Influence of PCDD/Fs from a Simple Waste Incinerator on the Plant Environment

Gang Zhang¹, Shimin Kang¹*, Xiangxuan Huang¹, Wenbo Liao¹, Jing Hai², Mingzhong Ren², Rujin Chen¹, Wantong Nin¹, Hanjie Weng¹ and Doudou Wu¹

¹School of Chemical Engineering and Energy Technology, Dongguan University of Technology, Dongguan 523808, China
²South China Institute of Environmental Sciences, Ministry of Environmental Protection, Guangzhou 510000, China

*Corresponding author e-mail: 2013068@dgut.edu.cn

Abstract. The influence of polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/Fs) on the plant environment were investigated on the basis of analyzing PCDD/Fs content and congener profiles in the soil and wastewater by washing ash from a simple waste incinerator (SWI). The mean PCDD/F concentrations for soil and wastewater by washing ash was 318.33 ng/kg and 151.04 ng/L, respectively, and the corresponding mean I-TEQ concentrations were 24.08 ng I-TEQ/kg and 10.52 ng I-TEQ/L. The high I-TEQ concentration in soil from the plant area indicated that the impact of PCDD/F emissions from the SWI on the plant environment was quite significant.

1. Introduction
Polychlorinated dibenzo-p-dioxins (PCDDs) and Polychlorinated dibenzofurans (PCDFs) are commonly known as dioxins that have become a global environmental problem because of their high toxicity and potential carcinogenic and mutagenic effect [1, 2]. PCDD/Fs originate from different sources, including waste incinerations, forest fires, chemical industries, vehicles and even cigarette smoking [3, 4]. Identifying potential PCDD/F sources is an essential key step to determine what kind of sources should be prioritized when implementing strict emission control.

As the largest developing country, China has constructed about 100 large MSWs in large and medium-sized cities by the year 2014. Based on remarkable advances in both combustion and air pollution control technologies in recent years, PCDD/F emissions from these large MSWs can be effectively controlled below Chinese environmental standard (0.1 ng I-TEQ/Nm³). Due to the disparity between cities and rural areas, there still exist some simple small waste incinerators (SWIs) in the suburban and rural areas.

The objective of this study was to assess the influence of PCDD/Fs from the SWI on the plant environment. So the PCDD/F concentrations in the soil and wastewater by washing ash of the plant area were examined.
2. Materials and methods

2.1. Basic information on the simple SWI
The investigation was carried out in a simple small-scale waste incinerator in the suburban area of South China. The SWI, with a combustion capacity of 400 kg/hr, operated for 8 h per day. The SWI was equipped with a grate and an air inlet at the bottom of the furnace. Waste was fed from the top of the furnace. Combustion air and flue gas for the incinerator are highly dependent on natural draft. The incinerator was not equipped with APCDs and gas cooling systems.

2.2. Sampling and analytical methodologies
To assess the influence of PCDD/F from the SWI on the plant environment, the soil and waste water by washing ash of the plant area were also sampled. The average value was determined from the three PCDD/F values. The PCDD/F flue gas samples were sampled isokinetically from the stack sampling point with a sampling time ranging between 120 and 180 min, according to the American Standard Method EPA 23A. The methods used for the PCDD/F analysis were adopted from EPA Method 1613B. These analytical procedures were reported previously [5-8].

3. Results and discussion

Table 1. The PCDD/Fs in soil and wastewater by washing ash

|            | Soil (ng/kg) | wastewater by washing ash (ng/L) |
|------------|--------------|----------------------------------|
| PCDD       | 172.87       | 74.16                            |
| PCDF       | 145.46       | 76.88                            |
| total PCDD/F | 318.33       | 151.04                           |
| total I-TEQ PCDD/F | 24.08       | 10.52                            |

Figure 1. PCDD/F congener profiles in soil and wastewater by washing ash.
To assess the influence of PCDD/F from the SWI on the plant environment, the PCDD/F concentrations in the soil and waste water by washing ash of the plant area were examined. Table 1 shows the mean PCDD/F concentrations for soil and wastewater by washing ash was 318.33 ng/kg and 151.04 ng/L, respectively, and the corresponding mean I-TEQ concentrations were 24.08 ng I-TEQ/kg and 10.52 ng I-TEQ/L. The I-TEQ concentrations in soil are the same order of magnitude as that from Spain (1.22-34.28 ng I-TEQ/kg), Finland (13-252 ng I-TEQ/kg), and Korea (1.25-74.98 ng I-TEQ/kg), but higher than that from Japan (average 7.10 ng I-TEQ/kg) and the United States (average 4.0 ng I-TEQ/kg) [9-12].

The observed PCDD/F I-TEQ concentrations in the present study all exceed the 5 ng I-TEQ/kg limit in Germany which restricts the cultivation of certain vegetables [13]. According to the soil dioxin guideline concentrations of Germany, the soil should be limited to cultivation of plants with minimum dioxin transfer, e.g., corn and soybeans [12]. In addition, the I-TEQ concentrations in waste water were much higher than those from the waste water of MSWI [14]. Fig. 4 shows the congener profiles of PCDD/Fs in soil and wastewater by washing ash in terms of total concentration and I-TEQ, respectively. Table 2 provides the complete data on the analyses conducts. The profiles were consistent with those found in stack gas, fly ash and bottom ash from the SWI, which indicated that PCDD/Fs in soil and wastewater derived from PCDD/F emissions of the SWI.

### Table 2. The complete PCDD/F data in soil and wastewater by washing ash

| PCDD/Fs | I-TEF | soil | wastewater |
|---------|-------|------|------------|
|         | ng/kg | ng I-TEQ/kg | ng/L       | ng I-TEQ/L |
| 2378-TCDF | 0.100 | 10.30 | 1.03 | 5.68 | 0.57 |
| 12378-PeCDF | 0.050 | 11.10 | 0.56 | 4.98 | 0.25 |
| 23478-PeCDF | 0.500 | 18.60 | 9.32 | 10.56 | 5.28 |
| 123478-HxCDF | 0.100 | 12.40 | 1.24 | 7.31 | 0.73 |
| 123678-HxCDF | 0.100 | 11.90 | 1.19 | 6.82 | 0.68 |
| 234678-HxCDF | 0.100 | 15.40 | 1.54 | 9.95 | 0.99 |
| 123789-HxCDF | 0.100 | 4.15 | 0.42 | 1.70 | 0.17 |
| 1234678-HpCDF | 0.010 | 41.00 | 0.41 | 23.16 | 0.23 |
| 1234789-HpCDF | 0.010 | 1.51 | 0.02 | 1.44 | 0.01 |
| OCDF | 0.001 | 19.10 | 0.02 | 5.28 | 0.01 |
| 2378-TCDD | 1.000 | 1.43 | 1.43 | 0.37 | 0.37 |
| 12378-PeCDD | 0.500 | 6.51 | 3.26 | 0.89 | 0.44 |
| 123478-HxCDD | 0.100 | 3.43 | 0.34 | 1.05 | 0.11 |
| 123678-HxCDD | 0.100 | 10.30 | 1.03 | 2.94 | 0.29 |
| 123789-HxCDD | 0.100 | 8.50 | 0.85 | 1.86 | 0.19 |
| 1234678-HpCDD | 0.010 | 45.50 | 0.46 | 14.51 | 0.15 |
| OCDD | 0.001 | 97.20 | 0.97 | 52.54 | 0.05 |
| Total PCDD/Fs | | 318.33 | 24.08 | 151.04 | 10.52 |

### 4. Conclusion
The plant environment became a serious problem since high I-TEQ concentration soil was found. An appropriate control strategy should be taken immediately with the purpose of eliminating PCDD/F emissions from the SWI sources.
Acknowledgments
This work was financially supported by the National Natural Science Foundation of China (21606045), Natural Science Foundation of Guangdong Province of China (2017A030313084, 2017A030313261), and Young Innovative Talents Program from Department of Education of Guangdong Province (2015KQNCX163). The authors greatly appreciate the South China Institute of Environmental Sciences, Ministry of Environmental Protection for the sampling and analytical work.

References
[1] W.Y. Chen, J.H. Wu, S.C. Lin, J.E. Chang, Bioremediation of polychlorinated-p-dioxins/dibenzofurans contaminated soil using simulated compost-amended landfill reactors under hypoxic conditions, Journal of Hazardous Materials, 312 (2016) 159-168.
[2] M. Zhang, A. Buekens, X. Li, Brominated flame retardants and the formation of dioxins and furans in fires and combustion, Journal of Hazardous Materials, 304 (2016) 26-39.
[3] Y. Han, W. Liu, W. Pan, P. Wang, Z. Tian, Y. Zhao, M. Wang, X. Chen, X. Liao, M. Zheng, Formation Pathways of Mono- to Octa-Chlorinated Dibenzo-p-dioxins and Dibenzofurans in Main Organochemical Industries, Environmental Science & Technology, 49 (2015) 10945-10950.
[4] M. Wang, W. Liu, M. Hou, Q. Li, Y. Han, H. Li, N. Yan, M. Zheng, Mono- to Octachlorinated Polychlorinated Dibenzo-p-dioxin and Dibenzofuran Emissions from Sintering Plants Synergistically Controlled by the Desulfurization Process, Environmental Science & Technology, 50 (2016) 5207-5215.
[5] G. Zhang, J. Hai, J. cheng, Characterization and mass balance of dioxin from a large-scale municipal solid waste incinerator in China, Waste Management, 32 (2012) 1156-1162.
[6] G. Zhang, X. Guo, X. Fu, Y. Shao, Y. Xu, J. Hai, M. Ren, S. Zhang, Emission characteristics of PCDD/Fs from a samlr waste incinerator in China, Organohalogen Compounds, 77 (2015) 137-140.
[7] G. Zhang, J. Hai, M. Ren, S. Zhang, J. Cheng, Z. Yang, Emission, Mass Balance, and Distribution Characteristics of PCDD/Fs and Heavy Metals during Co-combustion of Sewage Sludge and Coal in Power Plants, Environmental Science & Technology, 47 (2013) 2123-2130.
[8] G. Zhang, J. Hai, J. Cheng, Z. Cai, M. Ren, S. Zhang, J. Zhang, Evaluation of PCDD/Fs and metals emission from a circulating fluidized bed incinerator co-combusting sewage sludge with coal, Journal of Environmental Sciences, 25 (2013) 231-235.
[9] J.L. Domingo, S. Granero, M. Schuhmacher, Assessment of the environmental impact of PCDD/Fs in the vicinity of a municipal waste incinerator: Congener profiles of PCDD/Fs in soil and vegetation samples, Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering, 35 (2000) 1195-1209.
[10] L. Chang qing, Z.S. Chen, L. Wei, G.Y. Wang, Source and level of dioxins in the soil environment, Geology-geochemistry, (2004) 63-70.
[11] T. T, Araki S, K. M, M. M, Environmental levels of dioxins in Japan: results of nationwide survey of dioxins, Organohalogen Compounds, 46 (2000) 475-478.
[12] Y.Y. Deng, L.J. Jia, K. Li, Z.Y. Rong, H.W. Yin, Levels of PCDD/Fs in Agricultural Soils near Two Municipal Waste Incinerators in Shanghai, China, Bulletin of Environmental Contamination and Toxicology, 86 (2011) 65-70.
[13] J.E. Oh, S.D. Choi, S.J. Lee, Y.S. Chang, Influence of a municipal solid waste incinerator on ambient air and soil PCDD/Fs levels, Chemosphere, 64 (2006) 579-587.
[14] M. Giugliano, S. Cernuschi, M. Grosso, R. Miglio, E. Aloigi, PCDD/F mass balance in the flue gas cleaning units of a MSW incineration plant, Chemosphere, 46 (2002) 1321-1328.