Emission of PCDD/PCDF from Open Burning of Municipal Solid Waste in China: Field Test

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Introduction

Open burning of municipal solid waste in developing countries has recently received particular attention since high emissions of various hazardous chemicals, especially unintentional persistent organic pollutants (unintentional POPs) including PCDD/PCDF, PCBs and HCB, has been anticipated[1]. Even in developed, urbanized and industrialized countries, people still burn their domestic waste in open piles, barrels, fireplaces, household heating stoves, or primitive incinerators. For example, open burning of domestic waste has been identified as the largest quantifiable source of dioxin releases to the air in the United States[2]. In national emission inventories, open burning of municipal solid waste was identified as a large source of PCDD/PCDF in developing countries and countries with economies in transition. In the current dioxin inventory of China (UNEP, 2004), open burning has contributed 9.93% to the total dioxin emission with an amount of 1017 g TEQ/yr. However, waste burning was excluded due to lack of proper emission factors while other emissions from open burning activities like forest fires, grassland and moor fires or agriculture residue burning were quantified using UNEP default emission factors (EFs) from the Standardized Toolkit and Chinese statistical data[3]. As to the different situation of waste recovery in China, many useful materials like paper, plastics, metal were recovered by scavengers in multi step recovery of waste. For the Chinese situation, a sound methodology to determine emission factors of PCDD/PCDF from open burning of waste and identify the driving parameters for the scale of these emission factors for the Toolkit subcategory of open burning of waste in developing countries is urgently needed to complete its national emission inventory.

Materials and methods

Determination of waste composition

Briefly, waste composition for the northeast, north, southeast and southwest areas in China was determined using surveys, statistical information, and published literature. All of the researches referred to have used the same methodology to conduct the determination of waste composition in different areas of China. The final determined waste types in China were defined as three different compositions including urban, semi-urban and rural.

Field sampling of open burning events

A new sampler was developed for sampling from open burn events. The high-volume sampler had the sampling head downwards to collect the fumes from the burning of waste. The filter head consisted of a glass fiber filter (GFF) and a surrogate-spiked polyurethane foam (PUF) cartridge to collect particles and the gas-phase pollutants. Open burning was performed at three cities of China where the waste composition was close to the identified typical Chinese municipal solid waste described in the section above. Waste was collected from the selected dumping sites and an amount of 100 to 150 kg was burned for each sampling event. A total of five different burns were done with all of these in replicates. The burning usually lasted between one and one and a half hours. CO and CO_2 were continuously monitored over the burning period using a Shimadzu CGT-7000 (Shimadzu, Tokyo, Japan) to follow the burning quality and allow for quantification of material burned and calculation of emission factors.

Organic analysis
After the termination of the burn, the GFF and the PUFs were wrapped with aluminum foil, stored, and shipped to Umeå University for analysis. Filters and PUFs were extracted, cleaned up and quantified following EN 1948 European standard method. The quantification was based on the isotope-dilution technique and performed on HRGC-HRMS (Waters Corporation, Milford, MA, USA). Detailed description can be referred to Liljelind et al.[4]

Determination of emission factors:
The emission factors (EF) of PCDD/PCDF released to air are given in ng WHO-TEQ per kg of waste. Determination was done by measuring the amount of PCDD/PCDF (as WHO-TEQ) collected in the GFF and PUF and dividing the result by the mass of waste. The amount of waste burned was determined *via* the formation of CO and CO_2 during the combustion experiment assuming that all carbon burned was converted into CO and CO_2.

Results and discussion
Typical waste composition in China
The compositions of the typical municipal solid waste in China are shown in Table 1. They were grouped into three types which were discussed and concluded on the base of literature review and field studies. It was found that there was not much variation in the wet waste fraction in all three types of waste (40-50%). High in content and variation was the proportion of dust in the three types of waste, highest content of dust was found in the rural area waste with 38 %. The content of combustible materials like plastics and paper differ slightly across the three waste types, with the highest proportions in the urban sample. Metal content is uniformly low with 1-2 % in all waste types.

Table 1 Typical composition of municipal solid waste in China

Composition	Urban (%)	Semi-Urban (%)	Rural (%)
Dust	5	20	38
Wet waste	50	48	40
Plastics	16	10	5
Paper	16	10	5
Metal	2	2	1
Glass	2	1	1
Textile	2	2	2
Rubber	2	1	1
Disposable diapers, etc.	1	1	0
Others	4	5	7

Emission factors of PCDD/PCDF released to air
The emission factors of PCDD/PCDF released from open burning of waste to air range from 5.2 to 121 ng TEQ/kg waste (see Table 2). As can be seen from Table 2, the ranges of emission factors are overlapping and no distinction can be made according to the origin of the waste. Further, the range of emission factors is quite narrow with only a factor of five between the lowest and the highest values.

Table 2: Emission factors from open burning of waste in China (n=10)

Waste Type	Number of experiments	Emission factor to air (ng TEQ/kg waste)
Waste from urban area	4	20-121
Waste from semi-urban area	4	5.2-52
Waste from rural area	2	19-80
Minimum		5.2
Maximum		121

Emission characterization of PCDD/PCDF

Among the 17 toxic congeners of PCDD/PCDF, 1,2,3,6,7,8-HxCDF is the dominant congener, followed by 1,2,3,4,7,8-HxCDF and 2,3,4,7,8-PeCDF. HxCDF has contributed the most to total TEQ of all the field samples and then come PeCDF and PeCDD. It was concluded primarily that emission characterization of PCDD/PCDF from open burning of municipal solid waste is similar as that from emission from municipal solid waste incinerator.

Conclusion

The emission factors determined in this study were lower than the emission factor of 300 ng TEQ/kg waste as proposed in the Toolkit. However, it should be noted that statistical analysis and importance of cofactors such as humidity or burn quality still needs to be undertaken. It also should be noted that the sometimes high dust content "dilutes" the emission factor when EFs are reported on a mass of waste – and not a carbon-burned or waste-burned – basis.

These are the first field data for PCDD/PCDF from open burning of waste in China and also in developing countries. No indication that waste composition has significant effect on emission factor. Burning condition seems to be more important. Other drivers are not yet apparent and other variables haven't extensively tested. More field open burning events shall be conducted to obtain better scientifically sound emission factor for China and provide more useful data for other developing countries.

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