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PCDD/F and dioxin-like PCB in Hong Kong air in relation to their regional transport in the Pearl River Delta region

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Abstract

PCDD/F and dioxin-like PCB were measured in 142 air samples of Hong Kong. The annual average PCDD/F and dioxin-like PCB concentrations obtained for Hong Kong air at Tap Mun (PCDD/F: 1724 ± 1984; dioxin-like PCB: 1572 ± 1170 fg m^{-3}), Yuen Long (PCDD/F: 2927 ± 2695; dioxin-like PCB: 4331 ± 1962 fg m^{-3}) and Tsuen Wan (PCDD/F: 1875 ± 1502; dioxin-like PCB: 2972 ± 1510 fg m^{-3}) from January 2004 to March 2005 were comparable to other urban centers around the world and were within the Japanese and USA ambient air quality guidelines. A clear seasonal pattern was observed for PCDD/F, generally with a 50–60 times higher air concentration in winter when background northerly wind was weaker and land–sea breeze prevailed, resulting in regional transport; and a lower concentration in summer, due to the inflow of clean oceanic southeasterly wind from the South China Sea. A higher WHO-TEQ value of dioxin-like PCB (mainly attributed to the relatively higher WHO-TEQ value of PCB 126) in Yuen Long during winter, compared with other months, could also be related to the regional transport by the winter monsoon wind and the low mixing height in winter. Spatially, air concentrations of PCDD/F and dioxin-like PCB demonstrated a west-to-east gradient (with Yuen Long > Tsuen Wan > Tap Mun). It is suggested that PCDD/F and dioxin-like PCB were transported into the western airshed of Hong Kong from the Pearl River Delta by land–sea breeze circulation and confined to the northwestern part, due to the blocking effect of the northwestern airshed in Hong Kong.

Keywords: Land–sea breeze; Seasonal pattern; Spatial variation; Persistent organic pollutants

1. Introduction

Dioxin-like PCB are conformationally similar and express similar toxic responses as 2,3,7,8-TCDD (Safe, 1990, 1994). The persistence of PCDD/F and PCBs, with long half-lives, combined with their low vapour pressures render these compounds accumulative in the environment (ATSDR, 1994, 1998, 2002; IOMC, 1995; UNEP Chemicals, 2002). PCDD/F emissions in Hong Kong were estimated for 1997 with the annual release to the atmosphere of 22.5–33.1 g I-TEQ (HKEPD, 2000). Municipal solid waste (MSW) incineration was the dominant source (81.6–93.2%) of PCDD/F. The closure of all MSW incineration plants in 1997 resulted in a substantial decrease in the release of PCDD/F (2.6 g I-TEQ a^{-1} for year 2003 with <1% from waste incineration) (HKEPD, 2006). The Hong Kong Environmental Protection Department (HKEPD) has been monitoring the Chemical Waste Treatment Center (CWTC) and two power stations (Castle Peak Power Station and Lamma Power Plant) since 1997 and

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up-to-date data have revealed that the contribution of PCDD/F from these local emission sources has been small (Lau et al., 2003; Tung et al., 2005). Whereas for mainland China in 2004, the total release of PCDD/F to the atmosphere was 5040 g I-TEQ a^{-1} with 12% from waste incineration and 26% from heat and power generation (China NIP, 2007).

Since mid-1997, the concentrations of 2,3,7,8-PCDD/F in Hong Kong air have been monitored by the HKEPD (Sin et al., 2002; Louie and Sin, 2003; HKEPD, 2004; Tung et al., 2005). Studies of PCDD/F in Hong Kong air have also been undertaken by Sin et al. (2002), Louie and Sin (2003) and Tung et al. (2005). However, there have been no studies of dioxin-like PCB in Hong Kong air. Therefore, based on the abovementioned studies, the major aim of our study was to quantify the concentrations of both individual PCDD/F and dioxin-like PCB congeners, taking advantage of our lower method detection limits, in order to provide a clearer picture of the contamination level and the source of PCDD/F and dioxin-like PCB in Hong Kong air. The seasonal and spatial variation of PCDD/F and dioxin-like PCB were also investigated. The possible sources of PCDD/F and dioxin-like PCB were identified with the aid of circular pollution wind rose diagrams.

2. Methodology

2.1. Sampling

Hong Kong (22.37 °N, 114.11 °E) is situated at the southern part of the Pearl River Delta (PRD), China, and the provincial capital, Guangzhou, is located at the northern apex. The Special Economic Zones of Shenzhen and Zhuhai are located at the south-east side and the south-west side of the Pearl River estuary, respectively. Ambient air samples of PCDD/F (January 2004–February 2005) and dioxin-like PCB (March 2004–March 2005) were collected in Hong Kong at Tap Mun Station (TMS) (a rural remote background site), Yuen Long Station (YLS) (a residential area nearby Shenzhen) and Tsuen Wan Station (TWS) (an urban residential site with mixed commercial and industrial development) (Fig. 1). Additional samples in Mong Kok (MK) (a roadside site) were collected in summer (July 2004) and winter (December 2004). In accordance to USEPA method TO-9A (USEPA, 1999a), air samples of approximately 300 m^3 were collected over 24 h, using a high volume air sampler (TE-1001 PUF, Tisch Environmental, USA). The sampling head consisted of a quartz microfibre filter (QM-A, 20.5 cm × 25.5 cm, Whatman, England) with sampling cut point <50 μm (total suspended particulates) and a cylinder containing a pre-cleaned polyurethane foam (PUF) (6 cm diameter, 7.5 cm length) to respectively capture both the particulate-bound and vapour phase portion of the contaminants in air. The total number of samples collected, including field blanks, was 142.

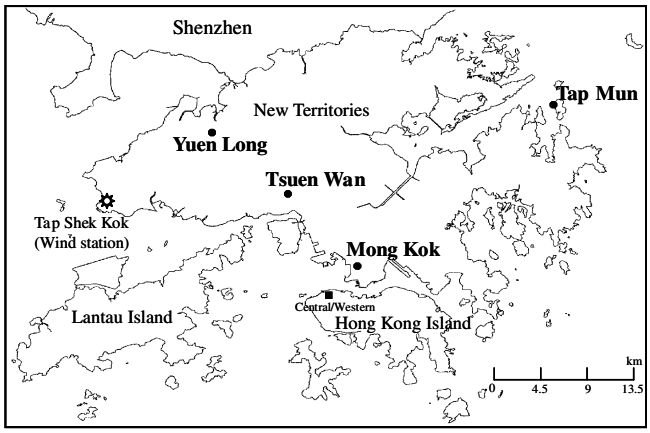

Fig. 1. Map of Hong Kong, showing sampling locations.

2.2. Laboratory analysis

According to USEPA method TO-9A (USEPA, 1999a), 1613B (USEPA, 1994), and 1668A (USEPA, 1999b), the PUF was pre-cleaned prior to sampling and then the PUF together with filter were extracted using Soxhlet extraction with 300 ml toluene for at least 16 h. Sample clean-up steps included liquid–liquid partition with concentrated sulfuric acid, column chromatography using acidic silica gel, acidic alumina and activated carbon (for PCDD/F only), and gel permeation (for dioxin-like PCB only). The QA and QC samples, including solvent blanks, matrix blank and spiked matrix, were analyzed together with the collected PUF/filter samples. Quantification of target congeners was performed by a high resolution GC-high resolution MS (Micromass: Autospec-Ultima) with resolution $\geqslant 10000$. A DB-5MS column (J&W Scientific, USA) was used for analysis. Method detection limits (MDLs) of PCDD/F analyses were determined by using the standard deviations obtained from the analyses of seven matrix-spiked samples. For dioxin-like PCB, the LOQ was determined based on the baseline variation ($S/N = 10$) of blank matrix samples in GC–MS analyses.

3. Results and discussion

3.1. QA/QC results

The concentrations of almost all PCDD/F congeners in the field blanks for TMS, YLS and TWS were found to be below the MDL. As for dioxin-like PCB, although some congeners in the field blank samples were above the LOQ, the concentrations detected were relatively low and were 2.6–7.4% of the concentrations of the samples collected on the same day for YLS and TWS. Only concentrations of some dioxin-like PCB in field blank samples collected at TMS were found to be relatively higher (19–34%).

Recoveries of ^{13}C labeled surrogate standards (SS) and internal standards (IS) for all samples were within the