274	272	99.4	253	251	99.3	212	210	99.1	130	128	98.6	111	109	98.3
PCDDs/PCDFs ratio	0.677	0.679	-	0.707	0.71	-	0.74	0.745	-	0.784	0.790	-	0.925	0.935	-	1.31	1.33	-
Total PCDD/Fs	**442**	**441**	**99.7**	**467**	**465**	**99.6**	**441**	**439**	**99.5**	**378**	**376**	**99.4**	**249**	**247**	**99.1**	**256**	**253**	**99.1**
PCDDs (WHO-TEQ)	4.05	3.99	98.5	3.84	3.76	97.9	3.24	3.16	97.5	2.45	2.37	96.7	1.17	1.10	94.0	0.998	0.932	93.4
PCDFs (WHO-TEQ)	11.3	11.1	98.2	10.7	10.5	98.1	9.03	8.82	97.7	6.74	6.53	96.9	3.03	2.86	94.4	2.45	2.28	93.7
PCDDs/PCDFs WHO-TEQ ratio	0.360	0.359	-	0.359	0.358	-	0.359	0.358	-	0.363	0.362	-	0.386	0.386	-	0.407	0.409	-
Total PCDD/Fs (WHO-TEQ)	**15.3**	**15.1**	**98.6**	**14.5**	**14.3**	**98.2**	**12.3**	**12.0**	**97.6**	**9.18**	**8.90**	**96.9**	**4.19**	**3.96**	**94.4**	**3.45**	**3.21**	**93.0**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 4. Simulated PCDD/F dry deposition fluxes in the ambient air of Tainan City during July 2013 to December 2013 (pg/m^2-month).

PCDD/Fs	July			Aug.			Sep.			Oct.			Nov.			Dec.		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
2,3,7,8-TeCDD	0.025	0.0126	50.3	0.0236	0.0118	49.8	0.0494	0.0301	61.0	0.127	0.0973	76.6	0.198	0.167	84.5	0.247	0.223	90.2
1,2,3,7,8-PeCDD	0.192	0.161	84.1	0.180	0.151	83.8	0.418	0.372	89.1	1.15	1.09	94.6	1.72	1.67	96.8	2.06	2.02	98.1
1,2,3,4,7,8-HxCDD	0.560	0.540	96.3	0.528	0.508	96.2	1.12	1.10	97.6	2.42	2.39	98.9	2.95	2.93	99.4	2.8	2.79	99.7
1,2,3,6,7,8-HxCDD	1.21	1.17	96.5	1.14	1.10	96.4	2.42	2.36	97.7	5.15	5.10	98.9	6.22	6.18	99.4	5.59	5.57	99.7
1,2,3,7,8,9-HxCDD	1.07	1.04	96.9	1.01	0.979	96.8	2.11	2.06	98.0	4.38	4.34	99.1	5.22	5.19	99.5	5.08	5.07	99.7
1,2,3,4,6,7,8-HpCDD	18.7	18.6	99.3	17.8	17.6	99.3	30.2	30.1	99.6	47.9	47.8	99.8	50.2	50.1	99.9	45.7	45.6	99.9
OCDD	95.1	94.9	99.9	90.8	90.6	99.9	138	138	99.9	196	196	100	198	198	100	127	127	100
2,3,7,8-TeCDF	0.188	0.0763	40.6	0.178	0.0712	40.1	0.357	0.183	51.3	0.865	0.594	68.7	1.31	1.03	78.4	1.88	1.62	85.8
1,2,3,7,8-PeCDF	0.521	0.382	73.2	0.490	0.357	72.8	1.11	0.900	80.9	3.10	2.79	90.0	4.87	4.58	93.9	6.62	6.38	96.3
2,3,4,7,8-PeCDF	0.998	0.787	78.9	0.937	0.736	78.6	2.16	1.84	85.2	6.02	5.57	92.5	9.30	8.88	95.5	10.9	10.6	97.3
1,2,3,4,7,8-HxCDF	2.92	2.73	93.4	2.75	2.56	93.3	6.17	5.90	95.7	15.0	14.7	98.0	19.8	19.6	98.8	21.1	21.0	99.3
1,2,3,6,7,8-HxCDF	2.84	2.66	93.7	2.67	2.50	93.6	5.97	5.72	95.9	14.4	14.1	98.1	18.9	18.6	98.9	19.7	19.6	99.4
1,2,3,7,8,9-HxCDF	0.370	0.356	96.0	0.349	0.335	95.9	0.748	0.728	97.4	1.64	1.62	98.8	2.01	2.00	99.3	1.98	1.97	99.6
2,3,4,6,7,8-HxCDF	4.23	4.03	95.2	3.98	3.78	95.1	8.70	8.43	96.8	19.8	19.6	98.5	25.0	24.8	99.2	24.2	24.1	99.5
1,2,3,4,6,7,8-HpCDF	27.0	26.6	98.5	25.5	25.1	98.5	48.0	47.5	99.1	85.2	84.9	99.6	93.7	93.5	99.8	97.4	97.2	99.9
1,2,3,4,7,8,9-HpCDF	6.51	6.46	99.3	6.18	6.14	99.3	10.6	10.6	99.5	16.9	16.9	99.8	17.8	17.8	99.9	16.2	16.2	99.9
OCDF	38.9	38.8	99.8	37.1	37.1	99.8	57.4	57.3	99.9	82.7	82.7	99.9	84.0	83.9	100	75.2	75.2	100
PCDDs	117	116	99.7	111	111	99.7	174	174	99.8	257	257	99.9	265	264	99.9	188	188	99.9
PCDFs	84.4	82.9	98.1	80.2	78.7	98.1	141	139	98.5	246	243	99.0	277	275	99.3	275	274	99.5
PCDDs/PCDFs ratio	1.38	1.40	-	1.39	1.41	-	1.23	1.25	-	1.05	1.06	-	0.956	0.962	-	0.683	0.686	-
Total PCDD/Fs	**201**	**199**	**99.0**	**192**	**190**	**99.0**	**315**	**313**	**99.2**	**503**	**500**	**99.5**	**541**	**539**	**99.6**	**463**	**462**	**99.7**
PCDDs (WHO-TEQ)	0.717	0.663	92.5	0.677	0.625	92.3	1.38	1.30	94.2	3.01	2.90	96.3	3.92	3.83	97.7	4.14	4.08	98.4
PCDFs (WHO-TEQ)	1.72	1.57	91.3	1.62	1.48	91.4	3.48	3.27	94.0	8.12	7.85	96.7	10.8	10.5	97.2	11.5	11.4	98.6
PCDDs/PCDFs WHO-TEQ ratio	0.418	0.421	-	0.419	0.422	-	0.396	0.396	-	0.371	0.370	-	0.364	0.363	-	0.360	0.359	-
Total PCDD/Fs (WHO-TEQ)	**2.43**	**2.24**	**91.9**	**2.29**	**2.11**	**91.8**	**4.85**	**4.57**	**94.2**	**11.1**	**10.8**	**96.7**	**14.7**	**14.4**	**97.8**	**15.7**	**15.4**	**98.5**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 5. Simulated PCB dry deposition fluxes in the ambient air of Tainan City during January 2012 to June 2012 (pg/m^2-month).

PCBs	Jan.			Feb.			March			April			May			June		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
PCB-77 (4CL)	13.5	9.34	69.3	13.9	9.58	68.9	14.1	8.70	61.6	6.39	2.48	38.8	4.48	1.34	29.9	3.13	0.797	25.5
PCB-81 (4CL)	1.24	0.767	61.8	1.28	0.786	61.4	1.32	0.707	53.4	0.642	0.199	31.0	0.463	0.107	23.2	0.357	0.0693	19.4
PCB-105 (5CL)	32.5	28.8	88.7	33.4	29.6	88.5	31.9	27.0	84.4	11.6	7.80	67.4	7.26	4.2	57.9	5.90	3.08	52.3
PCB-114 (5CL)	2.82	2.34	82.9	2.90	2.40	82.6	2.81	2.17	77.2	1.09	0.62	56.7	0.715	0.334	46.6	0.670	0.276	41.1
PCB-118 (5CL)	61.4	51.3	83.7	63.2	52.7	83.4	61.2	47.9	78.2	23.6	13.8	58.2	15.4	7.42	48.2	11.4	4.87	42.6
PCB-123 (5CL)	1.55	1.28	82.1	1.60	1.31	81.8	1.55	1.18	76.2	0.609	0.337	55.3	0.401	0.181	45.2	0.470	0.186	39.7
PCB-126 (5CL)	4.85	4.59	94.6	4.99	4.71	94.5	4.76	4.39	92.2	1.62	1.32	81.3	0.963	0.713	74.1	0.913	0.635	69.5
PCB-156 (6CL)	19.0	18.6	98.0	19.6	19.2	97.9	20.2	19.6	97.0	7.61	7.04	92.4	4.47	3.97	88.9	4.01	3.47	86.4
PCB-157 (6CL)	5.38	5.29	98.2	5.57	5.47	98.2	5.79	5.64	97.4	2.22	2.07	93.2	1.31	1.18	90.0	1.24	1.09	87.7
PCB-167 (6CL)	8.28	8.06	97.3	8.54	8.30	97.2	8.53	8.19	96.0	3.04	2.73	89.8	1.77	1.51	85.2	1.48	1.21	82.1
PCB-169 (6CL)	2.88	2.86	99.6	3.00	2.98	99.6	3.52	3.50	99.4	1.89	1.85	98.3	1.23	1.20	97.3	1.29	1.24	96.6
PCB-189 (7CL)	7.60	7.58	99.7	7.93	7.90	99.7	9.55	9.51	99.6	5.67	5.60	98.8	3.89	3.82	98.2	3.32	3.24	97.7
Total PCBs	**161**	**141**	**87.5**	**166**	**145**	**87.3**	**165**	**138**	**83.7**	**66.0**	**45.8**	**69.4**	**42.3**	**26.0**	**61.3**	**34.2**	**20.2**	**59.0**
Total PCBs (WHO-TEQ)	**0.577**	**0.550**	**95.2**	**0.595**	**0.566**	**95.1**	**0.588**	**0.549**	**93.3**	**0.221**	**0.189**	**85.4**	**0.135**	**0.108**	**80.2**	**0.131**	**0.101**	**77.3**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 6. Simulated PCB dry deposition fluxes in the ambient air of Tainan City during July 2012 to December 2012 (pg/m^2-month).

PCBs	July			Aug.			Sep.			Oct.			Nov.			Dec.		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
PCB-77 (4CL)	2.51	0.531	21.2	2.93	0.726	24.8	4.88	1.55	31.7	8.36	3.89	46.5	8.03	4.02	50.0	11.1	6.93	62.2
PCB-81 (4CL)	0.289	0.0460	15.9	0.334	0.0631	18.9	0.546	0.135	24.7	0.893	0.34	38.1	0.859	0.362	42.2	1.22	0.738	60.6
PCB-105 (5CL)	4.44	2.05	46.1	5.46	2.81	51.5	9.95	5.96	59.8	20.2	15.0	74.0	20.7	16.0	77.3	32.2	28.3	88.0
PCB-114 (5CL)	0.518	0.183	35.3	0.623	0.251	40.3	1.10	0.534	48.7	2.09	1.35	64.3	2.10	1.44	68.2	2.77	2.28	82.1
PCB-118 (5CL)	8.81	3.24	36.8	10.6	4.44	41.8	18.8	9.43	50.2	36.1	23.7	65.6	36.3	25.2	69.4	60.5	50.1	82.8
PCB-123 (5CL)	0.364	0.124	34.0	0.437	0.17	38.9	0.765	0.361	47.2	1.45	0.911	62.9	1.45	0.973	66.9	1.53	1.24	81.2
PCB-126 (5CL)	0.659	0.421	63.9	0.843	0.58	68.8	1.61	1.22	75.6	3.53	3.03	85.7	3.68	3.24	87.9	4.93	4.64	94.2
PCB-156 (6CL)	2.81	2.34	83.2	3.69	3.17	86.1	7.24	6.49	89.7	15.7	14.9	94.4	16.2	15.4	95.3	21.0	20.5	97.8
PCB-157 (6CL)	0.866	0.734	84.8	1.14	0.997	87.4	2.24	2.03	90.7	4.84	4.60	95.0	4.97	4.77	95.9	6.01	5.90	98.1
PCB-167 (6CL)	1.04	0.811	78.1	1.36	1.11	81.6	2.66	2.29	86.2	5.9	5.45	92.4	6.12	5.74	93.7	8.87	8.61	97.1
PCB-169 (6CL)	0.925	0.885	95.7	1.19	1.15	96.5	2.18	2.12	97.5	3.92	3.87	98.7	3.83	3.79	99.0	3.61	3.60	99.6
PCB-189 (7CL)	2.45	2.37	97.1	3.08	3.01	97.7	5.43	5.34	98.3	9.04	8.97	99.2	8.65	8.59	99.3	9.77	9.74	99.7
Total PCBs	**25.7**	**13.7**	**53.5**	**31.7**	**18.5**	**58.3**	**57.4**	**37.4**	**65.3**	**112**	**85.9**	**76.6**	**113**	**89.6**	**79.3**	**163**	**143**	**87.2**
Total PCBs (WHO-TEQ)	**0.0946**	**0.0691**	**73.0**	**0.121**	**0.093**	**76.8**	**0.228**	**0.187**	**81.7**	**0.475**	**0.422**	**88.8**	**0.487**	**0.440**	**90.4**	**0.607**	**0.577**	**95.0**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 7. Simulated PCB dry deposition fluxes in the ambient air of Tainan City during January 2013 to June 2013 (pg/m^2-month).

PCBs	Jan.			Feb.			March			April			May			June		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
PCB-77 (4CL)	19.2	14.3	74.3	15.8	10.5	66.4	12.2	7.16	58.5	8.73	4.33	49.6	4.26	1.32	31.1	3.53	0.916	25.9
PCB-81 (4CL)	1.74	1.18	67.5	1.47	0.860	58.6	1.16	0.580	50.1	0.849	0.349	41.1	0.438	0.106	24.2	0.402	0.0795	19.8
PCB-105 (5CL)	47.2	42.9	91.0	37.2	32.4	87.1	27.0	22.3	82.5	17.8	13.6	76.5	7.02	4.17	59.4	6.68	3.53	52.8
PCB-114 (5CL)	4.10	3.53	86.2	3.25	2.62	80.8	2.39	1.79	74.8	1.61	1.08	67.3	0.687	0.331	48.1	0.758	0.316	41.6
PCB-118 (5CL)	89.2	77.4	86.8	70.8	57.8	81.6	52.1	39.5	75.8	35.0	24.0	68.5	14.8	7.34	49.6	12.9	5.58	43.1
PCB-123 (5CL)	2.26	1.93	85.4	1.79	1.43	79.8	1.32	0.974	73.6	0.894	0.590	65.9	0.385	0.180	46.6	0.531	0.214	40.2
PCB-126 (5CL)	6.90	6.60	95.8	5.54	5.19	93.7	4.03	3.67	91.1	2.61	2.28	87.5	0.943	0.711	75.4	1.04	0.723	69.8
PCB-156 (6CL)	25.4	25.0	98.4	22.5	22.0	97.6	17.5	16.9	96.6	11.9	11.3	95.1	4.39	3.94	89.6	4.55	3.95	86.6
PCB-157 (6CL)	7.16	7.06	98.6	6.41	6.28	97.9	5.04	4.89	97.0	3.46	3.31	95.7	1.29	1.16	90.6	1.41	1.24	87.9
PCB-167 (6CL)	11.3	11.1	97.9	9.67	9.36	96.8	7.32	6.98	95.4	4.87	4.54	93.4	1.75	1.50	86.1	1.68	1.38	82.3
PCB-169 (6CL)	3.55	3.54	99.7	3.61	3.59	99.5	3.21	3.19	99.3	2.53	2.50	98.9	1.20	1.17	97.5	1.45	1.40	96.7
PCB-189 (7CL)	9.26	9.24	99.8	9.63	9.60	99.7	8.82	8.78	99.5	7.19	7.13	99.3	3.76	3.69	98.3	3.73	3.65	97.8
Total PCBs	**227**	**204**	**89.6**	**188**	**162**	**86.1**	**142**	**117**	**82.1**	**97.5**	**75.1**	**77.0**	**40.9**	**25.6**	**62.6**	**38.7**	**23.0**	**59.4**
Total PCBs (WHO-TEQ)	**0.804**	**0.774**	**96.2**	**0.669**	**0.633**	**94.5**	**0.505**	**0.467**	**92.5**	**0.341**	**0.306**	**89.8**	**0.132**	**0.107**	**81.1**	**0.148**	**0.115**	**77.5**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

Table 8. Simulated PCB dry deposition fluxes in the ambient air of Tainan City during July 2013 to December 2013 (pg/m^2-month).

PCBs	July			Aug.			Sep.			Oct.			Nov.			Dec.		
	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)	$F_{d,T}$	$F_{d,p}$	P (%)
PCB-77 (4CL)	2.66	0.594	22.4	2.52	0.554	22.0	4.65	1.43	30.8	9.83	4.75	48.3	13.9	8.46	61.0	8.74	3.32	38.0
PCB-81 (4CL)	0.305	0.0516	16.9	0.290	0.0481	16.6	0.522	0.124	23.9	1.04	0.415	39.8	1.47	0.803	54.5	0.973	0.358	36.8
PCB-105 (5CL)	4.78	2.29	48.0	4.51	2.14	47.5	9.37	5.51	58.8	24.1	18.2	75.3	40.7	34.6	84.9	19.1	13.9	72.8
PCB-114 (5CL)	0.554	0.205	370	0.524	0.192	36.6	1.04	0.494	47.6	2.49	1.64	65.9	4.03	3.14	78.0	1.76	1.11	62.9
PCB-118 (5CL)	9.43	3.63	38.5	8.91	3.39	38.0	17.8	8.72	49.1	43.0	28.9	67.2	69.9	55.1	78.9	38.3	24.6	64.3
PCB-123 (5CL)	0.389	0.139	35.6	0.368	0.130	35.2	0.724	0.334	46.1	1.72	1.11	64.5	2.77	2.13	76.9	0.98	0.603	61.5
PCB-126 (5CL)	0.720	0.472	65.6	0.678	0.442	65.2	1.51	1.13	74.7	4.22	3.66	86.6	7.35	6.79	92.4	2.74	2.33	84.8
PCB-156 (6CL)	3.10	2.61	84.2	2.91	2.44	84.0	6.76	6.03	89.2	18.7	17.8	94.7	30.4	29.5	97.1	13.0	12.2	94.0
PCB-157 (6CL)	0.957	0.820	85.7	0.899	0.769	85.5	2.09	1.89	90.3	5.75	5.48	95.3	9.23	8.99	97.5	3.77	3.57	94.6
PCB-167 (6CL)	1.14	0.908	79.3	1.08	0.850	79.1	2.48	2.13	85.6	7.04	6.53	92.9	11.8	11.4	96.1	5.18	4.76	91.9
PCB-169 (6CL)	1.02	0.974	96.0	0.957	0.918	95.9	2.06	2.00	97.4	4.55	4.49	98.8	6.03	6.00	99.4	3.07	3.02	98.6
PCB-189 (7CL)	2.67	2.59	97.3	2.52	2.45	97.2	5.15	5.06	98.2	10.4	10.3	99.2	13.1	13.0	99.6	9.08	8.99	99.1
Total PCBs	**27.7**	**15.3**	**55.2**	**26.2**	**14.3**	**54.8**	**54.1**	**34.8**	**64.4**	**133**	**103**	**77.6**	**211**	**180**	**85.4**	**107**	**78.8**	**73.9**
Total PCBs (WHO-TEQ)	**0.103**	**0.0769**	**74.3**	**0.0975**	**0.0722**	**74.0**	**0.214**	**0.174**	**81.1**	**0.563**	**0.504**	**89.4**	**0.924**	**0.865**	**93.7**	**0.37**	**0.326**	**88.1**

Note: Spring: March–May; Summer: June–Aug.; Fall: Sep.–Nov.; Winter: Dec.–Jan.

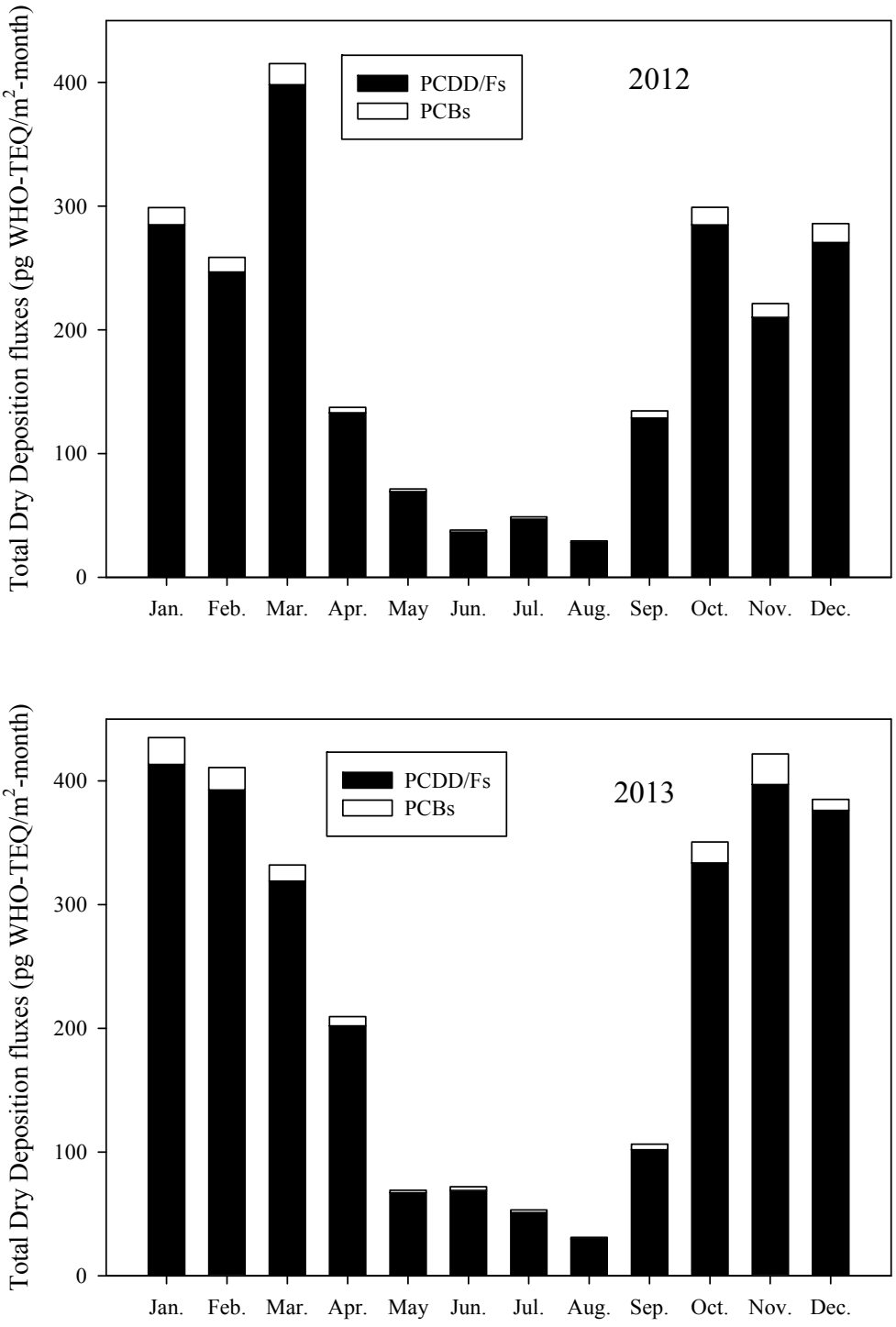

Fig. 2. Total PCDD/F and PCB dry deposition fluxes (pg WHO-TEQ/m^2-month) during 2012 and 2013, respectively.

deposition fluxes in the ambient air of Tainan City during 2012 to 2013 as well as the contribution fractions of particle-phase dry deposition fluxes. The maximum and minimum total PCDD/F dry deposition fluxes in winter during 2012 are 286 (98.4% contributed by particulate phase) and 246 (98.4% contributed by particulate phase) pg WHO-TEQ/m^2-month, respectively. The maximum and minimum total PCDD/F dry deposition fluxes in winter during 2013 are 413 (98.6% contributed by particulate phase) and 377 (98.5% contributed by particulate phase) pg WHO-TEQ/m^2-month, respectively.

For the part of PCBs, the maximum and minimum total PCB dry deposition fluxes in winter during 2012 are 15.2 (95.0% contributed by particulate phase) and 11.9 (95.1% contributed by particulate phase) pg WHO-TEQ/m^2-month, respectively. The maximum and minimum total PCB dry deposition fluxes in winter during 2013 are 21.7 (96.2% contributed by particulate phase) and 8.88 (88.1% contributed by particulate phase) pg WHO-TEQ/m^2-month, respectively.

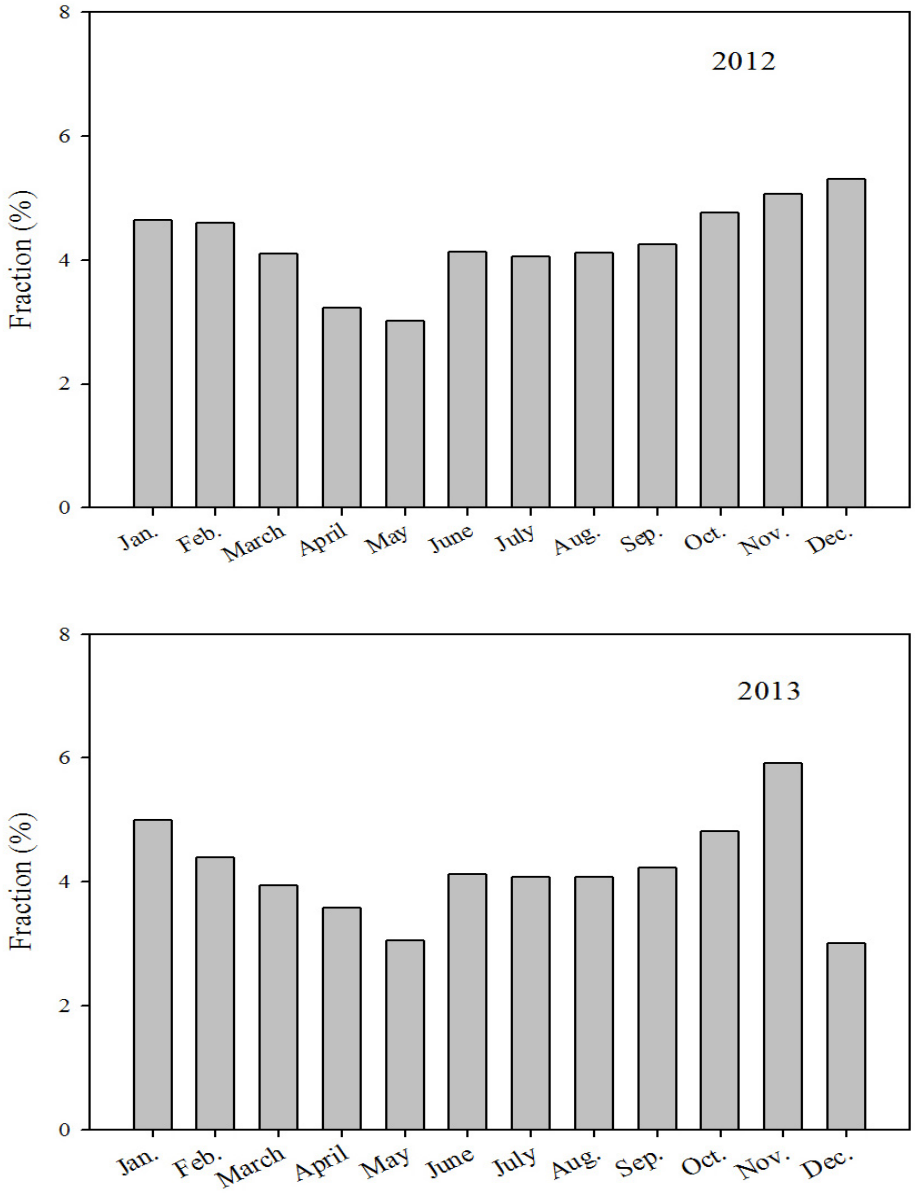

Fig. 3. Fraction of WHO-TEQ contributed by PCB dry depositions during 2012 and 2013, respectively.

The simulated maximum and minimum dry deposition fluxes of PCDD/Fs during whole 2012 are 397 and 28.2 pg WHO-TEQ/m^2-month in March and August, respectively. The simulated maximum and minimum dry deposition fluxes of PCDD/Fs during whole 2013 are 413 and 29.8 pg WHO-TEQ/m^2-month in January and August, respectively. The simulated maximum and minimum dry deposition fluxes of PCBs during whole 2012 are 15.2 and 1.21 pg WHO-TEQ/m^2-month in December and August, respectively. The simulated maximum and minimum dry deposition fluxes of PCBs during whole 2013 are 24.9 and 1.27 pg WHO-TEQ/m^2-month in November and August, respectively.

The highest dry deposition fluxes of PCDD/Fs and PCBs during 2012 to 2013 occurred in spring and winter. For the lowest value for dry deposition fluxes occurred in summer. The results demonstrate that, during 2012 to 2013, dry deposition of PCDD/Fs and PCBs decreased with the ambient temperature increased, which is similar to previous studies (Shih *et al.*, 2006; Wang *et al.*, 2010; Huang, 2011a).

Fig. 2 present total (PCDD/Fs plus PCBs) dry deposition fluxes. From Fig. 2, the maximum total dry deposition during 2012 and 2013 are 415 and 435pg WHO-TEQ/m^2-month in March and January, respectively. The minimum monthly total dry deposition during 2012 and 2013 are 29.4 and 31.1 pg WHO-TEQ/m^2-month both in August, respectively. Fig. 3 shows the fraction of WHO-TEQ contributed by PCB dry deposition fluxes. The contribution fractions from 2.28% to 5.87%, which means the dry PCDD/F deposition fluxes dominate the total dry deposition fluxes. The simulated results demonstrate the dry deposition fluxes of PCDD/Fs and PCBs are dominated by particulate phase, which is probably owing to the higher value of particulate deposition velocities of PCDD/Fs and PCBs (0.479–0.718 cm/s) than the gaseous phase deposition velocity (0.010 cm/s). Furthermore,

among all PCDD/F congeners, the dry deposition fluxes are dominated by OCDD, 1,2,3,4,6,7,8-HpCDF, OCDF and 1,2,3,4,6,7,8-HpCDD. In terms of WHO-TEQ_{2005}, the dry deposition fluxes are dominated by 2,3,4,7,8-PeCDF, followed by 2,3,4,6,7,8-HxCDF, 1,2,3,4,7,8-HxCDF and 1,2,3,7,8-PeCDD.

Among all PCB congeners, the dry deposition fluxes are predominated by PCB-118, PCB-105, PCB-156 and PCB-189. In terms of WHO-TEQ_{2005}, the dry deposition fluxes are predominated by PCB-126, followed by PCB-169, PCB-118 and PCB-77. Previous studies also reported similar results (Lee *et al.*, 1996b; Lin *et al.*, 2010a; Wang *et al.*, 2010; Huang, 2011a).

CONCLUSIONS

Average PCDD/F dry deposition fluxes in spring, summer, fall and winter are 69.3, 28.2, 129 and 246 pg WHO-TEQ/m^2-month during 2012, respectively. As for 2013, the average PCDD/F dry deposition fluxes in spring, summer, fall and winter are 67.0, 29.8, 102 and 377 pg WHO-TEQ/m^2-month, respectively. The maximum PCDD/F dry deposition fluxes occurred in winter, while the minimum value were in summer. Average PCB dry deposition fluxes in spring, summer, fall and winter are 2.16, 1.99, 5.70 and 11.9 pg WHO-TEQ/m^2-month during 2012, respectively. As for 2013, the average PCB dry deposition fluxes in spring, summer, fall and winter are 2.11, 1.27, 4.49 and 8.88 pg WHO-TEQ/m^2-month, respectively. The maximum PCB dry deposition fluxes occurred in winter, while the minimum value were in summer.

The results also demonstrate that the dry deposition fluxes of PCDD/Fs and PCBs are dominated by particulate phase, which is owing to a higher value of particulate deposition velocity of both PCDD/Fs and PCBs (0.479–0.718 cm/s) than the gaseous phase deposition (0.010 cm/s), respectively.

REFERENCES

Agrell, C., Larsson, P., Okla, L. and Agrell, J. (2002). PCB Congeners in Precipitation, Wash Out Ratios and Depositional Fluxes within the Baltic Sea Region, Europe. *Atmos. Environ.* 36: 371–383.

Altarawneh, M., Dlugogorski, B.Z., Kennedy, E.M. and Mackie, J.C. (2009). Mechanisms for Formation, Chlorination, Dechlorination and Destruction of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans (PCDD/Fs). *Prog. Energy Combust. Sci.* 35: 245–274.

Andersson, M., Ottesen, R.T. and Volden, T. (2004). Building Materials as a Source of PCB Pollution in Bergen, Norway. *Sci. Total Environ.* 325: 139–144.

Aristizábal, B.H., Gonzalez, C.M., Morales, L., Abalos, M. and Abad, E. (2011). Polychlorinated Dibenzo-*p*-dioxin and Dibenzofuran in Urban Air of An Andean City. *Chemosphere* 85: 170–178.

Atkinson, R. (1996). Atmospheric Chemistry of PCBs, PCDDs and PCDFs, In *Chlorinated Organic Micropollutants*, Hester, R.E. and Harrison, R.M. (Eds.), Issues in Environmental Science and Technology, Number 6, Royal Society of Chemistry, Cambridge, UK, p. 53–72.

Berg, M.V.D., Birnbaum, L., Bosveld, A.T.C., Brunström, B., Cook, P. and Feeley, M. (1998). Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife. *Environ. Health Perspect.* 106: 775–792.

Bidleman, T.F. (1988). Atmospheric Processes: Wet and Dry Deposition of Organic Compounds are Controlled by Their Vapor-Particle Partitioning. *Environ. Sci. Technol.* 22: 361–367.

Chao, M.R., Hu, C.W., Chen, Y.L., Chang-Chien, G.P., Lee, W.J., Chang, L.W., Lee, W.S. and Wu, K.Y. (2004). Approaching Gas-Particle Partitioning Equilibrium of Atmospheric PCDD/Fs with Increasing Distance from an Incinerator: Measurements and Observations on Modeling. *Atmos. Environ.* 38:1501–1510.

Coutinho, M., Pereira, M. and Borrego, C. (2007). Monitoring of Ambient Air PCDD/F Levels in Portugal. *Chemosphere* 67:1715–1721.

Davidson, C.I. and Wu, Y.L. (1987). Dry Deposition of Particles and Vapors, Submitted as a Chapter for Publication in D.C. Adiriano (Ed.): Acid Precipitation 2: Source, Emissions and Mitigation: Advances in Environmental Sciences Series Springer-Verlag, New York.

Donnelly, J.R., Munslow, W.D., Mitchum, R.K. and Sovocool, G.W. (1987). Correlation of Sstructure with Retention Index for Chlorinated Dibenzo-*p*-Dioxins. *J. Chromatogr. A* 392: 51–63.

Duarte-Davidson, R., Sewart, A., Alcock, R.E., Cousins, I.T. and Jones, K.C. (1997). Exploring the Balance between Sources, Deposition, and the Environmental Burden of PCDD/Fs in the U.K. Terrestrial Environment: An Aid to Identifying Uncertainties and Research Needs. *Environ. Sci. Technol.* 31: 1–11.

Eitzer, B.D. and Hites, R.A. (1989). Atomospheric Transport and Deposition of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans. *Environ. Sci. Technol.* 23: 1396–1401.

Falconer, R.L. and Bidleman, T.F. (1994). Vapor Pressures and Predicted Particle/Gas Distributions of Polychlorinated Biphenyl Congeners as Functions of Temperature and Ortho-Chlorine Substitution. *Atmos. Environ.* 28: 547–554.

Hale, M.D., Hileman, F.D., Mazer, T., Shell, T L., Noble, R.W. and Brook, J.J. (1985). Mathematical Modeling of Temperature Programmed Capillary Gas Chromatographic Retention Indexes for Polychlorinated Dibenzofurans. *Anal. Chem.* 57: 640–650.

Heinzow, B., Mohr, S., Ostendorp, G., Kerst, M. and Körner, W. (2007). PCB and Dioxin-Like PCB in Indoor Air of Public Buildings Contaminated with Different PCB Sources – Deriving Toxicity Equivalent Concentrations from Standard PCB Congeners. *Chemosphere* 67: 1746–1753.

Hung, H., Blanchard, P., Poole, G., Thibert, B. and Chiu, C.H. (2002). Measurement of Particle-Bound Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans (PCDD/Fs) in Arctic Air at Alert, Nunavut, Canada. *Atmos. Environ.* 36: 1041–1050.

Jen, Y.H., Yuan, C. S., Hung, C. H., Ie, I. R., and Tsai, C. M. (2013). Tempospatial Variation and Partition of

Atmospheric Mercury during Wet and Dry Seasons at Sensitivity Sites within a Heavily Polluted Industrial City. *Aerosol Air Qual. Res.* 13:13–23.

Kerst, M., Bahner, S., Peichl, L., Reifenhäuser, W. and Körner, W. (2003). WHO-TEQ Concerning Dioxin-Like PCB and PCDD/PCDF in Ambient Air and Plant Samples in Southern Germany. *Organohalogen Compd.* 61: 498–501.

Lee, W.J., Lin, S.J., Chen, Y.Y., Wang, Y.F., Sheu, H.L., Su, C.C. and Fan, Y.C. (1996a). Polychlorinated Biphenyls in the Ambient Air of Petroleum Refinery, Urban and Rural Areas. *Atmos. Environ.* 30:2371–2377.

Lee, W.J., Su, C.C., Sheu, H.L., Fan, Y.C., Chao, H.R. and Fang, G.C. (1996b). Monitoring and Modeling of PCB Dry Deposition in Urban Area. *J. Hazard. Mater.* 49: 57–88.

Lee, W.J., Shih, S.I., Li, H.W., Lin, L.F., Yu, K.M., Lu, K., Wang, L.C., Chang-Chien, G.P., Fang, K. and Lin, M. (2009). Assessment of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans Contribution from Different Media to Surrounding Duck Farms. *J. Hazard. Mater.* 163:1185–1193.

Lin, L.F., Shih, S.I., Su, J.W., Shih, M., Lin, K.C., Wang, L.C. and Chang-Chien, G.P. (2010a). Dry and Wet Deposition of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans on the Drinking Water Treatment Plant. *Aerosol Air Qual. Res.* 10: 378–390.

Lin, W.Y., Wu, Y.L., Tu, L.K., Wang, L.C. and Lu, X. (2010b). The Emission and Distribution of PCDD/Fs in Municipal Solid Waste Incinerators and Coal-fired Power Plant. *Aerosol Air Qual. Res.* 10: 519–532.

Lohmann, R. and Jones, K. C. (1998). Dioxins and Furans in Air and Deposition: A Review of Levels, Behaviour and Processes. *Sci. Total Environ.* 219: 53–81.

Mandalakis, M. and Stephanou, E.G. (2004). Wet Deposition of Polychlorinated Biphenyls in the Eastern Mediterranean. *Environ. Sci. Technol.* 38: 3011–3018.

Mi, H.H., Wu, Z.S., Lin, L.F., Lai, Y.C., Lee, Y.Y., Wang, L.C. and Chang-Chien, G.P. (2012). Atmospheric Dry Deposition of Polychlorinated Dibenzo-*p*-dioxins/ Dibenzofurans (PCDD/Fs) and Polychlorinated Biphenyls (PCBs) in Southern Taiwan. *Aerosol Air Qual. Res.* 12: 1016–1029.

Oh, J.E., Choi, S.D., Lee, S.J. and Chang, Y.S. (2006). Influence of a Municipal Solid Waste Incinerator on Ambient Air and Soil PCDD/Fs Levels. *Chemosphere* 64: 579–587.

Pacyna, J.M., Breivik, K., Münch, J. and Fudala, J. (2003). European Atmospheric Emissions of Selected Persistent Organic Pollutants, 1970-1995. *Atmos. Environ.* 37: S119–S131.

Pankow, J.F. (1987). Review and Comparative Analysis of the Theories on Partitioning Between the Gas and Aerosol Particulate Phases in the Atmosphere. *Atmos. Environ.* 21: 2275–2283.

Pankow, J.F. (1991). Common Y-Intercept and Single Compound Regressions of Gas-Particle Partitioning Data vs 1/T. *Atmos. Environ.* 25: 2229–2239.

Pankow, J.F. and Bidleman, T.F. (1991). Effects of Temperature, TSP and Percent Non-Exchangeable Material in Determining the Gas-Particle Partitioning of Organic Compounds. *Atmos. Environ.* 25: 2241–2249.

Pankow, J.F. (1994). An Absorption Model of Gas/Particle Partitioning of Organic Compounds in the Atmosphere. *Atmos. Environ.* 28: 185–188.

Pankow, J.F. and Bidleman, T.F. (1992). Interdependence of the Slopes and Intercepts from log-log Correlations of Measured Gas-Particle Paritioning and Vapor Pressure—I. Theory and Analysis of Available Data. *Atmos. Environ.* 26: 1071–1080.

Quaß, U., Fermann, M. and Bröker, G. (2004). The European Dioxin Air Emission Inventory Project -- Final Results. *Chemosphere* 54: 1319–1327.

Rordorf, B.F. (1989). Prediction of Vapor Pressures, Boiling Points and Enthalpies of Fusion for Twenty-Nine Halogenated Dibenzo-*p*-dioxins and Fifty-Five Dibenzofurans by a Vapor Pressure Correlation Method. *Chemosphere* 18: 783–788.

Sheu, H.L., Lee, W.J., Su, C.C., Chao, H.R. and Fan, Y.C. (1996). Dry Deposition of Polycuclic Aromatic Hydrocarbons in Ambient Air. *J. Environ. Eng.* 122: 1101–1109.

Shih, M., Lee, W.S., Chang-Chien, G.P., Wang, L.C., Hung, C.Y. and Lin, K.C. (2006). Dry Deposition of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans (PCDD/Fs) in Ambient Air. *Chemosphere* 62: 411–416.

Shih, S.I., Lee, W.J., Lin, L.F., Huang, J.Y., Su, J.W. and Chang-Chien, G.P. (2008). Significance of Biomass Open Burning on the Levels of Polychlorinated Dibenzo-*p*-Dioxins and Dibenzofurans in the Ambient Air. *J. Hazard. Mater.* 153: 276–284.

Sun, W.Y., Yang, J.S. and Lin, N.H. (2013a). Numerical Simulations of Asian Dust-Aerosols and Regional Impact on Weather and Climate- Part I: Control Case-PRCM Simulation without Dust-Aerosols. *Aerosol Air Qual. Res.* 13: 1630–1640.

Sun, W.Y., Yang, J.S. and Lin, N.H. (2013b). Numerical Simulations of Asian Dust-Aerosols and Regional Impact on Weather and Climate- Part II: PRCM-Dust Model Simulation. *Aerosol Air Qual. Res.* 13: 1641–1654.

Tasdemir, Y., Odabasi, M. and Holsen, T.M. (2005). Measurement of the Vapor Phase Deposition of Polychlorinated Bipheyls (PCBs) Using a Water Surface Sampler. *Atmos. Environ.* 39: 885–897.

Tseng, Y.J. (2014). Atmospheric Deposition Modeling of Polychlorinated Dibenzo-*p*-dioxins, Dibenzofurans and Polychlorinated Biphenyls in the Ambient Air of Southern Taiwan. Master Thesis, Department of Environmental Engineering, National Cheng Kung University.

Wang, L.C., Lee, W.J., Lee, W.S., Chang-Chien, G.P. and Tsai, P.J. (2003). Effect of Chlorine Content in Feeding Wastes of Incineration on the Emission of Polychlorinated Dibenzo-*p*-dioxins/Dibenzofurans. *Sci. Total Environ.* 302: 185–198.

Wang, Y.F., Hou, H.C., Li, H.W., Lin, L.F., Wang, L.C., Chang-Chien, G.P. and You, Y.S. (2010). Dry and Wet Depositions of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans in the Atmosphere in Taiwan. *Aerosol*

Air Qual. Res. 10: 378–390.

Watcharavitoon, P., Chio, C.P. and Chan, C.C. (2013). Temporal and Spatial Variations in Ambient Air Quality during 1996–2009 in Bangkok, Thailand. *Aerosol Air Qual. Res.* 13: 1741–1754.

Yamasaki, H., Kuwata, K. and Miyamoto, H. (1982). Effect of Ambient Temperature on Aspects of Airbone Polycyclic Aromatic Hydrocarbons. *Environ. Sci. Technol.* 16: 189–195.

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