INFLUENCE OF TEMPERATURE, AIR FLOW AND MOISTURE ON PCDD/F CONCENTRATION IN FLY ASH OF A FLUIDIZED BED PILOT PLANT

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Abstract

Pelletized refuse derived fuel (RDF, Ecobric) was combusted in a fluidized bed pilot plant under different temperature, air flow and moisture conditions. While the moisture content of the fuel (5–25 % H_2O) had little influence on PCDD/F emissions, the variation of bed temperature and freeboard temperature resulted in variation of PCDD/F concentrations by a factor of 46. For oxygen concentration an optimum value of lambda = 1.4 was found. Lower air flow rates led to a shift in the distribution pattern of PCDD/F congeners to lower chlorinated isomers. For minimization of PCDD/F the CO content of the flue gas and the particulate carbon content of the fly ash should be < 50 mg/m^3 and < 1 %, respectively.

Introduction

A fluidized bed pilot plant was used to study the influence of temperature, air flow rate and moisture content of fuel on PCDD/F concentrations in the flue gas. Related studies on larger technical plants have been reported [1]. We used a pilot plant for a better control of incineration parameters.

The investigations presented herein were part of a project sponsored by BMFT (Bundesministerium für Forschung und Technologie). For details see the related research report [2].

Experimental

Pelletized refuse derived fuel (RDF, Ecobric) with an average chlorine content of 0.9 % was used as fuel. The average C, H, and S concentration of the RDF were 39.5 %, 5.2 %, and 0.4 %, respectively. The water content amounted to about 5 %.

A general scheme of the incinerator which was used in this study is shown in Figure 1. The air flow rate was described using lambda = $21/(21 - O_2$ concentration of the flue gas in %). The general burning conditions were as follows: 40 kg RDF (Ecobric) were burned per hour yielding 300–400 m^3 of stack gases, which contained about 5 kg of particulate material. The particulate material was separated and collected in two fly ash fractions:

I. Coarse fly ash (FA-1) with an average particle diameter of 100 μm, separated by mass, about 4 kg/h,
II. Fine fly ash (FA-2) with an average particle diameter of 10 μm, separated by a special fabric filter, about 1 kg/h.

These two fly ash fractions were sampled. Concentrations of PCDD/F in the flue gas were calculated from those determined for the fly ash. The determination of PCDD/F in the flue gas and stack gas by direct sampling can be found in reference 2. Identification and quantification of PCDD/F were performed by standard procedures using appropriate clean-up methods and GC/MS. For details see reference 2. Before sampling two days of burning under constant conditions were performed to equilibrate the incinerator.

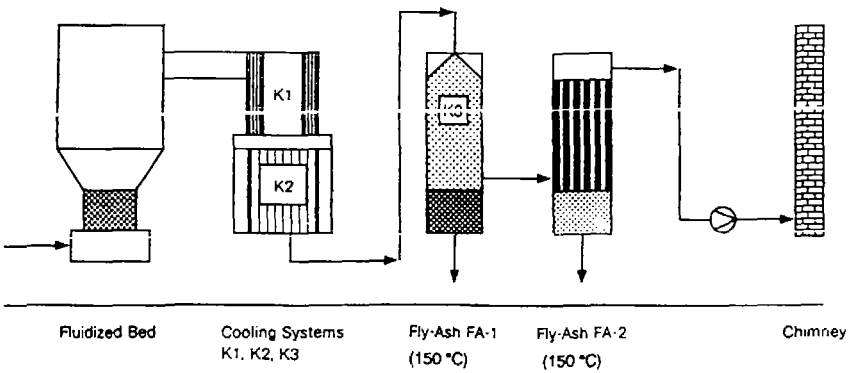

Figure 1: Scheme of the Fluidized Bed Reactor

Results and Discussion

In general, PCDD/F concentrations of fine fly ash FA-2 were about 8 times larger than those of coarse fly ash FA-1. Since the mass of FA-2 was one fourth that of FA-1, the contribution of FA-2 to the PCDD/F concentration of the flue gas was approximately two times larger than the contribution of FA-1.

The reproducibility of the PCDD/F measurements under controlled conditions was tested by repeating one of the experiments 4 times. A reproducibility of ± 10 % was obtained for the fly ash samples (Figure 2). It was also shown that the PCDD/F concentrations of the effluents correlated linearly with the sampling time.

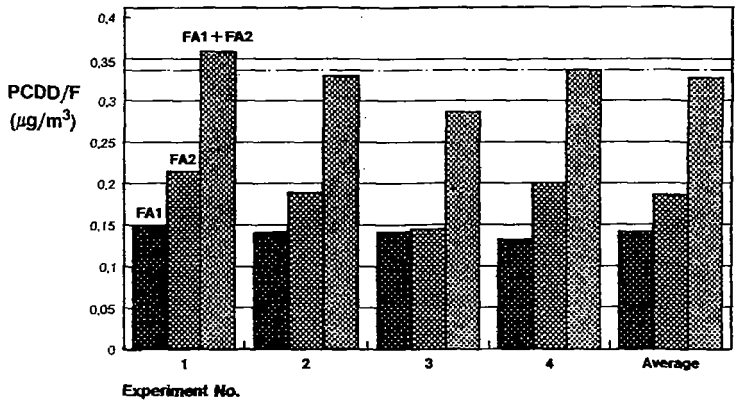

Figure 2: PCDD/F Concentration in Fly Ash Fractions FA-1 and FA-2 of the Fluegas under Constant Burning Conditions

1. Effect of Fluidized Bed Temperature and Freeboard Temperature

In 27 experiments from 6 different burning periods RDF (Ecobric) was burned without additives while the temperature of the bed and the freeboard was varied [2]. Some of these experiments are described in Table 1.

PCDD/F concentrations varied from 1.5 µg/m³ to 73 µg/m³. Increasing the fluidized bed temperature increased the PCDD/F formation, while increasing the freeboard temperature decreased PCDD/F formation due to a more complete burning. The optimal temperatures for PCDD/F minimization in the investigated pilot plant can be derived from these studies. A temperature of about 810 °C for the fluidized bed and a temperature of 940–950 °C for the freeboard gave the lowest PCDD/F concentrations (Table 1).

PCDD/F concentrations can be linearly correlated with the CO content of the flue gas (Figure 3). The CO content of the flue gas and the particulate carbon content of the fly ash are indicators of incomplete burning which increases PCDD/F concentrations. A CO content of the flue gas of < 50 mg/m³ was found to minimize PCDD/F emissions. Additionally, the C concentration of the flue gas should be < 0.15 g/m³ which is equivalent to a C concentration of the fly ash of < 1 %.

Table 1: Burning Conditions and Results of PCDD/F Measurements for Some of the Incineration Experiments

Entry No.	Fluidized Bed Temperature (°C)	Freeboard Temperature (°C)	CO Content of the Flue Gas (mg/m^3)	C Concentration of the Flue Gas (g/m^3)	Σ PCDD/F ($\mu g/m^3$)
1	872	994	527	0.67	22.51
2	821	973	444	0.58	42.98
3	784	917	829	0.31	46.25
4	717	890	826	0.46	27.07
5	829	871	2,259	0.45	39.76
6	820	923	1,748	0.85	33.06
7	811	975	3,261	1.05	73.37
8	819	990	1,024	0.43	28.71
9	808	943	51	0.13	1.68
10	814	947	51	0.16	1.51
11	798	935	212	0.33	5.33
12	831	913	15	0.42	1.71
13	826	915	62	0.36	6.12
14	832	898	25	0.30	4.92
15	826	898	53	0.32	3.07
16	807	887	14	0.87	24.32
17	819	922	31	0.32	2.05
18	822	902	23	0.40	2.59

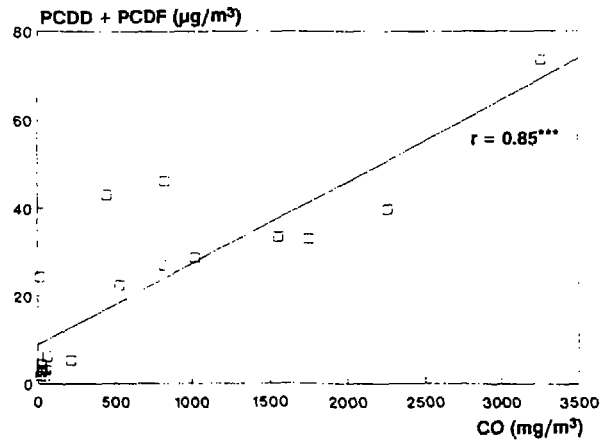

Figure 3: Correlation of PCDD/F Concentration and CO Content in Flue Gas from RDF Combustion. *** Significance at the 99.9 % Level of Confidence

2. Effect of Air Flow Rate on PCDD/F Concentrations

Air flow rates were varied from oxygen deficiency (lambda = 1.15) to excess of oxygen (lambda = 1.56). Under normal burning conditions an air flow rate with a lambda value of 1.4 was used. The results obtained for 5 different air flow rates are presented in Figure 4. Varying the lambda values from 1.38 to 1.56 did not change the PCDD/F concentrations substantially, but a low air flow rate with a lambda value of 1.15 (indicating oxygen deficiency) had a significant effect on PCDD/F concentrations. Oxygen deficiency resulted in an incomplete burning of the fuel with an increase of PCDD/F concentrations (Figure 4). More important, a change in the PCDD/F isomeric pattern was observed (Figure 5). The isomeric pattern was shifted from the higher chlorinated isomers to the lower chlorinated dioxins and furans, which are more toxic.

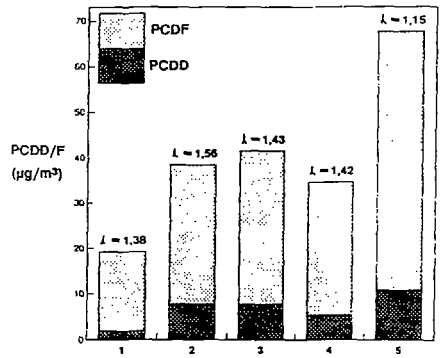

Figure 4: Effect of Air Flow Rate (Lambda Value) on PCDD/F Concentration of the Flue Gas

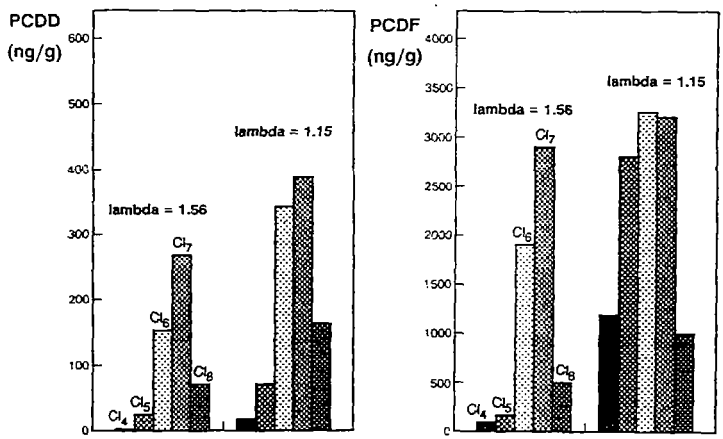

Figure 5: Effect of Air Flow Rate on PCDD/F Concentration of Fine Fly Ash (FA-2) and PCDD/F Isomeric Pattern (Note Different Scales of y-Axes)

3. Effect of Moisture Content of the Fuel on PCDD/F Concentrations

RDF (Ecobric) contained about 5 % moisture. In two experiments water was added to the fuel to give moisture contents of 20 % and 25 %. In all 3 experiments, incineration temperatures were different. No significant effect of the water content of the fuel on PCDD/F concentrations was observed (Figure 6).

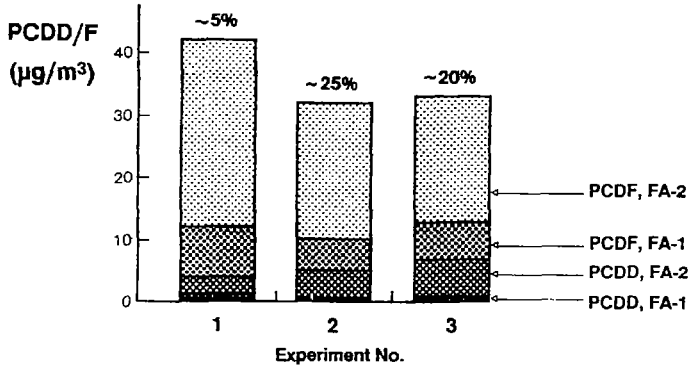

Figure 6. Effect of Water Content of Fuel (5–25 %) on PCDD/F Concentration of the Flue Gas

Acknowledgements

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References

1. Thomé-Kozmiensky, K. J. (ed.) (1989): Müllverbrennung und Umwelt, Volume 3. EF-Verlag für Energie und Umwelttechnik GmbH, Berlin.

2. Hutzinger, O., D. Lenoir, K. Horch, and G. Mützenich (1990): Verbrennungsversuche zur Minimierung der PCDD/F-Bildung an der Technikumsanlage der Deutschen Babcock Anlagen AG in Krefeld. Final Research Report, BMFT Project No. 1450434–4.