

Concentrations and possible sources of polychlorinated biphenyls in the soils of Hong Kong

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Abstract

A total of 66 surface (0–10 cm) soil samples covering the whole territory of Hong Kong were collected for analysis of the seven PCB congeners. The detectable concentrations of PCBs in the soils of Hong Kong ranged from 0.07 to 9.87 $\mu\text{g kg}^{-1}$, with a higher concentration in the urban area than in the countryside. PCB patterns were dominated by the low chlorinated congeners. PCB118, a dioxin-like congener, was found in samples from Tsuen Wan and Sha Tin and was assumed to be deposited from local sources. Principal component analysis (PCA) revealed that the sources of PCBs were mainly associated with Aroclor 1242 and Aroclor 1248. A significant linear correlation between the concentrations of soil organic matter (SOM) and the sum of 7 PCBs and of SOM and PCB153 was observed. In total, PCBs were not a severe contamination in the soils of Hong Kong from the current results. However, long-term monitoring is still recommended to keeping, especially in the landfill deposits and some urban parks.

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1. Introduction

Polychlorinated biphenyls (PCBs) have been used worldwide in electrical applications such as capacitors and transformers, in ship painting, and in carbon-free copy papers (Breivik et al., 2002). Soils are an important reservoir for many POPs including PCBs, and about 93% of the estimated UK environmental burden of $\sum\text{PCBs}$ was associated with soils (Harrad et al., 1994). Globally, approximately 21,000 t of PCBs have been discharged into the surface soils based on the estimate made by Meijer et al. (2003). This estimation has not

yet included those in heavily contaminated sites and urban areas. Certain soils receive inputs of such chemicals at contaminated sites, however, at a regional or global scale, most soils receive inputs of PCBs from local atmospheric deposition and long-range atmospheric transport (LRAT). Although the major portion of PCB pollution was found between latitudes 30 and 60°N (Meijer et al., 2003), PCBs have also been used and are still being used in tropical and sub-tropical zones (Wilcke et al., 1999). Moreover, certain POPs like PCBs have the potential to redistribution after volatilization from soil (Gouin et al., 2002.), and will also enter the hydrosphere by groundwater and surface runoff (Tanabe, 1991). In tropical and sub-tropical zones, where temperatures and rainfall levels are higher than in temperate areas, the rapid dissipation of PCBs through air transport and water runoff may lead to a global environmental contamination (Thao et al., 1993). The spatial distributions of PCB contamination in the soils have been studied in urban and rural areas. Creaser et al. (1989) found that urban soils of the

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temperate zone showed the highest PCBs concentrations due to the proximity and abundance of sources. It has been generally observed that PCB concentrations were higher in urban soils than in other soils (Creaser et al., 1989; Covaci et al., 2001). Such spatial distribution for these chemicals may be partly attributed to the human population density in view of the fact that sources of PCBs were mainly associated with activities such as energy use (Meijer et al., 2003).

Most studies on the PCB contamination of Hong Kong have focused on the marine and river sediments (Connell et al., 1998; Richardson and Zheng, 1999; Zhou et al., 1999; Tam and Yao, 2002), the atmosphere (Lau et al., 2003), waters and human breast milk (Chui et al., 1991; Chan et al., 1999; Wong et al., 2002; Lau et al., 2003). Some studies have revealed that PCB contamination may occur in the freshwater sediments adjacent to industrial estates (Zhou et al., 1999). In addition, the Environmental Protection Department (EPD) of Hong Kong has a monitoring program for persistent organic contaminants in sediments of Victoria Harbor. However, there is still little information on PCBs in the soils of Hong Kong. The main objectives of the present study were to investigate the PCBs in the soils of Hong Kong and to identify their possible sources in both urban and countryside areas.

2. Materials and methods

2.1. The study areas

Hong Kong is located at the southeast tip of the Chinese mainland, with a total area of slightly over 1100 km². It is composed of Hong Kong Island, Kowloon, the New Territories and a number of islands, of which Lantau Island is the largest. Urban development is concentrated on about one-quarter of the land, mainly centralized in the northern part of Hong Kong Island and the southern part of Kowloon, Kwai Chung, and Tsuen Wan districts, with a population density over 26,000 persons per km². Despite the limited land area available for development, 24 urban parks with a total area of 216.9 ha were established for recreation in the urban areas during the second half of the twentieth century. The other three-quarters of the land area are regarded as countryside, half of which have been designated as Country Parks and Special Areas. A total of 23 Country Parks and 15 Special Areas have been established for natural conservation, countryside recreation and outdoor education (AFCD (2002)). The limited agricultural and fallow lands are distributed over the alluvial plain of the New Territories. Manufacturing industries such as clothing and electronics are the primary industries in Hong Kong. However, most factories have been moved to mainland China, especially Guangdong province, to take advantage of the lower labor costs. Some small and medium sized enterprises are now located in newly developed towns such as Tai Po and Sha Tin.

Most soils in Hong Kong are oxisols typical of the humid tropics, characterized by strong weathering and leaching (Soil and Conservation Service, 1999). Hong Kong's climate is subtropical, tending towards temperate for nearly half of the year,

and the annual average temperature and relative humidity were 24 °C and 78% respectively in 2000 (Hong Kong Observatory, 2001). The mean annual rainfall ranges from around 1300 mm to over 3000 mm and about 80% of the rain falls between May and September.

2.2. Soil sampling and preparation

Surface soil (0–10 cm) samples were collected from 58 sites distributed in the New Territories, Kowloon, Hong Kong Island, and Lantau Island in December 2000 (Fig. 1). In the countryside areas sites were chosen for remoteness from potential sources such as roads and landfill in the Country Park and rural sites which include farmland, fallow land and uplands. In the urban areas the sites were selected in the urban parks of Hong Kong Island, Kowloon, Sha Tin, Tai Po, Tuen Men and Tsuen Wan because of the relatively long history of industrial activity and heavy traffic in these areas. All the samples were collected from the surface 0–10 cm in triplicate using a hand-held coring device. Overlying vegetation was removed prior to collection of the sample and a total of 66 samples were taken. The samples were freeze-dried in order to avoiding the volatilization and sieved to <2 mm after removing stones and residual roots, then stored in desiccators prior to analysis for PCBs.

2.3. Sample extraction and cleanup

For determination of PCBs the optimal experimental procedure was set up based on the Standard Operation Procedure of the German Federal Environmental Specimen Bank (Oxynos et al., 1992). 7.5 g of freeze-dried soil sample, together with 30 ml mixed solvents (20 ml *n*-hexane, 10 ml methanol and 5 ml deionized water) was added to the extraction vessel and extracted in an ultrasonic bath for 1 h. The mixture was centrifuged and the extract was collected. The extraction procedure was repeated once after adding a further 20 ml *n*-hexane to the residue. The two collections were then combined and anhydrous sodium sulfate was added for drying and then concentrated to around 1 ml by rotary evaporation. The concentrated extracts were passed through a silica gel column (6 ml) with a layer of 0.5 g Na₂SO₄ at the top. The silica gel column was eluted with 7 ml *n*-hexane and the eluate was concentrated down to 1 ml. The solution was finally concentrated to around 100 µl under a gentle stream of pure nitrogen. Ten microliters of the internal standard (pentachlorotoluene, 1 mg l⁻¹) was added to the purified extract prior to transferring to a glass microvial for gas chromatography (GC) injection.

2.4. PCB analysis

A Hewlett-Packard 6890 GC system equipped with a ⁶³Ni electron capture detector-µECD (Agilent Technology Co., USA) was used to perform the gas chromatographic analysis under the splitless mode. The solution was chromatographed on a 30 m × 0.32 mm i.d. HP-5 capillary column with a film

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