USE OF A SYNTHETIC REFUSE IN A PILOT COMBUSTION SYSTEM FOR OPTIMIZING DIOXIN EMISSION, PART II.

Ingrid Fängmark[1], Stellan Marklund[1], Christoffer Rappe[1],
Birgitta Strömberg[2], Niklas Berge[2]

[1]Institute of Environmental Chemistry, University of Umeå, S- 901 87 Umeå, SWEDEN.
[2]Studsvik Energy, s-611 82 Nyköping, SWEDEN

ABSTRACT

A synthetic refuse was used as fuel in a laboratory combustion reactor to study the influence of combustion parameters on the formation of chlorinated dioxins (PCDDs) and dibenzofurans (PCDFs). The experiments were performed according to an experimental plan of two level fractional factorial design. The parameters studied are bed temperature, O_2-concentration, temperature and residence time in the cooler, addition of extra HCl and H_2O. The results show that the reactor and fuel simulate municipal solid waste incineration well. The parameter of most importance for PCDD/F formation is the residence time in the cooler

INTRODUCTION

A laboratory combustion reactor was designed in order to study the formation of polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibensofurans (PCDFs) during combustion of a synthetic municipal solid waste The design of the reactor and the composition of the synthetic refuse was reported earlier (Marklund et al. 1989).

By performing the experiments in a small scale fluidized bed combustor the experimental conditions could easily be obtained and reproduced. By working in small scale it is also possible to clean the equipment between the experiments and thus the carry over bias found with full scale experiments is minimized The design and operational criteria for the reactor are that time, temperatures history and chemical environment in a full scale boiler can be simulated.

In order to evaluate the influence of combustion parameters on PCDD/PCDF formation, the fuel composition has to be carefully controlled. By using a pelletized fuel consisting of homogenious and well controlled materials, the composition will be known and the variation within a fuel batch will be neglible. The raw materials for the synthetic refuse are chosen to simulate normal Swedish municipal waste. The synthetic refuse, when burnt in the experimental reactor should give similar levels, patterns and profiles of PCDDs and PCDFs as from a full scale incinerator.

MATERIALS AND METHODS.

Experimental parameters

The aim of this part of the research work is to study the effect of combustion parameters on the formation of chlorinated hydrocarbons particulary on PCDDs and PCDFs. In order to study many parameters in as few experiments as possible an experimental plan of two level factorial design was used. This way the effect of 6 parameters on two levels could be investigated in only 16 experiments, instead of the 64 ($= 2^6$) experiments that would have been needed for all combinations of parameters and levels. The parameters studied and the levels are given in table 1.

Table 1. Parameters tested and levels ± standard deviation between experiments.

Parameter	Low	High
Temperature in bed (°C)	760 ± 8	874 ± 4
O_2 -concentration (%)	4.9 ± 0.5	7.5 ± 0.5
Flue gas temperature at sampling point (°C)	264 ± 35	456 ± 16
Residence time in cooler (sek)*	0.6 ± 0.1	1.6 ± 0.3
HCl mixed in primary air (g/h)	0	10.2
H_2O mixed in primary air (g/h)	0	136.5

*) Calculated from the total air flow in the reactor and the temperature.

The combustion reactor

The experimental rigg was modified in a few areas. The fuel feeding had to be redesigned to handle larger fuel-pieces than originally planned. The cooling section, simulating the boiler part of an incinerator, also had to be rebuilt in order to improve the control of the cooling process.

During the experiments temperatures were monitored in the fluidized bed at three levels in the combustion reactor and in four positions in the flue gas cooling section. There was also continous monitoring of O_2, CO_2 and CO and NO_x in the flue gases. All data were sampled by a computerized data system.

The supplied air as well as the HCl and water feed rate were measured by rotameters and gas velocities and residence times, particulary in the cooling section, were calculated from air supply, gas composition and local temperatures.

The artificial refuse

To improve homogenity of the synthetic fuel, as reported earlier (Marklund et al, 1989), the sand was omitted. A minor amount of a sulphur chemical (TMTD, tetrametyl-thiuram-disulphide) was added in order to simulate the rubber part of household waste. The dry components in table 2 were obtained as fine powders and mixed with a water solution of the salts. The mixture was extruded to small pellets with the dimension 6 mm diameter x 1-2 cm length.

Table 2. Composition of the synthetic derived fuel (SDF).

Kitchen sweepings	Bone meal	25 %
	Potatoe starch	25 %
Paper	Bleached pulp	16.5 %
	Unbleached pulp	15.5 %
Plastics, rubber	PVC	1.0%
	Polyethylene	7.5 %
	TMTD	0.5 %
Metals	Fe	5 %
	$AlCl_3$	0.5 %
	$CuCl_2$	0.25 %

The water content of the SDF is 7.7 % and the total chlorine content 1.1 %. At a fuel feed rate 1.1 kg/h, used in the experiments, the theoretical flow of HCl from the waste is 12 g/h. Calorific value was determined to 16.2 MJ/kg and the ash content to 13.3 %.

Test runs

Before start up of the experiments the reactor and the cooling section was vacuum cleaned and the bed material replaced.

The reactor was started and heated to operation temperature with propane before the pellets feeder was started. When stable conditions were achieved, 60 - 70 liters of flue gases were sampled isokinetically during a period of about 20 minutes. The sampling train used is the cooled probe - polyurethane foam sampling technique described by Fängmark et al (1989). In this sampling train the flue gases are cooled rapidly thus preventing further chemical reactions to occur.

After clean up the samples were analyzed for toxic isomers on a high resolution mass spectrometer (VG 70E). The results were compensated for sampling spike recovery.

RESULTS AND DISCUSSION

Performance of reactor and fuel

Stable conditions were obtained during each experiment. Temperature variation within every experiment was less than ± 2 % and O_2 and CO_2 variations were less than ± 10% relative. Repeatablity between experiment is also very good which is evident from table 1. It could therefore be concluded that the reactor works satisfactorily and that the fuel size is compatible to the reactor.

The isomeric pattern and profiles from the reactor are also similar to what can be found from a municipal solid waste incinerator (Marklund, 1989).

Memory effects

Carry over between experiments was tested in a separate series of experiments with pelletized household waste and propane as fuels. After a first run with pelletized waste the reactor was cooled down, vacuum cleaned and the sand replaced. The first blank flue gas sample (=blank 1) was collected immediately afterwards when burning propane. After switching the fuel to pelletized waste a second flue gas sample was collected. A third sample (= blank 2) was collected after cleaning the reactor by burning propane for 2,5 hours. The results given in table 3 show that in order to obtain less than a few percent carry over between experiments it is necessary to cool down the furnace, vacuum clean it and replace the sand.

Table 3. Memory effects in the reactor. results from three consecutive samples and different cleaning procedures (ng/Nm^3).

	Blank 1, after vacuum cleaning	Waste	Blank 2, after propane burning
SUM TCDF	17.8	4787	684
SUM TCDD	1.5	497	59
SUM PeCDF	10.9	8862	319
SUM PeCDD	2.0	1106	45
OCDD	4.4	495	17

Further works

The results from the sixteen experiments discussed above will be presented at the conference. Calculations from the first results indicate however that by far the parameter of greatest importance for PCDD/F formation is the residence time in the cooling section. Collecting the sample at 456° or 264° C or adding extra HCl makes no significant difference in flue gas concentrations of PCDDs and PCDFs.

REFERENCES

Fangmark I., Wikstrom L.-F., Marklund S, Rappe C. Studies on sampling methods for PCDDs and PCDFs in stack emission. Paper presented at Dioxin - 89, Toronto, Canada, September 1989.

Marklund S., Fangmark I., Rappe C., Berge N., Strömberg B. Use of a synthetic refuse in a pilot combustion system for optimizing dioxin emission, part I. Paper presented at Dioxin -89, Toronto, Canada, September 1989