Aerosol and Air Quality Research, 18: 2788–2800, 2018

ISSN: 1680-8584 print / 2071-1409 online
doi: 10.4209/aaqr.2018.10.0363

Atmospheric (Dry + Wet) Deposition of PCDD/Fs in Taiwan

Yen-Yi Lee[1], Wen-Che Hou[1*], Jinning Zhu[2*], Weiwei Wang[2*]

[1] *Department of Environmental Engineering, National Cheng Kung University, Tainan 70101, Taiwan*
[2] *School of Resources and Environmental Engineering, Hefei University of Technology, Hefei 246011, China*

ABSTRACT

Air pollution is becoming increasingly worse with economic development, and atmospheric deposition is an important mechanism for the removal of air pollutants. In 2017, the average dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan ranged between 57 (Lienchiang County in autumn) and 589 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City in winter), with an average of 221 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. The average total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan ranged between 65 (Lienchiang County in autumn) and 681 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City in winter), with an average of 263 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. The fractions of dry deposition fluxes contributing to the total deposition fluxes ranged between 37.8% (Yilan County in winter) and 99.9% (Kaohsiung City in winter), with an average of 82.1%. This study provided valuable information for the control strategies of PCDD/Fs.

Keywords: $PM_{2.5}$; PCDD/Fs; Dry deposition; Total deposition.

INTRODUCTION

Air pollution has been considered a danger to human health (morbidity, lung cancer, cardiovascular and cardiopulmonary diseases, etc.) for centuries (e.g., Dockery *et al.*, 1993; McDonnell *et al.*, 2000; Pope and Dockery, 2006; Pope *et al.*, 2009). The World Health Organization (WHO) estimates that ambient particulate matter (PM) is the world's 13th leading cause of death and contributes to approximately 800,000 premature deaths each year. The major effect of ambient PM on the pulmonary system is the exacerbation of inflammation, especially in susceptible people. Among particles of different sizes, the diameters of PM range from a few micrometres (µm) ($PM_{2.5}$ ranging from ~0 to 2.5 µm, PM_{10} ranging from ~0 to 10 µm) to around 100 micrometres (TSP ranging from ~0 to 100 µm) (Chow *et al.*, 2015; Lu *et al.*, 2016).

Increased vehicular traffic and other combustion processes have resulted in a significant increase in ambient persistent organic pollutants (POPs) over the past two decades. Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are typical POPs that are not formed as a result of industrial activities, but almost invariably as unwanted byproducts in all thermal systems and are distributed ubiquitously (U.S. EPA, 2003). They are generally formed unintentionally during a variety of anthropogenic combustion activities and industrial processes such as the manufacture and use of organochlorine chemicals (Hashimoto *et al.*, 1990; Lin *et al.*, 2014; Cheruiyot *et al.*, 2015, 2016). In addition, natural combustion processes such as forest fires, lightning and volcanic eruptions are thought to produce PCDD/Fs (Prange *et al.*, 2002; Kim *et al.*, 2003). Human exposure to high level PCDD/Fs may result in liver damage and chloracne in the short term (Marinković *et al.*, 2010), and may affect the endocrine, immune, reproductive, and nervous system in the long term (Srogi, 2008; Marinković *et al.*, 2010). Different PCDD/F sources are characterized by specific congeners. 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) was regulated as the most toxic congener, and the 2,3,7,8-substituted congeners (including 10 PCDDs and 7 PCDFs) are usually measured as molecular markers of specific sources to the environment (Alcock and Jones, 1996; Watanabe *et al.*, 1998; U.S. EPA, 2000). The atmosphere is an important pathway for the transport and global distribution of air pollutants. Once emitted to the receiving environment, atmospheric transport moves them away from their emission sources to where they pollute water and the soil and eventually enter to the food chain (Lohmann and Jones, 1998; Hu *et al.*, 2009).

Ambient pollutants are mainly removed by dry and wet deposition (Cheruiyot *et al.*, 2015, 2016). Atmospheric deposition is an important pathway for the air pollutants loading to the soil and water systems (Brzuzy and Hites,

* Corresponding authors.
E-mail address: whou@mail.ncku.edu.tw (W.C. Hou);
zhujinning@whu.edu.cn (J. Zhu);
1326642149@qq.com (W. Wang)

1996; Jurado *et al.*, 2005). PCDD/Fs partition between atmospheric particles and the corresponding gas phase in the atmosphere is an important factor in their transformation and transport (Pankow and Bidleman, 1991; Chang *et al.*, 2004; Lee *et al.*, 2008). The gas-particle partition is affected according to the ambient temperature, compound properties, humidity, vapor pressure and the particle surface available for sorption (Pankow, 1987; Lohmann *et al.*, 1999; Chang *et al.*, 2004). This process has a decisive influence on transport, deposition, and degradation processes (Bidleman *et al.*, 1988; Pankow *et al.*, 1994). The dry deposition fluxes of many substances appear to be dominated by large particles, even in the case of compounds with extremely low loading in this particle range (Shih *et al.*, 2006; Huang *et al.*, 2011), and the wet deposition fluxes are affected by the rainfall intensity and the levels of ambient pollutants (Kaupp and McLachlan, 1998).

Based on previous studies (Lee *et al.*, 2018), the objective of this study was to characteristic the meteorological conditions in Taiwan, including the ambient temperature and rainfall, to estimate the seasonal variations in the monthly dry deposition fluxes in Taiwan; to measure the seasonal variations in the monthly total (dry and wet) deposition fluxes in Taiwan, and to compare the fraction of dry and wet deposition fluxes contributing to the total deposition fluxes.

MATERIALS AND METHODS

Sample Collection

In this study, the meteorological data, including ambient temperature and rainfall are from 48 local air quality stations associated with 9 cities and 13 counties during the year 2017 in Taiwan. The PCDD/Fs concentrations and gas-particle partitions were collected from previous study (Lee *et al.*, 2018a, b). The detailed information for the air quality stations include Dongshan and Yilan in Yilan County, Hualien in Hualien County, Kinmen in Kinmen County, Chushan, Nantou and Puli in Nantou County, Pingtung, Hungchun and Chaojhou in Pingtung County, Sani, Miaoli and Toufen in Miaoli County, Dayuan, Zhongli, Pingchen, Taoyuan, Longtan and Guanyin in Taoyuan City, Daliao, Siaogang, Renwu, Tsoying, Linyuan, Qianqiu, Meinung, Fuxing, Nanzih, Fongshan and Ciaotou in Kaohsiung City, Keelung in Keelung City, Matsu in Lienchiang County, Douliou, Lunbei and Mailiao in Yunlin County, Sanchong, Tucheng, Yonho, Xizhi, Banqiao, Linkou, Tamsui, Cailiao, Xindian, Xinzhuang and Wanli in New Taipei City, Hsinchu in Hsinchu City, Zhudong and Hukou in Hsinchu County, Chiayi in Chiayi City, Puzi and Xingang in Chiayi County, Erlin, Changhua and Siansi in Changhua County, Dali, Xitun, Shalu, Zhongming and Fengyuan in Taichung City, Shilin, Tatung, Zhongshan, Guting, Songshan, Yangming and Wanhua in Taipei City, Taitung and Guanshan in Taitung County, Annan, Shanhua, Xinying and Tainan in Tainan City, Magong in Penghu County.

Atmospheric Dry Deposition of PCDD/Fs

The atmospheric dry deposition flux of PCDD/Fs is a combination of both gas- and particle-phase fluxes, which are given by:

$$F_{d,T} = F_{d,g} + F_{d,p} \tag{1}$$

$$C_T \times V_{d,T} = C_g \times V_{d,g} + C_p \times V_{d,p} \tag{2}$$

$F_{d,T}$: the total PCDD/F deposition flux contributed by the summation of both gas- and particle-phase fluxes;
$F_{d,g}$: the PCDD/F deposition flux contributed by the gas phase;
$F_{d,p}$: the PCDD/F deposition flux contributed by the particle phase;
C_T: the measured concentration of total PCDD/Fs in the ambient air;
$V_{d,T}$: the dry deposition velocity of total PCDD/Fs;
C_g: the calculated concentration of PCDD/Fs in the gas phase;
$V_{d,g}$: the dry deposition velocity of the gas-phase PCDD/Fs;
C_p: the calculated concentration of PCDD/Fs in the particle phase;
$V_{d,p}$: the dry deposition velocity of the particle-phase PCDD/Fs.

In this study, the mean dry deposition velocity of total PCDD/Fs ($V_{d,T}$ = 0.42 cm s^{-1}) as proposed by Shih *et al.* (2006) is used. The dry deposition of gas-phase PCDD/Fs occurs mainly by diffusion. Due to a lack of measured data for PCDD/Fs, a selected value (0.010 cm s^{-1}) of gas-phase PAH dry deposition velocity, $V_{d,g}$, proposed by Sheu *et al.* (1996) and used by Lee *et al.* (1996) is also used here to calculate the PCDD/F dry deposition flux contributed by its gas phase. Dry deposition of particle-phase PCDD/Fs is mainly achieved through gravitational settling, and the dry deposition velocity of particle-phase PCDD/Fs, $V_{d,p}$, can be calculated using an equation.

RESULTS AND DISCUSSION

Dry Deposition Fluxes

Ambient temperature plays an important role in PCDD/Fs dry deposition fluxes. The seasonal variations of average ambient temperature in Taiwan are presented in Table 1. During 2017, the average ambient temperature ranged between 17.82°C (Lienchiang County) and 25.42°C (Kaohsiung City), with an average of 22.67°C in spring. In summer, the average ambient temperature ranged between 27.10°C (Nantou County) and 29.86°C (New Taipei City), with an average of 29.12°C. In autumn, the average ambient temperature ranged between 25.04°C (Yilan County) and 27.52°C (Kaohsiung City), with an average of 25.95°C. In winter, the average ambient temperature ranged between 12.40°C (Lienchiang County) and 21.08°C (Pingtung County), with an average of 17.75°C. In whole, the average ambient temperature in 2017 ranged between 20.19°C (Lienchiang County) and 25.86°C (Kaohsiung City), with an average of 23.87°C. The ambient temperature shows distinct seasonal variations, but the temperature difference is relatively small.

Based on the PCDD/F concentrations and ambient temperature, the dry deposition fluxes were calculated by

Table 1. The seasonal variations of average ambient temperature in Taiwan during 2017 (Unit: °C).

Season	Yilan County	Hualien County	Kinmen County	Nantou County	Pingtung County	Miaoli County	Taoyuan City	Kaohsiung City
Spring	21.72	22.58	20.72	23.06	25.22	21.69	21.57	25.42
Summer	29.36	29.65	29.57	27.10	29.24	28.51	29.28	29.76
Autumn	25.04	26.12	25.84	26.21	27.40	25.07	25.39	27.52
Winter	17.38	19.16	14.95	18.21	21.08	16.46	16.73	20.74
Average	23.37	24.37	22.77	23.64	25.73	22.93	23.24	25.86
Season	Keelung City	Lienchiang County	Yunlin County	New Taipei City	Hsinchu City	Hsinchu County	Chiayi City	Chiayi County
Spring	20.93	17.82	24.04	22.10	22.00	22.23	24.32	24.39
Summer	29.26	27.27	29.68	29.86	29.56	29.06	29.13	29.64
Autumn	25.26	23.28	26.87	25.86	25.85	25.29	26.19	26.76
Winter	16.71	12.40	18.67	17.56	17.07	17.15	18.85	18.52
Average	23.04	20.19	24.81	23.85	23.62	23.43	24.62	24.82
Season	Changhua County	Taichung City	Taipei City	Taitung County	Tainan City	Penghu County	Average	
Spring	23.44	23.28	21.40	22.91	24.73	23.22	22.67	
Summer	29.51	28.58	28.99	28.97	29.65	29.02	29.12	
Autumn	26.62	25.98	25.06	26.08	27.05	26.12	25.95	
Winter	18.01	18.14	16.84	19.36	19.17	17.31	17.75	
Average	24.39	24.00	23.07	24.33	25.15	23.92	23.87	

using the equations given above. Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in spring 2017 are presented in Fig. 1(A). The dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ ranged between 73 (Lienchiang County) and 434 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Yunlin County), with an average of 221 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in summer 2017 are presented in Fig. 1(B). The dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ ranged between 83 (Chiayi City) and 531 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 190 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in autumn 2017 are presented in Fig. 1(C). The dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ ranged between 57 (Lienchiang County) and 418 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Yunlin County), with an average of 203 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in winter 2017 are presented in Fig. 1(D). The dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ ranged between 66 (Lienchiang County) and 588 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 269 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. In whole, the average dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan ranged between 57 (Lienchiang County) and 588 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 221 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. There are distinct seasonal variations suggesting that the dry deposition fluxes are higher in cool seasons (spring and winter) than that in warm seasons (summer and autumn). This is probably due to the fact that a lower fraction of PCDD/Fs is adsorbed to particles when temperatures are warmer (Koester and Hites, 1992).

The dry deposition fluxes were similar to those for industrial (22.1–632 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) and rural areas (7.8–418 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) in Taiwan in 2014 and 2015 (Lee *et al.*, 2016), Guangzhou (60.6–558 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) in China during 2014 (Zhu *et al.*, 2017a), commercial (7.67–18.2 pg I-TEQ m^{-2} day^{-1}), coastal (6.69–11.6 pg I-TEQ m^{-2} day^{-1}), and those for agricultural areas (5.73–15.6 pg I-TEQ m^{-2} day^{-1}) in Taiwan in 2006 (Wang *et al.*, 2010). They were lower than those in industrial areas (17.6–40.6 pg I-TEQ m^{-2} day^{-1}) in Taiwan in 2006 (Wang *et al.*, 2010), urban areas (3.72–56.8 pg I-TEQ m^{-2} day^{-1}) in Taiwan in 2009 (Wu *et al.*, 2009), Nanjing (104–1160 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$), and in Shijiazhuang (699–2230 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) and Harbin (208–1290 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) in China in 2014 (Zhu *et al.*, 2017a, b). However they were higher than those in coastal (33.6–104.3 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) and mountain areas (3.9–27.3 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$) in Taiwan in 2013 (Chandra Suryani *et al.*, 2015), urban (2.7–10.1 pg I-TEQ m^{-2} day^{-1}) and suburban areas (3.0–12.6 pg I-TEQ m^{-2} day^{-1}) in Korea in 2002 (Moon *et al.*, 2005), urban areas (1.5 pg I-TEQ m^{-2} day^{-1}) in USA during 2003 and 2004 (Correa *et al.*, 2006), industrial area (0–9.2 pg I-TEQ m^{-2} day^{-1}) in Italy in 1998 and 1999 (Guerzoni *et al.*, 2004). A comparison of atmospheric dry deposition flux in different areas is shown in Table 3.

Total Deposition Fluxes

Ambient temperature and rainfall are important factors that affect atmospheric dry and wet deposition fluxes. The monthly seasonal variations in the number of rainy days in Taiwan during 2017 are presented in Table 2. During 2017, the average monthly rainy days ranged between 5.7 (Kaohsiung City) and 18.3 (Keelung City), with an average of 12.0 in spring. In summer, the average monthly

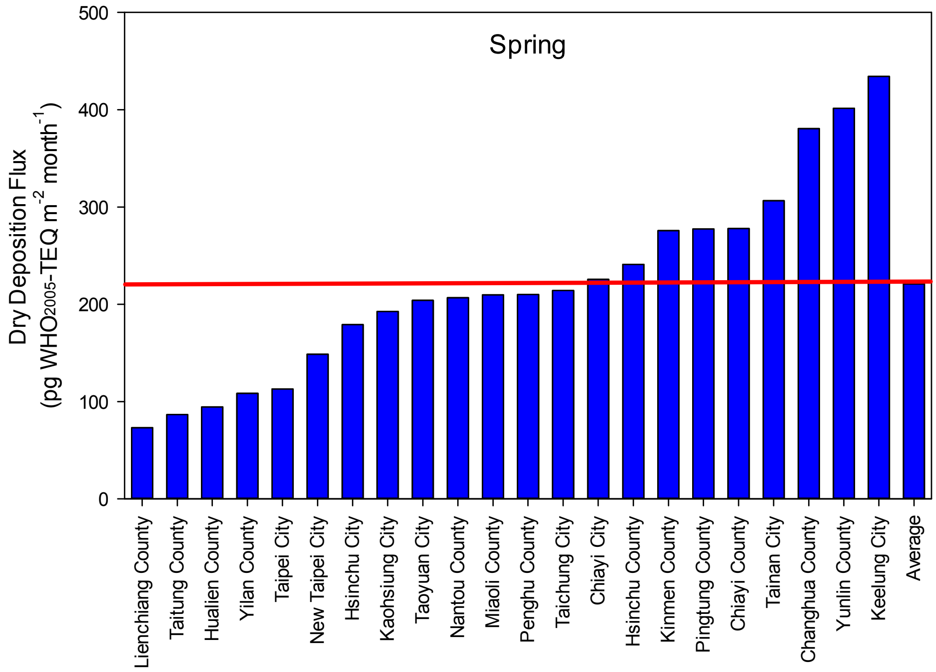

Fig. 1(A). Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in spring 2017.

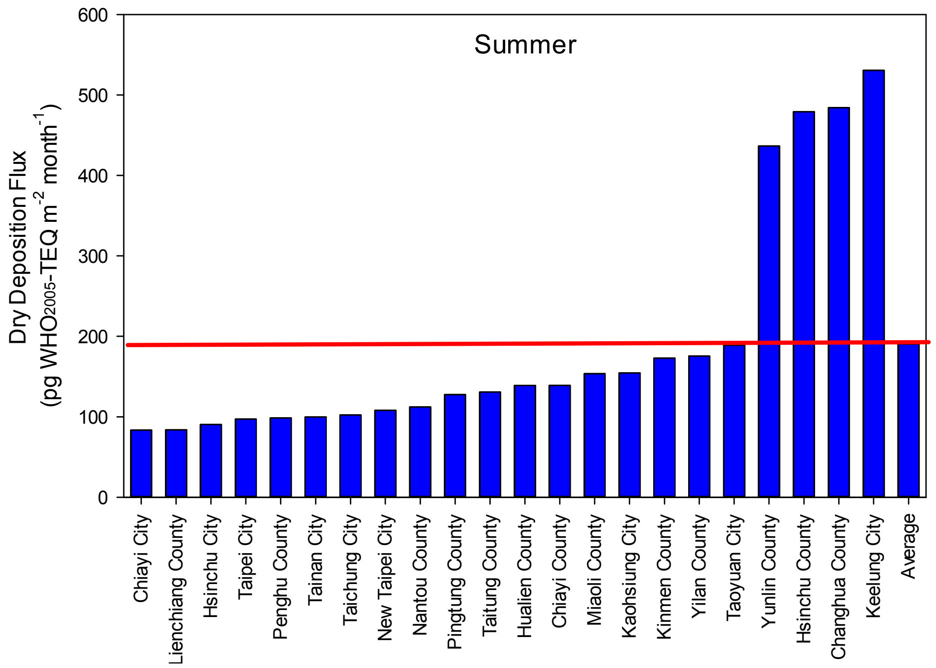

Fig. 1(B). Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in summer 2017.

rainy days ranged between 6.7 (Taoyuan County) and 16.9 (Chiayi City and Chiayi County), with an average of 11.7. In autumn, the average monthly rainy days ranged between 3.3 (Tainan City) and 19.7 (Keelung City), with an average of 9.4. In winter, the average monthly rainy days ranged between 0.3 (Kaohsiung City) and 19.2 (Yilan County), with an average of 7.3. In whole, the average monthly rainfall in various areas in Taiwan ranged between 0.3 (Kaohsiung City) and 19.7 (Keelung City), with an average of 10.1.

Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ are a combination of dry and wet deposition. The wet deposition data used here is from previous study (Lee *et al.*, 2018a). The atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in spring of 2017 are presented in Fig. 2(A). The total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ ranged between 102 (Taitung County) and 485 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 274 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in

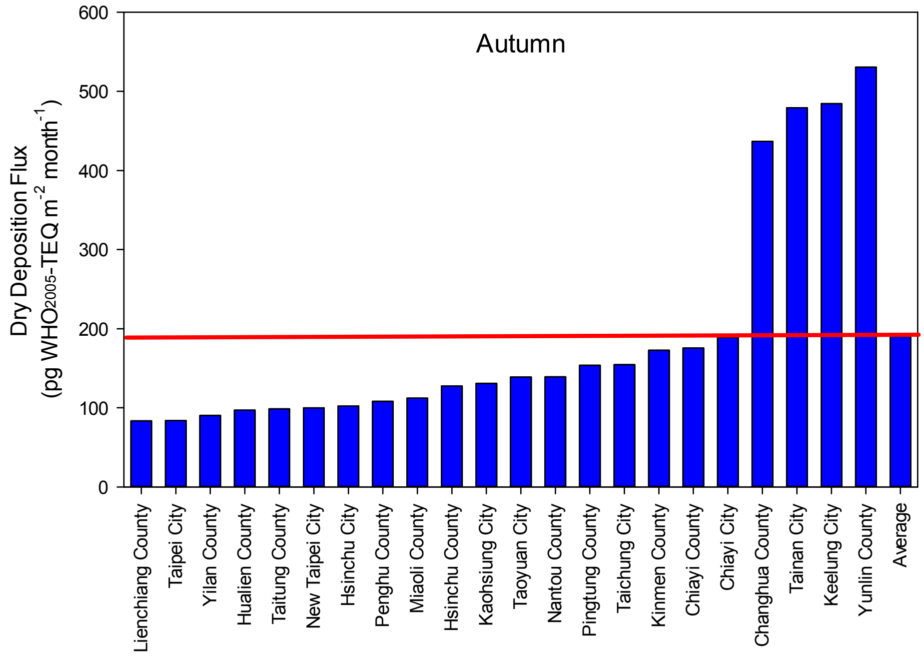

Fig. 1(C). Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in autumn 2017.

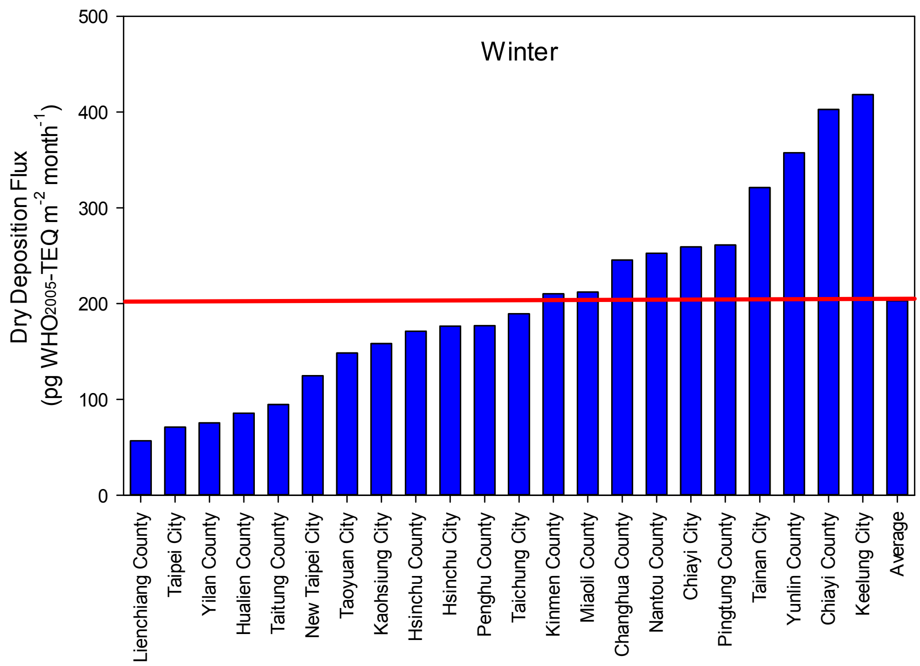

Fig. 1(D). Atmospheric dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in winter 2017.

Taiwan in summer of 2017 are presented in Fig. 2(B). They ranged between 111 (Hsinchu City) and 667 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Changhua County), with an average of 253 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in autumn of 2017 are presented in Fig. 2(C). They ranged between 65 (Lienchiang County) and 453 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 230 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in winter of 2017 are presented in Fig. 2(D). They ranged between 81 (Lienchiang County) and 681 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 296 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. In whole, the average total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan ranged between 65 (Lienchiang County) and 681 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 263 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$. The total deposition fluxes detected in this study are similar to those measured in mountainous and in

Table 2. The monthly seasonal variations of rainy days in Taiwan during 2017.

Area	Spring	Summer	Autumn	Winter
Keelung City	18.3	9.3	19.7	18.3
Taipei City	16.6	11.9	19.3	17.7
New Taipei City	14.3	11.2	14.0	8.7
Taoyuan City	12.3	6.7	11.0	8.7
Hsinchu City	11.7	9.3	10.0	8.0
Hsinchu County	11.7	9.3	10.0	8.0
Miaoli County	11.3	11.3	6.7	4.3
Taichung City	9.2	11.3	3.8	3.7
Nantou County	14.0	16.7	7.0	5.7
Changhua County	7.3	12.3	3.7	3.3
Yunlin County	8.0	15.3	5.0	2.3
Chiayi City	12.9	16.9	9.9	5.2
Chiayi County	12.9	16.9	9.9	5.2
Tainan City	6.0	13.0	3.3	1.7
Kaohsiung City	5.7	11.3	6.3	0.3
Pingtung County	6.7	15.3	9.2	2.3
Yilan County	17.8	10.5	17.5	19.2
Hualien County	17.7	9.0	12.0	13.3
Taitung County	16.6	11.9	12.7	12.6
Lienchiang County	13.3	9.7	6.7	6.3
Kinmen County	12.0	9.0	4.3	3.3
Penghu Country	7.3	10.2	4.3	2.7
Average	12.0	11.7	9.4	7.3

Table 3. The comparisons of atmospheric dry deposition flux in different area.

Area	Location	Period	Range (pg WHO_{2005}-TEQ m^{-2} $month^{-1}$)	Average (pg WHO_{2005}-TEQ m^{-2} $month^{-1}$)	Reference
Taiwan	Hengchun	2012	22.7–82.2	50.2	Chandra Suryani *et al.*, 2015
Taiwan	Hengchun	2013	33.6–104.3	64.0	Chandra Suryani *et al.*, 2015
Taiwan	Lulin	2012	4.50–31.3	11.8	Chandra Suryani *et al.*, 2015
Taiwan	Lulin	2013	3.90–27.3	10.6	Chandra Suryani *et al.*, 2015
Taiwan	Kaohsiung	2014	22.6–555.0	210.7	Lee *et al.*, 2016
Taiwan	Kaohsiung	2015	32.1–404.0	182	Lee *et al.*, 2016
Taiwan	Meinong	2014	9.7–418.0	148	Lee *et al.*, 2016
Taiwan	Meinong	2015	7.80–373.0	129	Lee *et al.*, 2016
Taiwan	Xiaogang	2014	22.1–632	234	Lee *et al.*, 2016
Taiwan	Xiaogang	2015	31.1–469	190.8	Lee *et al.*, 2016
China	Guangzhou	2014	60.6–558	205.8	Zhu *et al.*, 2017a
China	Nanjing	2014	104–1160	540.0	Zhu *et al.*, 2017a
China	Harbin	2014	308–1290	686.7	Zhu *et al.*, 2017b
China	Shijiazhuang	2014	699–2230	1283.3	Zhu *et al.*, 2017b
Taiwan	Mailiao	2014	197.4–847.2	472.3	Chen *et al.*, 2017
Taiwan	Mailiao	2015	238.1–645.6	456.7	Chen *et al.*, 2017
Taiwan	Mailiao	2016	239.5–604.4	413.8	Chen *et al.*, 2017
Taiwan	Lunbei	2014	163.6–627.0	398.5	Chen *et al.*, 2017
Taiwan	Lunbei	2015	156.1–498.5	342.1	Chen *et al.*, 2017
Taiwan	Lunbei	2016	178.3–433.9	319.8	Chen *et al.*, 2017
Taiwan	Taisi	2014	137.7–636.8	343.4	Chen *et al.*, 2017
Taiwan	Taisi	2015	151.3–434.0	301.3	Chen *et al.*, 2017
Taiwan	Taisi	2016	165.9–385.9	287.7	Chen *et al.*, 2017
China	Handan	2016	467–1959	965.8	Zhao *et al.*, 2018
China	Handan	2017	489–1765	1001.7	Zhao *et al.*, 2018
China	Kaifeng	2016	354–1213	802.5	Zhao *et al.*, 2018
China	Kaifeng	2017	377–1140	757.8	Zhao *et al.*, 2018

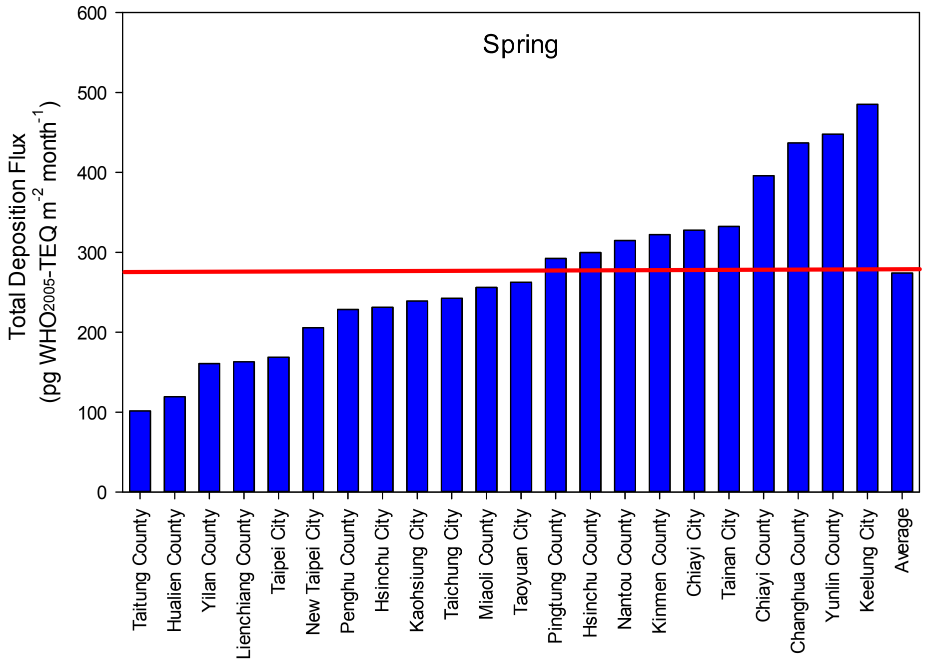

Fig. 2(A). Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in spring 2017.

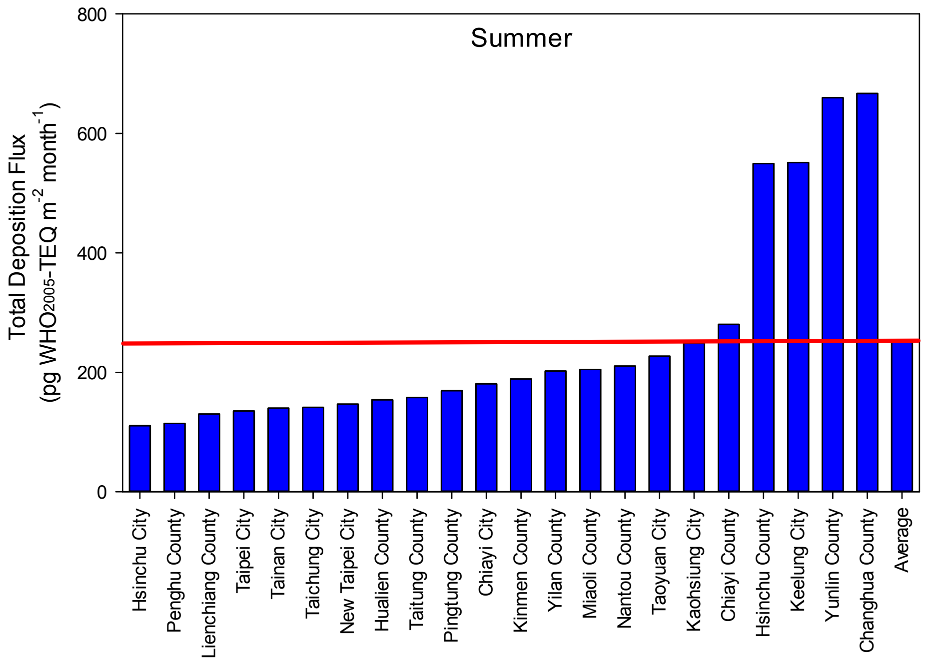

Fig. 2(B). Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in summer 2017.

rural areas (5020–5110 pg I-TEQ m^{-2} $year^{-1}$) in Taiwan in 2009 and 2010 (Huang *et al.*, 2011), Tanzawa (5700 pg I-TEQ m^{-2} $year^{-1}$) in Japan in 2001 (Ogura *et al.*, 2001), Lagoon (4280 pg I-TEQ m^{-2} $year^{-1}$) in France in 2001 (Guerzoni *et al.*, 2004), Guangzhou (3043 pg WHO_{2005}-TEQ m^{-2} $year^{-1}$) and Nanjing (7610 pg WHO_{2005}-TEQ m^{-2} $year^{-1}$) in China in 2014 (Zhu *et al.*, 2017a). These values were higher than those in coastal (657 pg WHO_{2005}-TEQ m^{-2} $year^{-1}$) and mountainous areas (249 pg WHO_{2005}-TEQ m^{-2} $year^{-1}$) in Taiwan in 2013 (Chandra Suryani *et al.*, 2015). But lower than that in urban area in Tokyo (17000 pg I-TEQ m^{-2} $year^{-1}$) and Yokohama (11000 pg I-TEQ m^{-2} $year^{-1}$) in Japan in 2001 (Ogura *et al.*, 2001), Shijiazhuang (16100 pg WHO_{2005}-TEQ m^{-2} $year^{-1}$) in China in 2014 (Zhu *et al.*, 2017b). A comparisons of atmospheric total deposition flux in different areas is provided in Table 4.

Fractions of Dry and Wet Deposition

The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition

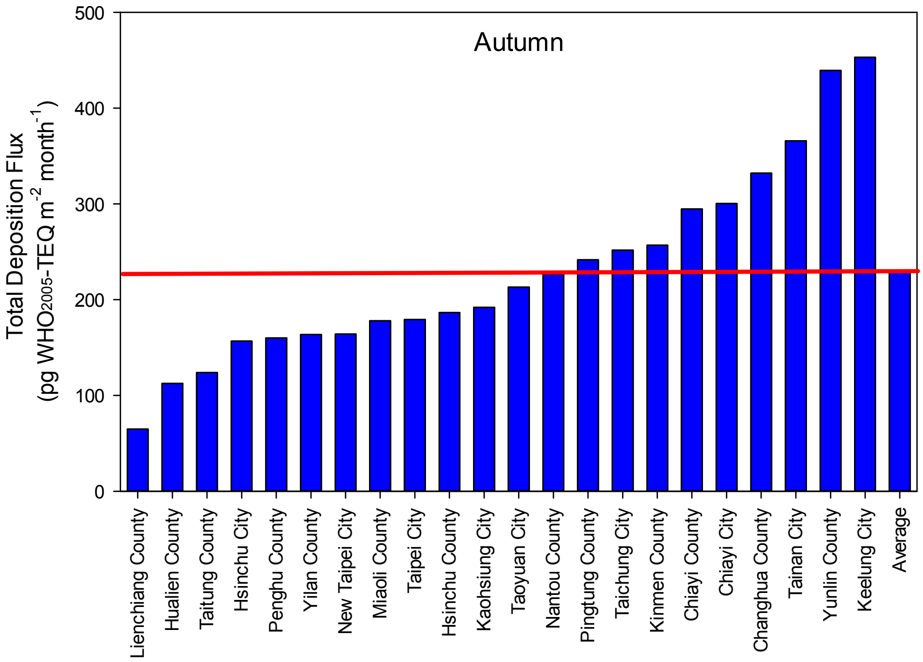

Fig. 2(C). Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in autumn 2017.

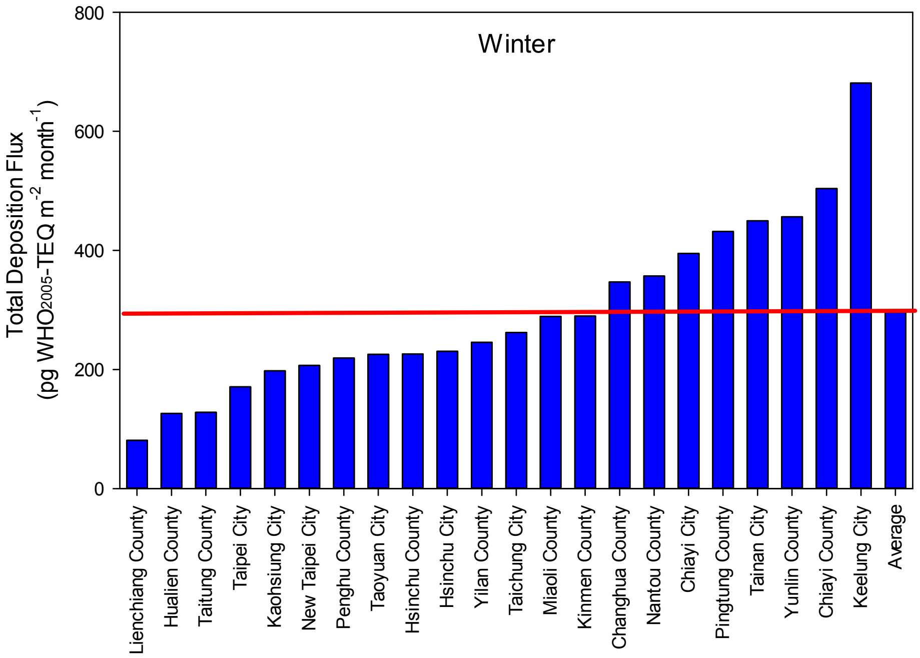

Fig. 2(D). Atmospheric total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan in winter 2017.

in spring are present in Fig. 3(A), the fractions of dry deposition fluxes contribute to the total deposition fluxes range between 44.9% (Lienchiang County) and 94.9% (Pingtung County), with an average of 79.0%. The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition in summer are present in Fig. 3(B), the fractions of dry deposition fluxes contribute to the total deposition fluxes range between 46.0% (Chiayi City) and 96.3% (Keelung City), with an average of 74.5%. The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition in autumn are present in Fig. 3(C), the fractions of dry deposition fluxes contribute to the total deposition fluxes range between 39.7% (Taipei City) and 98.8% (Penghu County), with an average of 86.2%. The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition in winter are present in Fig. 3(D), the fractions of dry deposition fluxes contribute to the total deposition fluxes range between 37.8% (Yilan County) and 99.9% (Kaohsiung City), with an

Table 4. The Comparisons of Atmospheric Total (wet + dry) Deposition of Total WHO_{2005}-TEQ Flux in Different Area.

Area	Location	Period	Range (pg WHO_{2005}-TEQ m^{-2} $month^{-1}$)	Average (pg WHO_{2005}-TEQ m^{-2} $month^{-1}$)	Reference
Taiwan	Hengchun	2012	26.9–100.2	62.8	Chandra Suryani *et al.*, 2015
Taiwan	Hengchun	2013	42.8–112.4	74.7	Chandra Suryani *et al.*, 2015
Taiwan	Lulin	2012	12.1–33.7	20.1	Chandra Suryani *et al.*, 2015
Taiwan	Lulin	2013	9.20–30.5	18.6	Chandra Suryani *et al.*, 2015
Taiwan	South	2012	100.3–408.4	–	Tseng *et al.*, 2014
Taiwan	South	2013	83.9–428.3	–	Tseng *et al.*, 2014
Taiwan	Kaohsiung	2014	75.0–555	254	Lee *et al.*, 2016
Taiwan	Kaohsiung	2015	46.4–400	220	Lee *et al.*, 2016
Taiwan	Meinong	2014	44.0–420	172	Lee *et al.*, 2016
Taiwan	Meinong	2015	36.3–376	155	Lee *et al.*, 2016
Taiwan	Xiaogang	2014	33.3–640	280	Lee *et al.*, 2016
Taiwan	Xiaogang	2015	47.7–480	230	Lee *et al.*, 2016
China	Guangzhou	2014	97.7–559	253.6	Zhu *et al.*, 2017a
China	Nanjing	2014	135–1250	643	Zhu *et al.*, 2017a
China	Harbin	2014	343–1290	718	Zhu *et al.*, 2017b
China	Shijiazhuang	2014	713–2230	1340	Zhu *et al.*, 2017b
Taiwan	Mailiao	2014	223.1–847.2	493.8	Chen *et al.*, 2017
Taiwan	Mailiao	2015	242.5–660.8	497.8	Chen *et al.*, 2017
Taiwan	Mailiao	2016	274.5–633.4	466.8	Chen *et al.*, 2017
Taiwan	Lunbei	2014	185.5–627.6	421.3	Chen *et al.*, 2017
Taiwan	Lunbei	2015	161.0–499.3	366.2	Chen *et al.*, 2017
Taiwan	Lunbei	2016	196.8–523.0	354.3	Chen *et al.*, 2017
Taiwan	Taisi	2014	151.1–637.8	365.2	Chen *et al.*, 2017
Taiwan	Taisi	2015	157.4–454.5	329.2	Chen *et al.*, 2017
Taiwan	Taisi	2016	533.7–190.8	335.5	Chen *et al.*, 2017
China	Handan	2016	545–2046	1048.3	Zhao *et al.*, 2018
China	Handan	2017	534–1813	1052.5	Zhao *et al.*, 2018
China	Kaifeng	2016	391–1227	867.5	Zhao *et al.*, 2018
China	Kaifeng	2017	412–1395	825.8	Zhao *et al.*, 2018

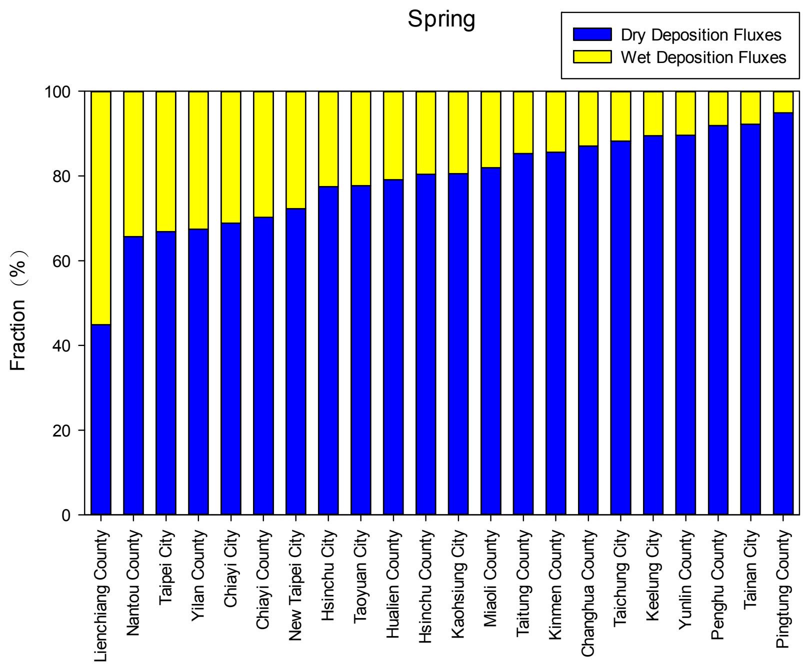

Fig. 3(A). The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition in spring, respectively.

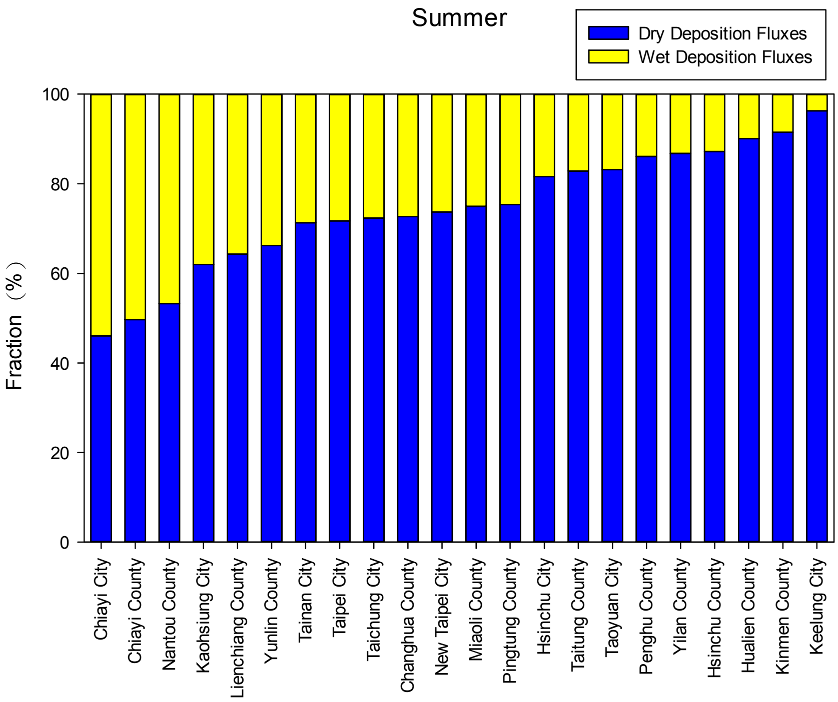

Fig. 3(B). The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition in summer, respectively.

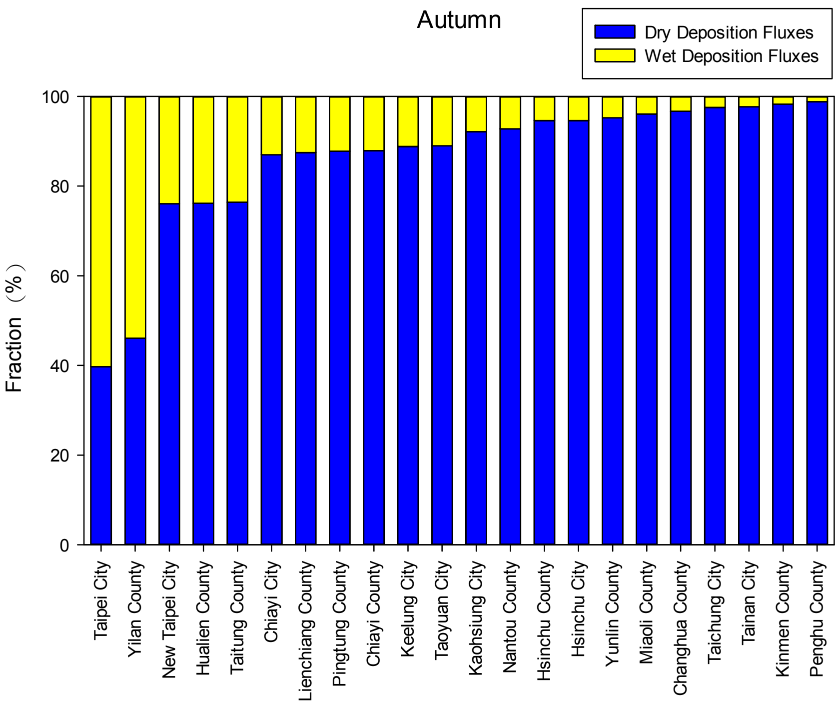

Fig. 3(C). The fraction of total deposition flux in total-PCDD/Fs-WHO_{2005}-TEQ contributed by the dry and wet deposition in autumn, respectively.

average of 88.8%. In whole, the fractions of dry deposition fluxes contribute to the total deposition fluxes range between 37.8% (Yilan County) and 99.9% (Kaohsiung City), with an average of 82.1%. The fractions of total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ are major contributed by dry deposition fluxes like previous studies (Wang *et al.*, 2010; Chandra Suryani *et al.*, 2015; Zhu *et al.*, 2017a, b). The contribution fractions of dry deposition on the atmospheric total (Wet + Dry) WHO_{2005}-TEQ deposition published on the previous documents were shown in Table 5.

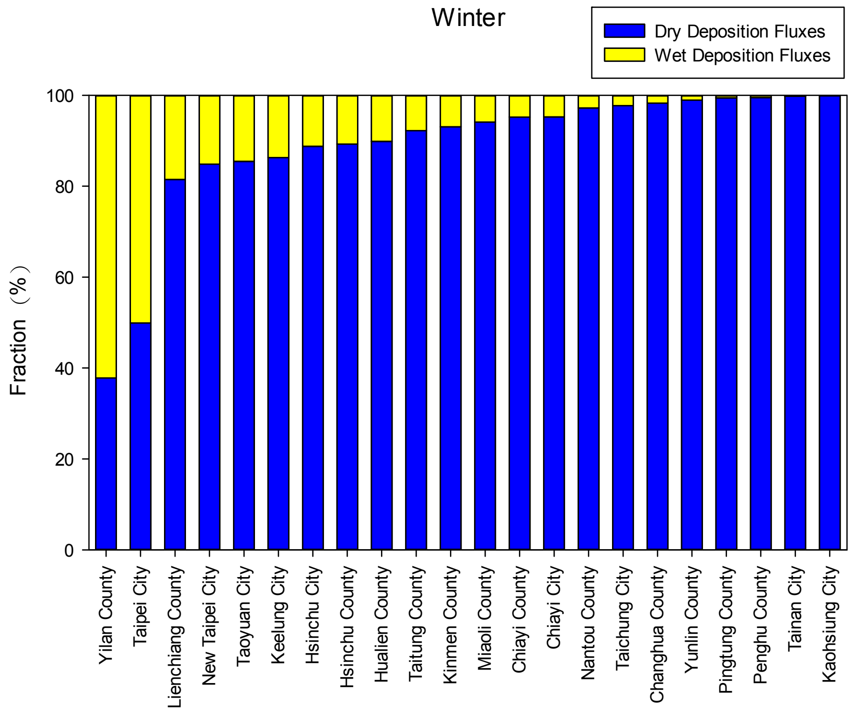

Fig. 3(D). The fraction of total deposition flux in total-PCDD/Fs-WHO$_{2005}$-TEQ contributed by the dry and wet deposition in winter, respectively.

Table 5. The contribution fractions of dry deposition on the atmospheric total (dry + wet) WHO$_{2005}$-TEQ deposition.

Area	Location	Period	Range (%)	Average (%)	Reference
Taiwan	Hengchun	2012	30.5–99.8	78.2	Chandra Suryani *et al.*, 2015
Taiwan	Hengchun	2013	51.7–99.1	78.9	Chandra Suryani *et al.*, 2015
Taiwan	Lulin	2012	19.2–97.0	56.5	Chandra Suryani *et al.*, 2015
Taiwan	Lulin	2013	23.6–98.6	69.1	Chandra Suryani *et al.*, 2015
Taiwan	South	2012	12.1–98.7	67.7	Tseng *et al.*, 2014
Taiwan	South	2013	12.4–100	73.7	Tseng *et al.*, 2014
Taiwan	Kaohsiung	2014	-	83.0	Lee *et al.*, 2016
Taiwan	Kaohsiung	2015	-	82.7	Lee *et al.*, 2016
Taiwan	Meinong	2014	-	86.0	Lee *et al.*, 2016
Taiwan	Meinong	2015	-	83.2	Lee *et al.*, 2016
Taiwan	Xiaogang	2014	-	83.6	Lee *et al.*, 2016
Taiwan	Xiaogang	2015	-	83.0	Lee *et al.*, 2016
China	Guangzhou	2014	50.6–99.8	78.6	Zhu *et al.*, 2017a
China	Nanjing	2014	66.5–98.6	82.4	Zhu *et al.*, 2017a
China	Harbin	2014	99.7–81.7	–	Zhu *et al.*, 2017b
China	Shijiazhuang	2014	84.3–100	–	Zhu *et al.*, 2017b
Taiwan	Mailiao	2014	76.2–100	93.9	Chen *et al.*, 2017
Taiwan	Mailiao	2015	68.8–99.8	91.3	Chen *et al.*, 2017
Taiwan	Mailiao	2016	74.9–98.4	88.6	Chen *et al.*, 2017
Taiwan	Lunbei	2014	72.0–100	93.3	Chen *et al.*, 2017
Taiwan	Lunbei	2015	73.5–99.8	92.5	Chen *et al.*, 2017
Taiwan	Lunbei	2016	77.1–98.6	90.8	Chen *et al.*, 2017
Taiwan	Taisi	2014	75.0–99.9	92.7	Chen *et al.*, 2017
Taiwan	Taisi	2015	71.7–99.8	90.4	Chen *et al.*, 2017
Taiwan	Taisi	2016	69.6–97.7	86.6	Chen *et al.*, 2017
China	Handan	2016	60.8–100		Zhao *et al.*, 2018
China	Handan	2017	88.0–99.9		Zhao *et al.*, 2018
China	Kaifeng	2016	78.5–99.9	90.9	Zhao *et al.*, 2018
China	Kaifeng	2017	84.5–99.7	91.8	Zhao *et al.*, 2018

CONCLUSION

1. The average dry deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan range between 57 (Lienchiang County) and 588 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 221 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$.
2. The average total deposition fluxes of total-PCDD/Fs-WHO_{2005}-TEQ in various areas in Taiwan range between 65 (Lienchiang County) and 681 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$ (Keelung City), with an average of 263 pg WHO_{2005}-TEQ m^{-2} $month^{-1}$.
3. The fractions of dry deposition fluxes contribute to the total deposition fluxes range between 37.8% (Yilan County) and 99.9% (Kaohsiung City), with an average of 82.1%.

REFERENCES

Alcock, R.E. and Jones, K.C. (1996). Dioxins in the environment: A review of trend data. *Environ. Sci. Technol.* 30: 3133–3143.

Bidleman, T.F. (1988). Atmospheric processes. *Environ. Sci. Technol*. 22: 361–367.

Brzuzy, L.P. and Hites, R.A. (1996). Global mass balance for polychlorinated dibenzo-*p*-dioxins and dibenzofurans. *Environ. Sci. Technol.* 30: 1797–1804.

Chandra Suryani, R., Lee, W.J., Endah Mutiara, M., Mwangi, J.K., Wang, L.C., Lin, N.H. and Chang-Chien, G.P. (2015). Atmospheric deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans at coastal and high mountain areas in Taiwan. *Aerosol Air Qual. Res.* 15: 1390–1411.

Chang, M.O., Chow, J.C., Watson, J.G., Hopke, P.K., Yi, S.M. and England, G.C. (2004). Measurement of ultrafine particle size distributions from coal-, oil-, and gas-fired stationary combustion sources. *J. Air Waste Manage. Assoc.* 54: 1494–1505.

Chen, C.L., Tang, S.T., Zhu, J.N. and Lin, S.L. (2017). Atmospheric $PM_{2.5}$ and polychlorinated dibenzo-*p*-dioxin and dibenzofuran in a coastal area of central Taiwan. *Aerosol Air Qual. Res.* 17: 2829–2846.

Cheruiyot, N.K., Lee, W.J., Mwangi, J.K., Wang, L.C., Lin, N.H., Lin, Y.C., Cao, J., Zhang, R. and Chang-Chien, G.P. (2015). An overview: Polycyclic aromatic hydrocarbon emissions from the stationary and mobile sources and in the ambient air. *Aerosol Air Qual. Res*. 15: 2730–2762.

Cheruiyot, N.K., Lee, W.J., Yan, P., Mwangi, J.K., Wang, L.C., Gao, X., Lin, N.H. and Chang-Chien, G.P. (2016). An overview of PCDD/F inventories and emission factors from stationary and mobile sources: What we know and what is missing. *Aerosol Air Qual. Res*. 16: 2965–2988.

Chow, J.C., Yang, X., Wang, X., Kohl, S.D., Hurbain, P.R., Chen, L.A. and Watson, J.G. (2015). Characterization of ambient PM_{10} bioaerosols in a California agricultural town. *Aerosol Air Qual. Res.* 15: 1433–1447.

Correa, O., Raun, L., Rifai, H., Suarez, M., Holsen, T. and Koenig, L. (2006). Depositional flux of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans inan urban setting. *Chemosphere* 64: 1550–1561.

Dockery, D.W., Pope, C.A., Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E., Jr, F. and Speizer, F.E. (1993). An association between air pollution and mortality in six US cities. *New Engl. J. Med.* 329: 1753–1759.

Guerzoni, S., Rossini, P., Molinaroli, E., Rampazzo, G.and Raccanelli, S. (2004). Measurement of atmospheric deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in the Lagoon of Venice, Italy. *Chemosphere* 54: 1309–1317.

Hashimoto, S., Wakimoto, T. and Tatsukawa, R. (1990). PCDDs in the sediments accumulated about 8120 years ago from Japanese coastal areas. *Chemosphere* 21: 825–835.

Hu, M.T., Chen, S.J., Lai, Y.C., Huang, K.L., Chang-Chien, G.P. and Tsai, J.H. (2009). Characteristics of polychlorinated dibenzo-*p*-dioxins/dibenzofuran from joss paper burned in Taiwanese temples. *Aerosol Air Qual. Res*. 9: 369–377.

Huang, C.J., Chen, K.S., Lai, Y.C., Wang, L.C. and Chang-Chien, G.P. (2011). Characterization of atmospheric dry deposition of polychlorinated dibenzo-*p*-dioxins/dibenzofuran in a rural area of Taiwan. *Aerosol Air Qual. Res.* 11: 448–459.

Jurado, E., Jaward, F., Lohmann, R., Jones, K., Simó, R. and Dachs, J. (2005). Wet deposition of persistent organic pollutants to the global oceans. *Environ. Sci. Technol.* 39: 2426–2435.

Kaupp, H. and McLachlan, M.S. (1998). Atmospheric particle size distributions of polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs) and their implications for wet and dry deposition. *Atmos. Environ*. 33: 85–95.

Kim, E.J., Oh, J.E. and Chang, Y.S. (2003). Effects of forest fire on the level and distribution of PCDD/Fs and PAHs in soil. *Sci. Total Environ.* 311: 177–189.

Koester, C.J. and Hites, R.A. (1992). Wet and dry deposition of chlorinated dioxins and furans. *Environ. Sci. Technol.* 26: 1375–1382.

Lee, K.L., Lee, W.J., Mwangi, J.K., Wang, L.C., Gao, X. and Chang-Chien, G.P. (2016). Atmospheric $PM_{2.5}$ and depositions of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in Kaohsiung area, southern Taiwan. *Aerosol Air Qual. Res*. 16: 1775–1791.

Lee, S.J., Ale, D., Chang, Y.S., Oh, J.E. and Shin, S.K. (2008). Seasonal and particle size-dependent variations in gas/particle partitioning of PCDD/Fs. *Environ. Pollut.* 153: 215–222.

Lee, Y.Y., Hou, W.C., Zhu, J. and Wang, W. (2018a). Wet deposition of PCDD/Fs in Taiwan. *Aerosol Air Qual. Res*. 18: 2600–2611.

Lee, Y.Y., Wang, L.C., Zhu, J., Wu, J.L. and Lee, K.L. (2018b). Atmospheric $PM_{2.5}$ and polychlorinated dibenzo-*p*-dioxins and dibenzofurans in Taiwan. *Aerosol Air Qual. Res*. 18: 762–779.

Lin, X., Huang, Q., Chen, T., Li, X., Lu, S., Wu, H., Yan, J., Zhou, M. and Wang, H. (2014). PCDD/F and PCBz emissions during start-up and normal operation of a hazardous waste incinerator in China. *Aerosol Air Qual. Res*. 14: 1142–1151.

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.

Lohmann, R., Green, N.J. and Jones, K.C. (1999). Detailed studies of the factors controlling atmospheric PCDD/F concentrations. *Environ. Sci. Technol.* 33: 4440–4447.

Lu, H.Y., Lin, S.L., Mwangi, J.K., Wang, L.C. and Lin, H.Y. (2016). Characteristics and source apportionment of atmospheric $PM_{2.5}$ at a coastal city in southern Taiwan. *Aerosol Air Qual. Res.* 16: 1022–1034.

Marinković, N., Pašalić, D., Ferenčak, G., Gršković, B. and Stavljenić Rukavina A. (2010). Dioxins and human toxicity. *Arh. Hig. Rada. Toksikol.* 61: 445–453.

McDonnell, W.F., Nishino-Ishikawa, N., Petersen, F.F., Chen, L.H. and Abbey, D.E. (2000). Relationships of mortality with the fine and coarse fractions of long-term ambient PM_{10} concentrations in nonsmokers. *J. Exposure Sci. Environ. Epidemiol.*10: 427–436.

Moon, H.B., Lee, S.J., Choi, H.G. and Ok, G. (2005). Atmospheric deposition of polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs) in urbanand suburban areas of Korea. *Chemosphere* 58: 1525–1534.

Ogura, I., Masunaga, S. and Nakanishi, J. (2001). Atmospheric deposition of polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and dioxin-like polychlorinated biphenyls in the Kanto Region, Japan.. *Chemosphere* 44: 1473–1487.

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. and Bidleman, T.F. (1991). Effects of temperature, TSP and per cent 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.

Pope, III, C.A. and Dockery, D.W. (2006). Health effects of fine particulate air pollution: Lines that connect. *J. Air Waste Manage. Assoc.* 56: 709–742.

Pope, III, C.A., Ezzati, M. and Dockery, D.W. (2009). Fine-particulate air pollution and life expectancy in the United States. *N. Engl. J. Med.* 360: 376–386.

Prange, J.A., Gaus, C., Päpke, O. and Müller, J.F. (2002). Investigations into the PCDD contamination of topsoil, river sediments and kaolinite clay in Queensland, Australia. *Chemosphere* 46: 1335–1342.

Sheu, H.L., Lee, W.J., Su, C.C., Chao, H.R. and Fan, Y.C. (1996). Dry deposition of polycyclic 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.

Srogi, K. (2008). Levels and congener distributions of PCDDs, PCDFs and dioxin-like PCBs in environmental and human samples: A review. *Environ. Chem. Lett.* 6: 1–28.

Tseng, Y.J., Mi, H.H., Hsieh, L.T., Liao, W.T. and Chang-Chien, G.P. (2014). Atmospheric deposition modeling of polychlorinated dibenzo-*p*-dioxins, dibenzofurans and polychlorinated biphenyls in the ambient air of southern Taiwan. Part II. Wet depositions and total deposition fluxes. *Aerosol Air Qual. Res*. 14: 1966–1985.

U.S. EPA (2000). Exposure and human health reassessment of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and related compounds. Part III: Integrated summary and risk characterization for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and related compounds. U.S. EPA, Washington DC, p. 264.

U.S. EPA (2003). Exposure and human health reassessment of 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) and related compounds National Academy Sciences (NAS) Review Draft, U.S. EPA, Washington DC.

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.

Watanabe, S., Kitamura, K. and Nagahashi, M. (1998). Effects of dioxins on human health: A review. *J. Epidemiol.* 9: 1–13.

Wu, Y.L., Lin, L.F., Hsieh, L.T., Wang, L.C. and Chang-Chien, G.P. (2009). Atmospheric dry deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in the vicinity of municipal solid waste incinerators. *J. Hazard. Mater*. 162: 521–529.

Zhao, R., Cui, K.P., Wang, W.W., Wang, L.C., Wang, Y.F. (2018). Sensitivity analyses for the atmospheric dry deposition of total PCDD/Fs-TEQ for Handan and Kaifeng cities, China. *Aerosol Air Qual. Res.* 18: 719–733.

Zhu, J., Tang, H., Xing, J., Lee, W.J., Yan, P. and Cui, K. (2017a). Atmospheric deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in two cities of Southern China. *Aerosol Air Qual. Res*. 17: 1798–1801.

Zhu, J., Xing, J., Tang, H., Lee, W.J., Yan, P., Cui, K. and Huang, Q. (2017b). Atmospheric deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in two cities of northern China. *Aerosol Air Qual. Res*. 17: 2027–2040.

Received for review, October 10, 2018
Revised, October 28, 2018
Accepted, October 28, 2018