Characteristics of ambient PCDD/Fs measured in a tropical city during rainy season

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Introduction

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs) have received much public concern worldwide during the past 30 years due to their high toxicity and bioaccumulation. Exposure to PCDD/Fs can lead to heart problems, cause cancer and affect the unborn children even with the exposures to low-concentration PCDD/Fs. Major PCDD/Fs emission sources include combustion activity (fossils fuel combustion, municipal, hazardous and medical waste incineration, open burning, vehicle), metal smelting, chemical producing and re-emission from water body, sediment and soil [1]. Ambient air is an important transportation pathway of PCDD/Fs from the emission source to other environmental matrixes and then bio-accumulate via food chains. Studies in Asian cities indicate that ambient PCDD/F concentration range from 18 to 1170 fg I-TEQ m^{-3} while those of PCBs range from 2 to 15 fg I-TEQ m^{-3}. Atmospheric gas/particle partitioning influences the fate of these POPs such as the deposition, chemical reaction, long-range transport and human and ecosystem health effects [2, 3]. Various studies indicate that PCDD/Fs in ambient air strongly distribute in particle phase, accounting for 70% to 80%. Therefore, it is essential to understand the gas/particle partitioning models and the effects of environmental parameters on gas/solid partitioning. In addition, industrial activities without strict environmental management in developing countries release significant amount of PCDD/Fs into various environmental compartments. Relocation of industrial manufactory and facility from China to South East Asia due to increasing wage has been significant in recent few years, however, studies focusing on level of PCDD/Fs in environment matrixes of South East Asia countries are limited. Therefore, it is important to conduct sampling and analysis to better understand POPs contamination in this area. As the biggest city in Vietnam, Hochiminh city has the population over 10 million in 2016 and the amount of motor vehicles is over 8 million. Beside traffic emission, dozens of industrial parks surrounding Hochiminh city could affect the local PCDD/Fs level in ambient air. The purpose of this study is to investigate the gas/particle partitioning of PCDD/Fs at different sites in Hochiminh city, Vietnam, including a historical Agent Orange spraying area during Vietnam conflict. In addition, the influence of meteorological parameters on POPs gas/particle distribution is also assessed and possible sources of these compounds are identified.

Methodology

Hochiminh city is located in sub equatorial climate zone with high temperature and humidity throughout the year. Southern Vietnam in general and Hochiminh city in particular is classified as "Tropical Monsoon" climate in the Koppen climate classification. Average temperature and relative humidity are 28^{o}C and 80%, respectively. He period starting from May to October is regarded as "rainy season" when monsoon bring high rainfall (nearly 2000 mm/year) to the city. Samples were collected simultaneously in commercial site (site A) and industrial site (site B) of Hochiminh city. In addition, the third sampling site (site C) is located in rural area in which 1.017.515 gallons of chemicals including Agent Orange was sprayed during the war. Detailed information of sampling sites is described in Figure 1. The sampling period began from July 25 to August 15, 2016 in rainy season of this city. Samples were collected using high volume samplers (Tisch PS1) complying with US EPA Method TO-9A and around 565 to 916 m^3 air volume was collected for a typical sampling duration of 2-3 days for each sample. PCDD/Fs in particle phase

was collected by quartz fiber filter (Whatman, 1851-101.6 mm) while those in gas phase was collected by polyurethane foam (PUF) plugs. Once the sampling was completed, they were spiked with known amounts of US EPA Method 23 internal standard solution before Soxhlet extraction with toluene for 16 h. The toluene extract was then concentrated to about 1 mL by rotary evaporation and was replaced by 5 mL hexane for pretreatment process. The PCDD/Fs sample was pretreated and fractionated by a series of clean-up columns including sulfuric acid silica gel column, Cape© column and active carbon column. Finally, the cleaned up solution of PCDD/Fs was spiked with known amounts of M23 recovery standard solution, and then analyzed for seventeen 2,3,7,8-substituted PCDD/Fs congeners with HRGC/HRMS.

Results and discussion

Table 1 indicates that the average total solid particle (TSP) measured during the sampling time in Hochiminh city are 37.25 μg m^{-3}, 47.75 μg m^{-3}, 20.03 μg m^{-3} in urban site, industrial site and rural site, respectively. The TSP concentration are significantly lower than those measured in Asian countries. High rainfall (from 165 to 295 mm during sampling period) which causes scavenging effect on ambient particles could be the reason of low particulate level in Hochiminh city during the sampling time. The levels of PCDD/Fs measured in rainy season were 2515 fg m^{-3} (108.7 fg-WHO-TEQ m^{-3}), 3943 fg m^{-3} (200.9 fg-WHO-TEQ m^{-3}) and 514.2 fg m^{-3} (29.96 fg-WHO-TEQ m^{-3}) at commercial site, industrial site and rural site, respectively, and all results were lower than the ambient air quality standard of 600 fg TEQ m^{-3} as proposed by Japan and South Korea but level in industrial site was higher than 150 fg WHO-TEQ m^{-3} as proposed by Germany. Figure 2 indicate that OCDD contributed around 40% of total PCDD/Fs at all three sites. This result matches the conclusions proposed by previous studies in other countries in North America, Asia and South America. In rainy season, the results of gas-particle partitioning (Figure 3) indicate that particle-phase PCDD/Fs accounts for 68.36 %,73.65% and 50% in commercial, industrial and rural site, respectively. The low ratio of particle-phase PCDD/Fs compared to other studies could be attributed to the low TSP, resulting from strong scavenging of particles by heavy rainfall. For congeners profile of PCDD/Fs in each phase, the highest contribution comes from OCDD, accounting for 54.63% in particle phase and 1,2,3,4,6,7,8-HpCDD, accounting for 13.06% in gas phase. The contribution of PCDFs in gas phase increases from commercial site (12.13%) to industrial site (18.36%) and to rural site (24.90%). Lohmann and Jones [3] suggest that the closer to the combustion source, the higher contribution of PCDFs is in the sample. Because there are no major combustion sources in the vicinity of the rural sampling site, we can assume that high PCDFs contribution in this area can be attributed to the open burning activities to remove wastes in rural site of Hochiminh city.

Acknowledgements:

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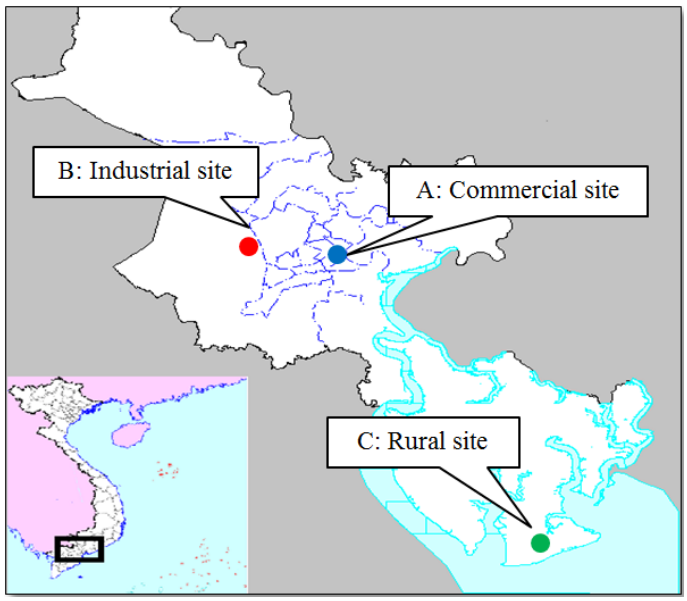

Figure 1. Locations of sampling sites in Hochiminh city.

Table 1 The PCDD/Fs and dl-PCBs concentrations in ambient air in rainy season in Hochiminh city

Sampling period	Sampling site	Meteorological data			TSP (μg m^{-3})	PCDD/Fs	
		Wind direction	Rainfall (mm)	Temp (^{o}C)		(fg m^{-3})	(fg-WHO-TEQ m^{-3})
27-29/07/16	A	South West	185	27.2	34.90	2905	114.0
	B				39.56	3230	84.51
29-31/07/16	A	South West	165	28.3	36.72	2247	85.11
	B				41.76	2763	137.2
31/7-2/8/16	A	West	203	29.6	39.56	2784	131.9
	B				55.50	5124	317.1
04-11/08/16	C	West South West	250	27.7	18.65	612.4	37.71
	C	West South West	250	27.7	18.66	497.2	27.15
	C	West South West	295	28.8	21.40	415.9	22.21

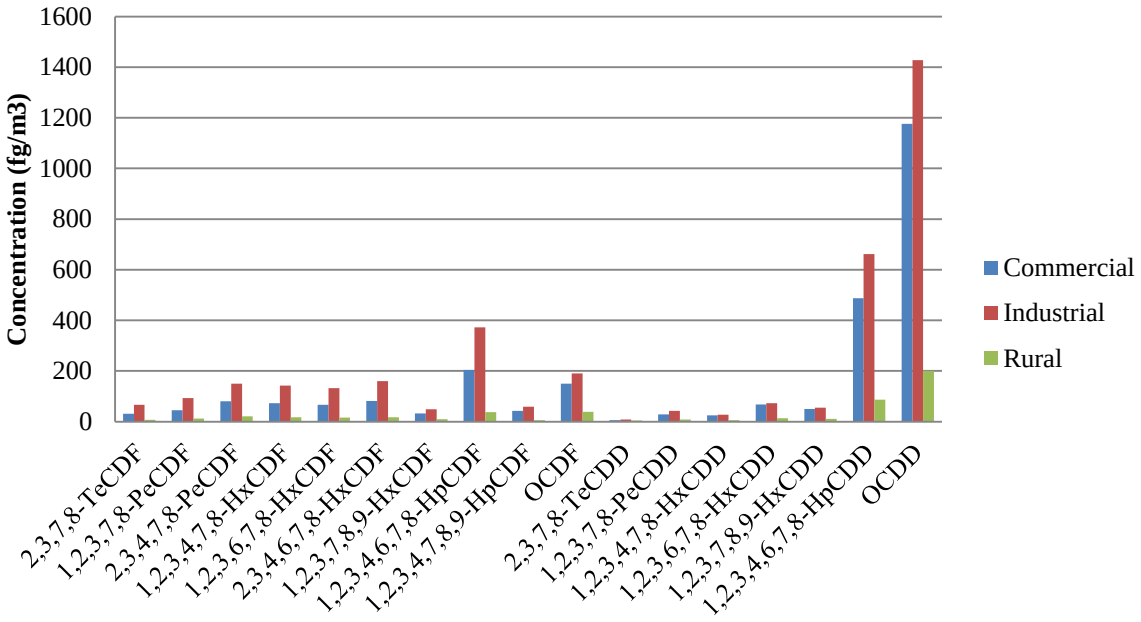

Figure 2. PCDD/Fs congeners profile in ambient air in rainy season

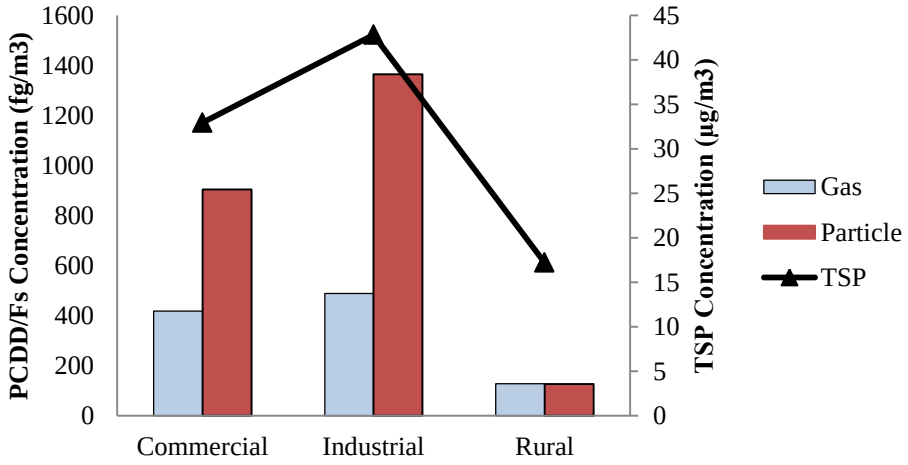

Figure 3. Gas-particle partitioning of PCDD/Fs in commercial, industrial and rural site