

Emissions of PCDD/F and PCB from uncontrolled combustion of domestic waste in Sweden

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Introduction

Combustion related activities are the dominating sources of release of PCDD/Fs and PCBs to ambient air. Municipal waste combustion, that previously was a major contributor, is today the most investigated combustion activity and is generally considered to have a low impact on the total emissions. However, there is a large uncertainty regarding the extent of emissions from diffuse combustion sources, such as small-scale bio fuel combustion, accidental fires and domestic small scale combustion of waste, so called “backyard burning”. It was therefore a governmental decision to perform a national Swedish survey of unintentionally produced persistent organic pollutants (POP’s), of which the present study is a part¹. In Sweden, garden waste is expected to dominate domestic waste burning and ordinary house-hold waste to constitute a minor part. With this assumption as a starting point, this study has been designed as a screening test of different possible cases of backyard burning.

Experimental

Nineteen combustion tests were done in a 200 liter steel barrel and two tests were performed as open fires. The experimental setup is shown schematically in figure 1. For supply of air, twelve 20 mm holes were bore up around the base of the barrel. A conical fume hood was mounted 0.1 m above the barrel. Temperatures were measured by thermocouples placed according to figure 1 and were continuously logged. A probe in the tube was connected for continuous measuring of CO₂, CO, O₂ and HC (hydrocarbon). The compositions of waste fuel are summarized in table 1. The garden waste was composed of approximately one half wood branches and one half leaves and grass. The RDF (refuse derived fuel) consisted of municipal waste where the combustible fractions mechanically had been sorted out from non-combustible waste and waste suitable for composting at a waste sorting plant. The wastes were put in layers in the barrel with coarse material (e.g. branches and paper packages) preferably in the bottom to allow supply of air. Sampling of organic compounds in flue gas and logging of temperatures started immediately whereas logging of gases started within a couple of minutes, after the first outburst of thick fuel gas. When a major part of the fuel was combusted and the temperature in the barrel sank below app. 100 °C, the smoldering remains were stirred with a stick to enhance further combustion. Flue gas samplings were interrupted when temperature in the barrel decreased below app. 70 °C. At six trials (No. 2, 4, 7, 9, 10 and 16, the gas logging equipment was not available or malfunctioning (Table1).

Two trials (No. 20 and 21) were performed as open fires. In these cases the fire was placed on a 1×1 m plate of steel. The hood was mounted 0.5 m above the plate. Except for the thermocouples in the barrel the same equipment was used and the same procedures were followed as in the barrel trials.

Dioxins and PCB in flue gas were iso-kinetically sampled with a cooled probe and sampling train. The sampling time was usually about one hour and the sampling volume about 0.5 m³. Because of dilution the CO₂ levels generally were very low (average values 0.4 – 2.8 % for barrel burnings and 0.2 % for open burnings) and this resulted in normalized sampling volumes of approximately 0.1 m³_n. Emission factors (emissions of the compounds per unit mass consumed by combustion) have been calculated from the relative amounts of carbon in fuel and in sampled emissions of CO₂, CO and HC. The values have been corrected for loss of flue-gas in sampling.

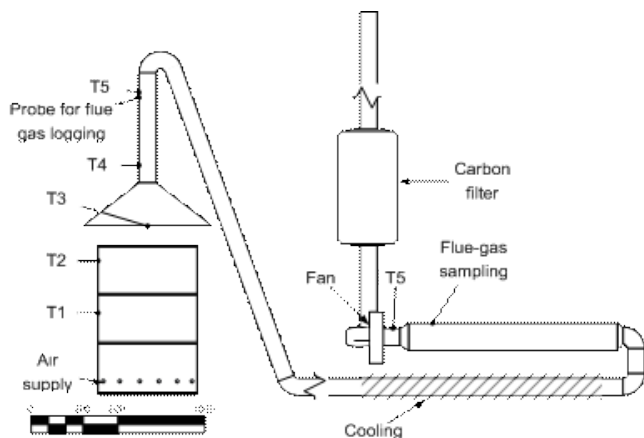


Figure 1. Schematic view of the experimental setup. The scaling is approximate. T1-T5 are thermocouples.

Results and discussion

In most of the trials the temperature in thermocouples T1-T5 (Fig 1) peaked within five or ten minutes to between 600 °C and 700 °C, a level that usually was maintained less than ten minutes after which it in 20-30 minutes temperatures decreased below 100 °C. Stirring the smoldering remains caused a temporary rise to approximately 300 °C.

The emissions of chloro-organic compounds from combustions of garden waste and PVC (trial no.10) are between one and three magnitudes larger than the other emissions because of the very high content of chlorine in PVC (Table 1). Also the combustion with computer scrap (trial no. 16) stands out from the other results. PVC probably is present in minor amounts in the computer scrap together with copper (i.e. in electric cables) that is known to catalyze formation of dioxins. In the other trials however, there are no obvious relations between the contents of the waste fuels and the emissions. A fuel like RDF could be expected to give more emissions than for garden waste since it is most likely more contaminated with chlorine and dioxin catalyzing elements, but no such tendency is visible. The effect of higher levels of contaminants may in some cases have been counteracted by higher energy contents, resulting in higher temperatures and more effective combustions. This effect can be seen when comparing combustion of comparable waste fuels without and with motor oil added, as for garden waste and RDF (trials 6, 7 and 8) and RDF and packages (trials 13, 14 and 15) (Table 1).

Table 1. Composition of combusted waste-fuel and emission factors from combustion

Trial No.	Composition	Emission factors in flue gas emissions		
		Σ PCDD/F, $\mu\text{g}/\text{kg}$	PCDD/F, ng/kg (WHO-TEQ)	PCB, ng/kg (WHO-TEQ)
1	6 kg garden waste	0.3	15	n.a
2	6 kg garden waste	15	0.10×10^3	2.0
3	6 kg garden waste, moisture.	1.0	24	2.0
4	4 kg garden waste, 1.7 kg paper pack. 0.3 plastic pack.	0.4	8	1.8
5	4 kg garden waste, 2 kg plastic pack.	5.5	53	0.9
6	4 kg garden waste, 2 kg RDF	1.6	28	2.4
7	4 kg garden waste, 2 kg RDF	1.3	15	1.4
8	6 kg garden waste, 0.5 liter waste (used) motor oil	0.1	2.2	0.0
9	4 kg garden waste, 2 kg silage film (polyethylene)	2.2	28	0.6
10	4 kg garden waste, 2 kg PVC	0.44×10^3	96×10^3	0.19×10^3
11	4 kg papers and magazines, 1.7 kg paper pack., 0.3 plastic pack.	0.8	13	0.5
12	4 kg papers and magazines, 1.7 kg paper pack., 0.3 plastic pack.	0.4	7.3	0.5
13	4.5 kg RDF (air dried), 1.5 kg paper packages	3.6	59	2.3
14	4 kg RDF, 2 kg paper pack.	4.6	47	2.1
15	3.4 kg RDF, 2.65 kg paper pack., 0.95 car tire, 0.5 liter waste (used) motor oil	0.7	13	0.7
16	4 kg RDF, 2 kg paper pack. 2.95 kg computer scrap	71	0.89×10^3	0.8
17	6 kg straw	0.3	3.4	2.2
18	6 kg moisture straw	0.5	10	0.6
19	4 kg moisture straw, 2 kg silage film (polyethylene)	0.3	4.2	0.3
20	6 kg garden waste, open combustion	3.6	27	3.2
21	4 kg garden waste, 2 kg RDF, open comb.	3.7	36	0.3

Generally, the dioxin emissions expressed as TEQ emission factors in most cases are at same levels with comparable wastes in other works on open uncontrolled combustion^{2,3}.

One of the garden waste combustions (trial no. 2) had markedly higher emissions than the other combustions of garden waste and also higher than all other combustions except for the previous mentioned combustions of PVC containing wastes. This significant deviation may be caused by an unknown contamination, however deviations of this magnitude have also been found previously between duplicate runs^{2,4}.

The emissions from open fires (trials no. 20 and 21) had relatively high levels of dioxins. This may be an effect of lower combustion efficiency because the produced heat is not withheld in the fire in the same way as in the barrel burnings. It should however be pointed out that the uncertainty in the sampling probably is larger in the open combustions.

Only the emissions of PCDD/F and PCB from highly contaminated wastes can clearly be related to waste contents. This is also concordant with other studies⁴. For wastes with lower grade of contamination, other factors more difficult to determine, seems to have larger influence of the emissions. Based on this assumption, a general emission factor range may be suggested for emissions of PCDF and PCB (WHO-TEQ) in combustion of different compositions of garden waste and other low and moderate contaminated wastes to be 4-72 ng/kg (9-95 percentile), with a median value of 17 ng/kg. In these values, the results from combustion of computer scrap and PVC are excluded and in assessments of local or national total emissions, contributions from such high contaminated wastes must be added separately. The major difficulty in such assessments still will be the uncertainty in what amounts the different wastes are actually burnt.

Acknowledgements

This work was financially supported by the Swedish Environmental Protection Agency.

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