

Emissions from Combustion of Waste Plastic Material in Fixed Bed Boiler

H. Mattila^A, T. Virtanen^B, T. Vartiainen^C and J. Ruuskanen^A

^A University of Kuopio, Dept. of Environmental Sciences, Box 1627, 70211 Kuopio, Finland

^B The Finnish Plastics Industries Federation, Mariank 26 B, 00170 Helsinki, Finland

^C National Public Health Institute, Div. of Environm. Health, Box 95, 70701 Kuopio, Finland

In our research we compared emissions caused by four different kinds of fuel mixtures; coal + bark (basic fuels), coal + bark + non-chlorinated plastic material, coal + bark + non-chlorinated plastic material + chlorinated plastic material, and coal + bark + chlorinated plastic material. The combustion tests were performed at a municipal district heating boiler as a full scale experiment. Our results prove that the response of additives in plastics, especially copper, to formation of PCDDs and PCDFs as a catalyst was clear. However, combustion of fuel mixture of coal, bark and waste plastic material related to PVC concentrations of municipal solid wastes, in weight percentages of PVC up to 1 %, did not result in the emission of increased PCDD and PCDF concentrations.

INTRODUCTION

Recycling of small size mixed plastic waste is troublesome because of other wastes, especially organic matter, present in it. One possibility is to recover its energy, which is almost as high as oil has. The recovery of energy may be done in several ways, one viable being co-combustion. It means that waste plastics can be used as supplementary fuel in power or district heating plants.

The presence of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) in the stack gas and on the fly ash from municipal waste combustion incinerators is of great concern because of the toxicity of these compounds. Combustion of organic materials, especially in the presence of chlorine is widely recognized as a major source of PCDDs and PCDFs. The major source of chlorine in combustion of waste plastic material is polyvinylchloride (PVC). The results of the experiments described by Bruce et al. (1991) gave strong support to PCDD/PCDF formation mechanism involving Cl₂ as the intermediate reactant responsible for chlorination. There are experimental results indicating that copper catalyst will activate the conversion of HCl to Cl₂ via the Deacon process (L. Stieglitz et al. 1989, Bruce et al. 1991).

The aim of this work was to investigate the effects of chlorine and copper containing compounds in formation of PCDDs and PCDFs in full scale experiments in fixed bed boiler. The emission data of PCDDs and PCDFs from co-combustion of mixed plastics and primary fuel were compared with the data from pure primary fuel combustion.

EXPERIMENTAL PROCEDURE

The combustion tests were performed in a district heating power plant of 60 MW. The type of the boiler was so called fixed bed boiler. The mass flow of primary fuel and mixed plastics is presented in Table.

The power plant was performed under good operation conditions to achieve the optimum combustion. The chlorine flows in tests 1 and 2 were based on chlorine concentrations in coal and bark. In tests 3 and 4, the increases in chlorine flows were due to PVC plastic material added into the primary fuel mixture. The chlorine contents were from 0.040 to 1.2% (w/w) (Table). PVC plastic material in test 4 contained 2.5 % copper (w/w) resulting the copper content of 0.04 % (w/w) in fuel mixture. The copper content in other tests was lower than 0.0003 % (w/w).

Table. Mass flow of fuel mixtures, chlorine content in fuel mixtures, and total PCDD/PCDF concentrations in toxic equivalents (TEQs).

Test	Coal (kg/h)	Bark (kg/h)	plastics (kg/h)		Cl (%) content*	TEQs (pg/Nm ₃)	
			non-Cl	Cl		before ESP [~]	after ESP [‡]
1	3550	6765 ^{†)}	-	-	0.040	27.7	16.4
2	3030	6767	401	-	0.043	52.1	23.2
3	2800	6765	363	60	0.400	111	38.4
4	3040	6765	-	236	1.200	3315	103

* chlorine content % in fuel mixture

‡) emissions of the plant

~) electrostatic precipitator

†) the density of bark is assumed to be 330 kg/m³

The fly ash samples were collected from the ash separated by the electrostatic precipitator (ESP). The samples of the flue gas components including particles and gas phase compounds were collected isokinetically at the sampling site just before an ESP. The particle samples were collected by quartz fiber filters and the gas fractions of the samples were adsorbed onto XAD-2 adsorbent columns.

PCDD/PCDF analysis of the separated, purified fractions were performed with a high resolution mass spectrometry equipped with a quartz capillary column (HP5) (HRGC/HRMS). The quantitation was made by a selective ion recording method using the VG 70 SE mass spectrometry (resolution 10,000). Total of 16 ¹³C-PCDD/Fs congeners (ED-998 tetra-octa chlorodioxin standard solution and EF-999 tetra-octa chlorofuran standard solution, Cambridge Isotope Laboratories) were used as internal standards.

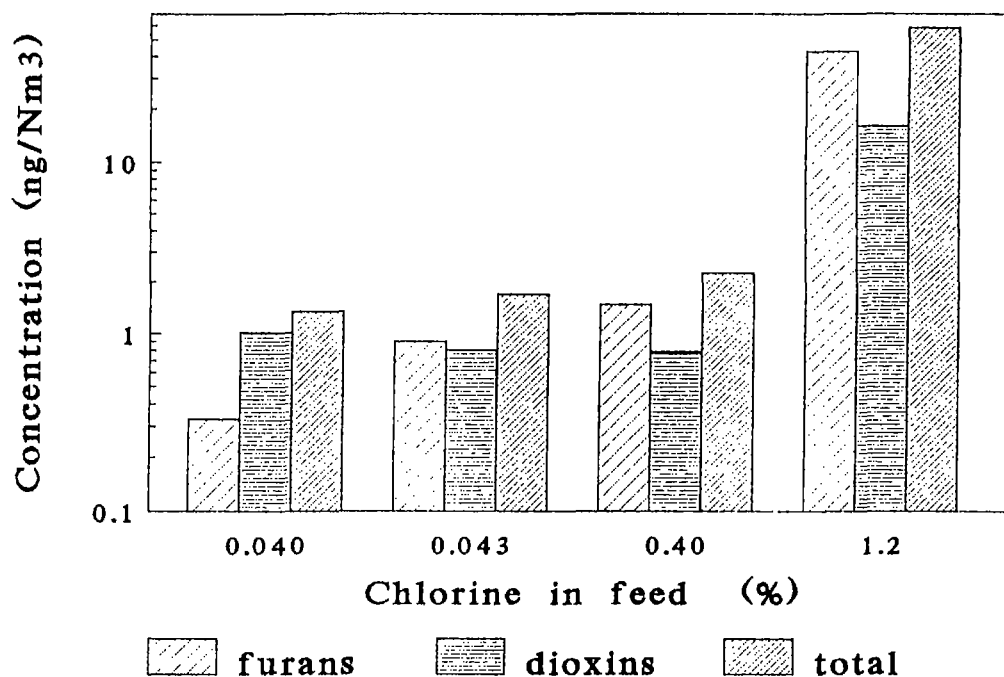


Figure 1. Total emissions of PCDD/PCDFs in flue gas sampled before ESP.

RESULTS AND DISCUSSION

The concentrations of PCDDs and PCDFs in the stack gas sampled before ESP are presented in Figure 1. The results show that the yields of PCDD/PCDFs were almost linearly dependent on the content of chlorine in fuel mixture. During all tests more PCDD/PCDFs were found in particles than in gas phases. The ratio of the concentrations of PCDD/PCDFs between gas phase and particles varied from 1:1.25 (test 1) to 1:57.8 (test 4).

As seen in Figure 1, the total amount of PCDD/PCDFs was closely related to the chlorine concentration in tests 1 to 3, but in test 4 the formation of PCDD/PCDFs was ten times higher than expected from the other tests. The explanation most probably lies in the presence of copper in fuel mixture. This demonstrates a dependency of the formation of PCDD/PCDFs on the catalytical activity of copper. Our results are in good agreement with laboratory experiments (Stieglitz et al. 1989, Gullet et al. 1990). The similar behavior could be seen in the samples of fly ash collected from the ESP (Figure 2).

PCDD/PCDFs were analyzed from the raw gas before ESP. The collection efficiency of ESP for flue gas particles is assumed to be 98%. Combining these facts the PCDD/PCDF emissions of the plant were calculated as Nordic toxic equivalents (TEQs). The results are presented in Table. All values were lower or equal to 0.1 ng/Nm³, which is the proposed EC standard for waste incineration. The results indicate that at higher levels of PCDD/PCDFs the removal of the particles from flue gas will be worthy of being considered.

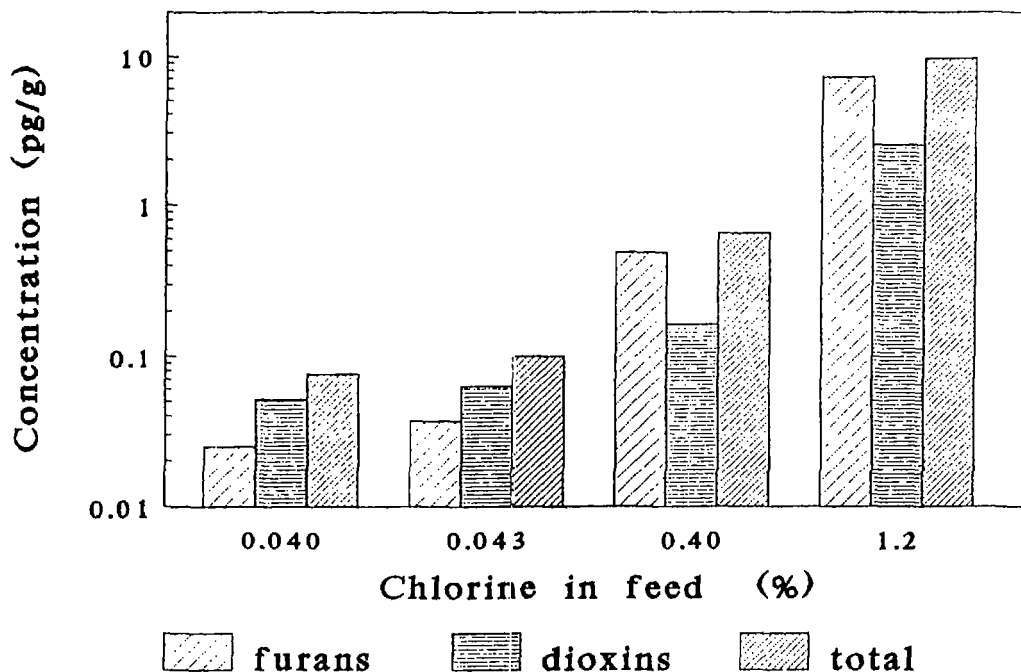


Figure 2. Total PCDD/PCDF concentrations in fly ash.

CONCLUSIONS

The co-combustion of coal/bark/plastics mixture was studied. The tests showed that waste plastic material can be used in co-combustion with coal and bark. The combustion of fuel mixture of coal, bark and waste plastic material related to PVC concentration of municipal solid waste, in weight percentages of PVC up to 1 % did not result increased PCDD/PCDF concentrations in flue gas emissions. The evidence of this full-scale study was that the formation of PCDD and PCDF was connected with the chlorine content in fuel mixtures. The results give strong support to the PCDD/PCDF formation mechanism involving chlorinated plastics as the identified chlorine source. The second major implication of the PCDD/PCDF formation its relationship to concentration of copper.

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