PCDD AND PCDF EMISSIONS FROM OPEN BURNING OF GARDEN AND HOUSEHOLD WASTE AND APPLICATION OF THE CARBON BALANCE METHOD

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Introduction

Open burning of garden and household waste is suspected to be an important source of dioxins in the air. The aim of this work was to evaluate the influence of open burning on locally measured dioxin concentrations in air and deposition and to apply the carbon balance method to determine emission factors from air concentrations increments in the plume..

Materials and methods

Three series of combustion experiments were performed, two with burning of garden waste in barrels and in open fires and one with household waste in a barrel. Each series took four weeks with two burning cycles a week each of about four hours.

Garden waste was burned in two barrels with a diameter of 45 cm and a height of 55 cm, with three legs. Barrel 1 had 24 holes (∅=25 mm) for air intake, 14 in the side and 10 in the bottom, while barrel 2 had a capped central intake (∅=100 mm) and a 30 mm wide gap in the bottom rim, resulting in far better combustion. The covers were equipped with a small chimney of 9 cm diameter. These barrels are commercially available in garden shops in Belgium.

The garden waste was a mixture of collected fallen leaves and wood from pine or alder (±85%), chestnut (5%), birch (5%) and black poplar (5%). An average of 27 kg wood and 10 kg leaves was burned each day. During the combustion of garden waste in open fires, a similar fuel composition was used. About 450 kg wood and 16 kg leaves were burned each period of four hours.

The tests with household waste were performed in an empty oil barrel with a volume of 200 l. Five holes with a section of 1 dm^2 on the side of the barrel were supplying combustion air. The fuel was the combustible fraction of household waste, collected by 15 families during 1 month, mainly a mixture of plastics, milk cartons, drink boxes, paper and cardboard. This composition is considered representative for backyard waste burning, but lower in water, organic and inert materials, heavy metals and chlorine than municipal waste. The fire was lighted with 6 kg wood. About 40 kg waste was burned in three hours.

At a distance of about 20 m from the fire, four sets of three Bergerhoff gauges were put up in NE, SE, SW and NW direction. A fifth set was mounted as a background sample at a distance of 400 m SW. The sampling and analytical methods were described elsewhere [1]. The gauges remained open for the standard period of 1 month, each with 8 combustion tests.

During the individual experiments the concentrations of CO_2/CO and dioxins in the emissions were measured in the smoke plume at a distance of 6 m. CO_2/CO were continuously monitored with an infrared analyser while dioxins were sampled in the same gas stream with a GPS-1

sampler equipped with a quartz fibre filter (∅=10 cm) and a plug of polyurethane foam (∅=5 cm, thickness=7.5 cm).
The meteorological data were collected automatically by a mobile station with a 10 m pylon. Because of interference from the surrounding buildings and trees the local direction of the plume was registered manually.

Short description of the carbon balance method
The carbon balance method assumes that an increment of the carbon concentration (CO_2+CO+TOC) in the atmosphere relative to the background is due to the combustion process. This increment can be used to calculate the dilution factor of the air samples taken in the smoke plume.
Furthermore from the differences in carbon and pollutant concentrations, in and outside the plume, emission factors can be calculated if the carbon content of the fuel is known.
Practically the fraction of carbon carried by CO and by hydrocarbons can be neglected and the CO_2 concentration alone is used to calculate the dilution. The carbon balance method was first used in traffic tunnels [2].

Results and discussion

Effects on measured depositions
The dioxin depositions during the experiments are summarised in table 1.

Table 1: Deposition during the combustion tests

Location with respect to the source	Period of direct contact between plume and gauge	Concentration in pg TEQ/(m².day)
Combustion of garden waste in barrels: 11/01/2001 – 12/02/2001 Combusted waste: 213 kg wood; 75.6 kg leaves – Total combustion time: 32 hours		
NW	3.17 hours	7.4
NE	2.50 hours	5.9
SE	1.84 hours	4.7
SW	4.00 hours	8.1
Background		4.9
Combustion of garden waste in open fires: 13/02/2001 – 08/03/2001 Combusted waste: 3 582 kg wood; 130 kg leaves – Total combustion time: 29 hours		
NW	0.00 hours	8.1
NE	0.67 hours	8.7
SE	0.67 hours	8.5
SW	2.80 hours	9.2
Background		6.9
Combustion of household waste in barrels: 12/03/2001 – 13/04/2001 Combusted waste: 48 kg wood; 323 kg household waste – Total combustion time: 19 hours		
NW	0.83 hours	7.3
NE	2.08 hours	10.5
SE	0.00 hours	8.2
SW	1.05 hours	7.0
Background		4.6

Compared to the background significant increments in deposition, proportional to the period of direct contact between plume and collector are noted. From the increased deposition over the background of the most exposed collectors and the effective increase of dioxin air concentrations, a minimal dry deposition velocity of 0.69 cm/s for smoke from garden waste and 0.72 cm/s for smoke from household waste combustion was calculated for total PCCDs and PCDFs in I-TEQ.

Concentrations in air and emission factors

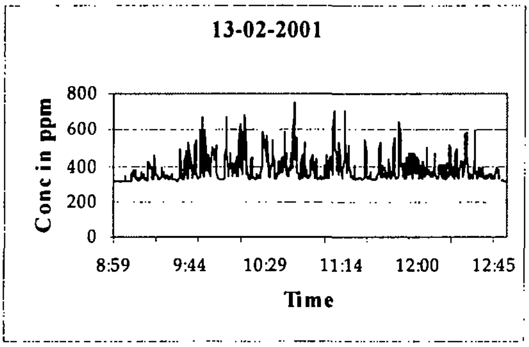
The dioxin concentrations in the smoke plume and on the background location are summarised in table 2.

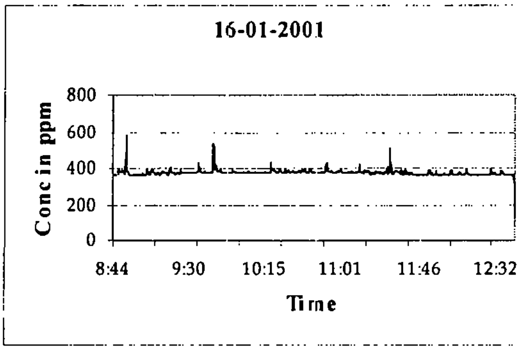
Table 2: Results of the dioxin analyses in the air sampled by the GPS-1

Sampling period	Sampling time in hours		Sampled volume in m³		Conc in fg TEQ/m³	
	Plume	Background	Plume	Background	Plume	Background
11/01 – 25/01: barrel 1	18.7	18.9	172	267	1146	646
30/01 – 06/02: barrel 2	11.8	10.5	104	139	591	431
13/02 – 08/03: open fire	31.3	28.3	330	407	402	162
13/03 – 12/04: barrel 3	21.6	30.0	219	531	683	103

Simultaneously with the GPS-1 sampling, the CO_2 concentrations were continuously monitored in the plume. Some typical CO_2 evolutions as a function of time during a combustion process are illustrated in figure 1. The first picture shows the results when the plume is frequently in direct contact with the sampling equipment. The second reflects a situation with hardly any contact due to a vertical rising of the smoke plume.

Figure 1: Examples of CO_2 registration as a function of time





For both components, dioxins and CO_2, the concentration increment in the smoke plume is calculated with respect to the background. The results, expressed as increment collected dioxins in pg TEQ and grams carbon from CO_2 in the total air sample are given in table 3. The two last columns give the calculated emission factors in pg TEQ/g C and ng TEQ/kg burned waste. The carbon contents of the respective fuels were 25.7 %, 26% and 47%.

Table 3: Increments of dioxin and CO_2 in the plumes and calculated emission factors

Air Sample	Increment dioxins in pg TEQ	Increment CO_2 in g carbon	Emission factor in pg TEQ/g C	Emission factor in ng TEQ/kg burned waste
11/01 – 25/01: barrel 1	86.0	1.1	78.2	20
30/01 – 06/02: barrel 2	16.6	0.9	18.4	4.7
13/02 – 08/03: open fire	79.3	4.7	16.9	4.4
13/03 – 12/04: barrel 3	127	1.7	74.7	35

With the dilution factors, calculated from the CO_2 measurements, dioxin concentrations in the smoke at 9% CO_2 were determined as in table 4. From the results it is clear that barrel 1 with starved air combustion gives much higher emissions for the same fuel.

Table 4: Dioxin concentrations in the undiluted smoke, referred to 9% CO_2

Experiment	Dilution factor of the air sample	Dioxin increment fg TEQ/m³	Conc at 9% CO_2 ng TEQ/m³
Garden waste/barrel 1	7042	500	3.5
Garden waste/barrel 2	5221	160	0.84
Garden waste/open fire	3298	240	0.79
Household waste/barrel 3	6224	580	3.6

Conclusions

Measurements of dioxin deposition and air concentrations can be significantly influenced by backyard combustion of garden and household waste in open fires and barrels.

In this work, the carbon balance method was applied successfully to calculate emission factors and emission concentrations from open air combustion.

The dioxin concentrations in the undiluted smoke as well as the emission factors in ng TEQ/kg are comparable with those from poorly controlled MSW incinerators.

Limitations of the method in practice were meandering of the plume and plume rising in some of the experiments, resulting in low measured increments in dioxins and CO_2 concentrations and therefrom increased measurement uncertainty. The results however indicate that the method may find further application in estimating emissions from open air fires.

References

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