Emission factors of PCDD/DF and PBDE by landfill fire simulation

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Introduction

Landfill fires are a potential source of persistent organic pollutants[1] that cause elevated blood levels of PCDD/DFs in residents near waste dumping sites[2]. Knowledge of fires' emission factors and their fate (i.e. partitioning between flue gas and combustion residues) are important to assess risks from these emission sources. This study is intended to obtain emission factors of PCDD/DFs and PBDEs through laboratory-scale experiments that simulate landfill fires.

Materials and Methods

Two types of waste feed were used. In run 1, refuge derived fuel (RDF) made from municipal waste (Table 1) was used. In run 2, RDF with three types of brominated flame-retardants (BFR) was used. The expected concentrations of BFRs in the waste feed were 1,600 mg/kg of TBBPA, 1,100 mg/kg of DBDE and 400 mg/kg of HBCD.

Figure 1 shows a schematic of the experimental apparatus. A 15-cm-deep stainless steel bowl was filled with 15 kg of soil (10 cm depth); then 3 kg of waste (RDF or RDF+BFR) were loaded on the soil. The stainless bowl was covered with a hood and a tent. A torch was used for 10 min to ignite the waste. Sampling of the flue gases was started 12 min after the first ignition. The flue gas was drawn and sampled through a duct on the hood. This flue gas passed through a gas combustion chamber, a bag filter, and a scrubber before emission to the air. Flue gas which overflowed the hood was drawn and sampled through a duct connected to the tent.

The emission factors to the flue gas and to the residues (ash and carbonized waste) were respectively calculated using eqs. 1) and 2). For run 2, the emission factors of PBDEs and PBDD/DFs to the flue gas per PBDEs input were calculated using eq. 3).

$$EF_{gas} = (C_{tent\ duct}\ FR_{tent\ duct} + C_{hood\ duct}\ FR_{hood\ duct})\ T_{burn}/m_{burned} \quad (1)$$

$$EF_{residue} = \{C_{residue}\ m_{residue} - C_{waste}\ (m_{residue} - m_{ash})\}/m_{burned} \quad (2)$$

$$EF2_{gas} = EF_{gas}/C_{wastePBDE} \quad (3)$$

EF: emission factor; C: concentration; m: mass; FR: flow rate; T: duration

Results and Discussion

The duration of burning, the burn masses and flue gas flow rates are shown in Table 2. Figure 2 shows the time/temperature and time/mass histories of Run 1. Note that the loss of mass in figure 1 includes the evaporation of water from the soil.

The emission factors of PCDD/DFs per mass burned in run 1/run 2 were 23/46 ng-TEQ/kg for the flue gas, 170/120 ng-TEQ/kg for the residue and 190/160 ng-TEQ/kg overall. About 70%-90% of PCDD/DFs were partitioned to the residue in this study (Fig. 3). The ratios seemed to be higher than those of the previous study (1.9%-70%, average 26%)[3]. One possible reason for the higher ratios is that our experiments included both flaming combustion and smoldering combustion, whereas those of the previous study[3] included only the flaming combustion.

The emission factor of PBDEs to the flue gas per PBDE (DBDE) input was 9.1%. The O8BDEs were the single dominant congener in the flue gas. The ratios of N9BDEs and D10BDE for the Sum PBDEs in the flue gas were 9.4% and 1.1%, respectively. The emission factor of PBDEs obtained in this study was about 1000 times higher than the emission factor (0.01%) used in the PBDE inventory by the Danish EPA[4].

References

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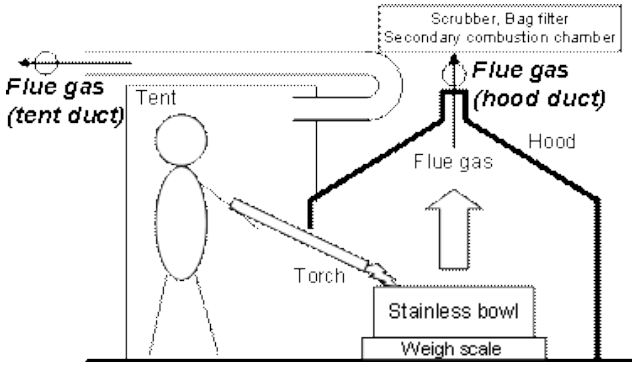

Fig. 1 Schematic of experimental apparatus

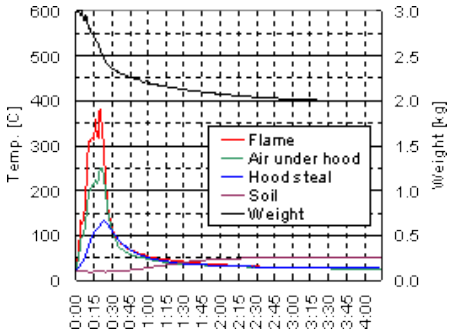

Fig. 2 Temperature and mass (Run 1)

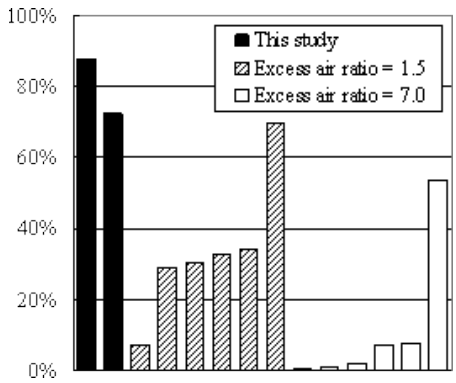

Fig. 3 Patitioning rate of PCDD/DFs to residues: $EF_{residue}/(EF_{residue} + EF_{gas})^3$

Table 1: Waste Composition

Waste category	dry mass
Paper and textile	51.8%
Plastics and leather	32.0%
Wood and grass	5.3%
Garbage	9.5%
Noncombustible	0.4%
Others (> 5mm)	1.0%
Total	100.0%

Table 2: Run duration, burn mass and flow rate of flue gas

test no.	Run 1	Run 2
waste type	RDF	RDF+BFRs
mass [kg]		
start mass	3.00	3.00
final mass	2.15	2.20
ash + carbonized waste	1.11	1.30
unburnt waste	1.04	0.90
mass burned	0.85	0.80
flow rate [m^3_N-dry/h]		
hood duct	47	46
tent duct	650	610
duration [min]		
flue gas sampling	240	240
flaming combustion	31	20
smoldering combustion	~150	~160

Table 3: Concentrations of PCDD/DFs and PBDEs in wastes, residues and flue gases

Test no.	Run 1				Run 2			
Sample name	RDF	Residue	Tent duct	Hood duct	RDF+BFR	Residue	Tent duct	Hood duct
Unit	ng/g	ng/g	ng/m^{3}N	ng/m^{3}N	ng/g	ng/g	ng/m^{3}N	ng/m^{3}N
PCDD (TEQ)	0.0081	0.038	0	0	0.0076	0.018	0	8.9E-05
PCDF (TEQ)	0.013	0.11	0.00065	0.094	0.013	0.050	0.00065	0.15
Co-PCB (TEQ)	0.0029	0.0097	1.1E-05	0.00018	0.0026	0.026	1.4E-05	0.042
TeCDDs	0.33	1.1	0.033	4.6	0.32	0.64	0.057	6.8
PeCDDs	0.18	1.0	0.0096	1.7	0.17	0.69	0.023	3.7
HxCDDs	0.21	1.2	0.011	0.79	0.19	1	0.017	2.9
HpCDDs	0.18	0.31	<0.007	0.2	0.19	0.25	<0.008	0.73
OCDD	0.72	0.5	0.028	0.32	0.78	0.54	0.035	0.89
TeCDFs	0.42	1.4	0.12	10	0.4	1.3	0.47	16
PeCDFs	0.25	1.7	0.019	2.7	0.24	1.2	0.2	7.4
HxCDFs	0.16	1.4	<0.007	0.78	0.14	0.71	0.021	2.6
HpCDFs	0.076	0.36	<0.007	0.23	0.064	0.21	<0.008	<0.09
OCDF	0.028	0.048	<0.01	<0.2	0.021	0.044	<0.02	<0.2
PCB (1-10 Cl)	78	290	53	2,100	76	260	89	2,600
BDE-47	2.2	27	0.79	11	0.56	52	15	290
BDE-99	5.3	23	0.47	3.1	0.65	230	60	1,100
BDE-100	0.85	3.5	0.32	1.3	0.14	230	70	1,400
BDE-153	3.7	8.8	0.27	<2	1.9	500	52	1,300
BDE-154	0.79	3.6	0.45	2.2	0.29	710	94	2,100
M1BDE	0.086	<0.008	<0.05	<0.6	<0.03	2.4	9.5	170
D2BDE	0.11	0.69	0.15	0.72	<0.03	22	28	580
T3BDE	2.6	9.9	0.91	4.2	0.18	150	140	3,300
T4BDE	10	48	1.8	19	1.3	510	170	3,400
P5BDE	8.8	36	1.5	4.4	1.1	1,300	370	7,200
H6BDE	8.1	25	1.9	5.8	3.8	5,000	370	14,000
H7BDE	16	40	3.4	4.8	10	8,400	980	18,000
O8BDE	23	33	20	2.1	3,900	11,000	8,400	240,000
N9BDE	1,800	16	5.1	<3	540,000	24,000	1,100	2,100
D10BDE	8,100	180	3.1	23	890,000	67,000	130	680
PBDE	9,900	390	38	64	1,400,000	120,000	12,000	290,000
HBCD	2,400	150	1.8	1.2	220,000	43,000	19	140
TBBP-A	980	240	5.2	16	22,000	1,100	83	1,400
PBDD	0.015	0.068	N.D.	N.D.	33	74	5.5	130
PBDF	2.7	42	5.3	19	25	17,000	2300	45,000