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PCDD/F concentrations of agricultural soil in the vicinity of fluidized bed incinerators of co-firing MSW with coal in Hangzhou, China

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Abstract

The concentrations of 17 PCDD/F congeners as well as tetra- to octa-homologues were determined in 33 soil samples collected within a radius of 7 km from a municipal solid waste (MSW) incineration plant that is equipped with three fluidized bed incinerators (FBIs) of co-firing MSW with coal in Hangzhou, China. The total PCDD/F concentrations ranged from 0.39 to 5.04 pg I-TEQ g^{-1} (54–285 pg g^{-1}), with an average and a median value of 1.22 and 0.84 pg I-TEQ g^{-1} (105 and 86 pg g^{-1}), respectively. A systematic decrease of PCDD/F levels was observed with the increasing distances and with the decreasing downwind frequencies from the plant. The comparisons of homologue and congener patterns and multivariate analysis of soil and flue gas samples strongly indicated that most of the soil samples were influenced by the FBIs. Apart from the incineration plant, historical PCDD/F emissions of hazardous waste incinerator (HWI) and motor vehicles as well as the application of 1,3,5-trichloro-2-(4-nitrophenoxy) benzene (CNP) seemed to play an important role in soil samples adjacent to these potential sources.

Keywords: Polychlorinated-*p*-dioxins and dibenzofurans; Fluidized bed incinerators; Municipal solid waste incinerators; Agricultural soil; Multivariate analysis

1. Introduction

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are two groups of most toxic and carcinogenic organic persistent contaminants that are produced unintentionally. It is well documented that their emissions and the subsequent atmospheric transport and behavior have resulted in their widespread dispersal through the environment [1]. Since the first detection of PCDD/Fs in the flue gas of municipal solid waste incinerators (MSWIs), the emissions of PCDD/Fs have become one of the most controversial issues worldwide [2].

Recent studies on the inventories of potential emissions of PCDD/Fs in a number of countries have showed that the combustion is a major contributor to the total PCDD/F concentration in the environment [3]. Given the semi-volatile and hydrophobic character, PCDD/Fs can be easily accumulated in the environment, especially in organic-rich media such as soil and sediment [4]. Therefore, the comprehensive researches have been conducted to investigate the levels of PCDD/Fs in soils in the vicinity of MSWIs over the last three decades [3–18].

Being the largest developing country, China generates annually 170 billion kg of municipal solid waste (MSW), accounting for 26.5% of the total production of the world [19]. The lack of landfill sites for the wastes has forced the local government (especially for developed regions) to choose the incineration as a substitute option. As a result, the project of constructing incineration plants in China has been booming since 2000 and 70 MSWIs were running by 2003, with a daily treatment capacity of 15 million kg [20]. Among these incineration plants, fluidized bed incinerators (FBIs) of co-firing MSW with coal have been widely applied due to its characteristics that can deal with low heat MSW value (the heat value of MSW in most Chinese cities is about 4200 kJ/kg) and keep stable burning [21].

However, till now, in China there are limited studies focused on the occurrence of PCDD/Fs in the soil near the MSWIs. Accordingly, the objectives of this study were to investigate the levels of PCDD/Fs in agricultural soil in the vicinity of a MSW incineration plant that is equipped with FBIs of co-firing MSW with coal, to compare the concentrations of PCDD/Fs with regulations currently in vigor and previous studies, and attempt to

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identify the local sources that might mean a potential elevation of PCDD/F levels in the surrounding agricultural soil.

2. Materials and methods

2.1. Sampling sites

Hangzhou, located 180 km southwest of Shanghai, is a famous scenic city in China. The study area belongs to a satellite town, in the northeast part of this city, where industrial and residential area co-exist (Fig. 1). The town has about 37,000 inhabitants, and covers an area of 30 km^2, of which 57% is agricultural land. The regional agricultural soil in this area is made up of two types, with the prevailing Fluvo-aquic type and paddy soil only in the eastern part of the stack.

The MSW incineration plant referred in this study is located in an industrial zone in the center of the town, adjacent to two motorways with heavy traffic in the west and north sides. In addition, a small-scale hazardous waste incinerator (HWI), about 800 m northward to the MSW incineration plant, had once been occasionally in operation during 2002 and 2004. However, the capacity and PCDD/F emission data from this HWI were not available due to secrecy.

The MSW incineration plant is equipped with three FBIs and began its operation of first two lines in 2002, and has been in full operation with a total daily capacity of 0.8 million kg since 2003, the ratio of MSW to coal of each incinerator is 80:20. All of flue gases are purified by the air pollution control device consists of a semi-dry scrubber and a bag-house filter. Consequently, the emission level measured during its fully operational in 2003 varied from 0.0054 to 0.1961 ng I-TEQ N m^{-3}, which was quite below the national legal limit of 1 ng I-TEQ N m^{-3} [21].

The sampling points were selected according to the atmospheric dispersion modeling based on the wind rose resulting from pluriannual (2002–2005) observations [22]. Meteorological data were obtained from the Meteorological Bureau of Hangzhou and used to make a wind frequency distribution diagram depicted in Fig. 1. Thirty-three soil samples were collected from agricultural land in a two-day period, in September 2006. The exact sampling points were determined and recorded within ~10 m of accuracy by a handheld GPS device (*Meridian Color*, Thales Navigation, USA). Thirty samples were collected within a radius of 3 km from the stack mainly in the historical prevailing downwind directions (W, S, SE, SSE, SW and NE) (Fig. 1). The other three samples collected in the least downwind frequency direction of east, 6–7 km from the stack were served as background controls. The location of the MSW incineration plant, HWI and the sampling sites within a radius of 2 km from the stack were depicted in Fig. 1 by transforming the coordinate of each point into the Geographic Information System (GIS) software packages of Google Earth (2006).

2.2. Sample preparation and analysis

The soil samples were collected by mixing five different aliquots (each in four main directions of 5 m to the center) within a 25 m^2 area. As the agricultural soil is often being farmed, the sampling was carried out by inserting a cylindrical steel

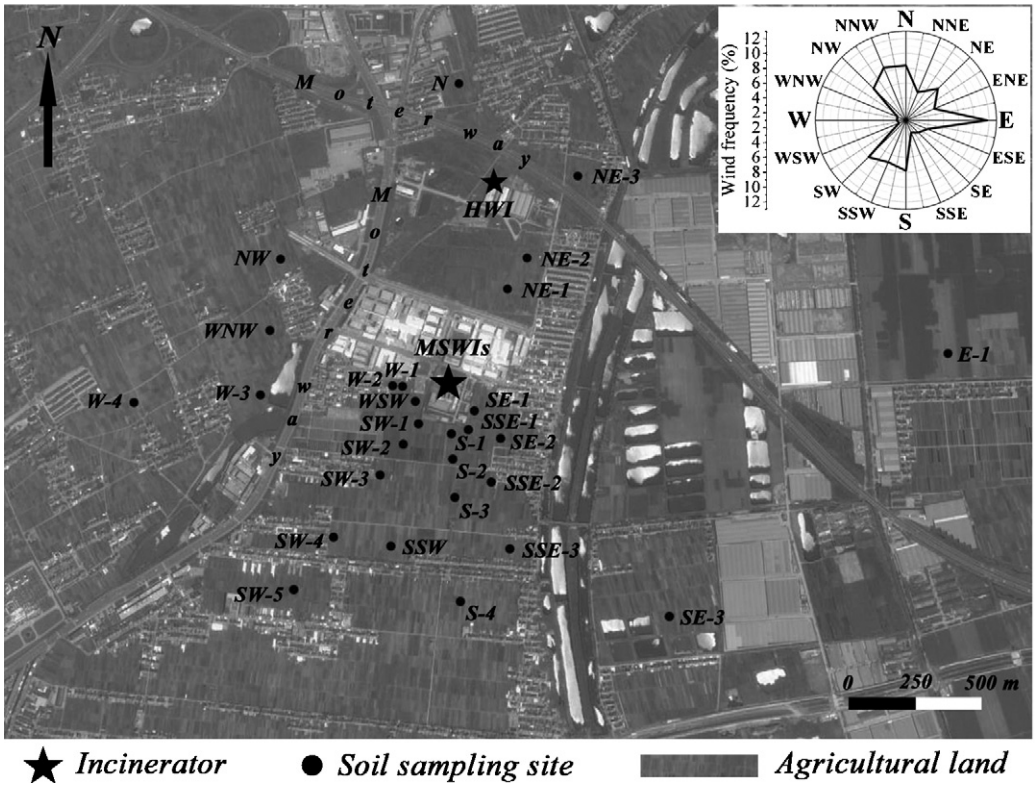

Fig. 1. Schematic of wind frequency diagram and the distribution of soil samples around the MSWIs.