Organic emissions from co-combustion of mixed plastics with coal in a bubbling fluidized bed boiler

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The incineration of waste is generally opposed on the grounds that incineration plants pollute the environment and represent significant sources of polychlorinated dibenzodioxines and dibenzofurans (PCDD/PCDFs). Combustion conditions, however, generally have a greater influence on the nature of emissions than, for example, variations in the chlorine content of feed material.

Extensive research has been done on the formation of PCDD/PCDF compounds. The main focus of this has been on the Denovo Synthesis and Deacon processes[1] and the role of $CuCl_2$ as a catalyst.

It has been suggested that a high sulphur content in fuel, in relation to chlorine content, could prevent the formation of free chlorine and accompanying PCDD/PCDF compounds[2].

In laboratory experiments it has been shown that S/Cl-ratio and HCl concentration in flue gas affect total PCDD/PCDF concentrations in fly ash[3].

Objectives

The objectives of this study were to examine the extent to which mixed plastics (4 % Cl) can be burned in a modern boiler together with coal (0,5% S), and to check the influence of the sulphur/chlorine ratio in the fuel on emissions.

Approach

The term "mixed plastics" is taken here to refer to a typical fraction of packaging plastics. In Finland, this normally comprises roughly 60% polyethylene (PE), 15% polypropylene (PP), 15% polystyrene (PS), 5% polyvinyl chloride (PVC), and 5% other polymers. The thermal value of this mixture is as high as that of fuel oil, and it can be used in solid-fuel fired power and heating plants.

The tests were performed in a 7 MW bubbling fluidized bed boiler fitted with limestone injection equipment and an electrostatic precipitator for processing flue gas. Milled mixed

plastics waste (300 kg/m^3) was pneumatically fed into the fluidized bed. The tests were carried out at a 3 MW thermal load and using a bed temperature of 850°C. The oxygen content of the flue gas was maintained at approx. 10%.

Two different plastics mixtures were used: a PE/PP/PS/PVC mixture (used in tests A-E) as described above, and a PS/PVC mixture (used in Test F_2), representing a 75% PS/25% PVC blend extracted from the former by washing. The materials contained printing inks and fertilizer residues, but no food waste. The test series was initially run without limestone (index 1) and then with limestone (index 2), $Ca/(S + Cl_2) = 1.4 - 5$. Test A, using a 100% coal firing (1,5 kg S/h, 0,4 kg Cl/h input), was used as a reference, while 100% mixed plastics were fired in Test E (0,02 kg S/h, 12 kg Cl/h input). Tests B, C, D, and F utilized varying mixtures of plastics and coal, in which the proportion of plastics ranged from 15% to 70% of the thermal value of the fuel feed. The tests were performed in the following daily sequence: $A_1 - B_1$, $C_1 - D_1$, $E_1 - E_2$, $D_2 - B_2$, $F_2 - A_2$. Sampling and analysis were carried out using standard methods.

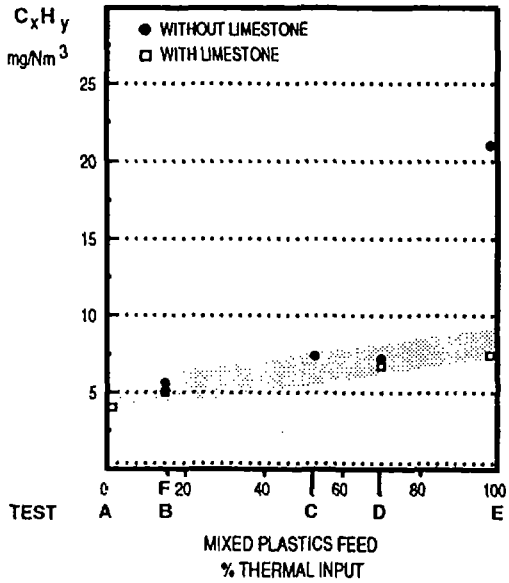

Figure 1. Total hydrocarbons in flue gas

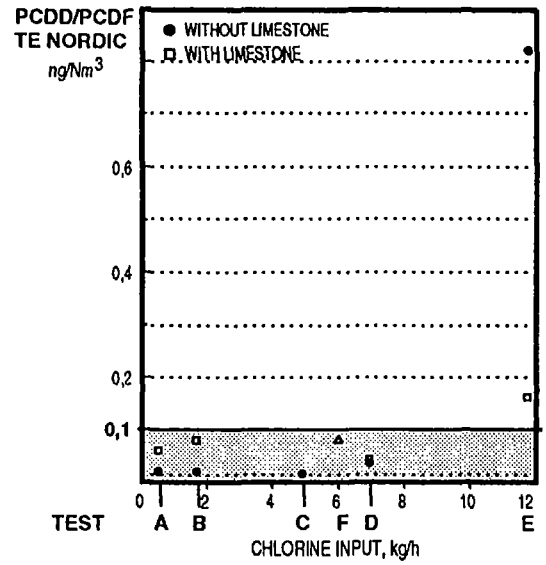

Figure 2. Total PCDD/PCDF in flue gas

Results

Total hydrocarbon emissions (Fig. 1) were below 10 mg/Nm^3, except in the case of Test E_1, and they closely followed carbon monoxide levels. Hydrocarbon emissions during Test F_2 (PS/PVC blend) were at the same level as in Tests B_1 and B_2.

PCDD/PCDF, PCB, PAH, chlorobenzene, and chlorophenole concentrations are presented in Table 1. They were measured separately in both the gas and particle phase. The PCDD/PCDF TE-levels are shown as a function of chlorine feed in figure 2. The components involved are mainly furans.

PCDD/PCDF TE-levels were also measured prior to the electrostatic precipitator in Test D_2. The gas phase concentration of 0.05 ng/Nm^3 indicates that PCDD/PCDF is not formed in a "cold" electrostatic precipitator (170°C).

TABLE 1. ORGANIC EMISSIONS

	A_1	B_1	C_1	D_1	E_1	E_2	D_2	B_2	F_2	A_2	D_2*
PCDD/PCDF(Nordic)											
Gas, ng/Nm^3	0.01	0.004	0.003	0.02	0.6	0.06	0.01	0.06	0.04	0.04	0.05
Dust, ng/Nm^3	0.01	0.009	0.008	0.01	0.2	0.1	0.03	0.01	-	0.02	1.6
Σ	0.02	0.01	0.01	0.03	0.8	0.2	0.04	0.07	-	0.05	1.6
Ash, ng/g	0.03	0.01	0.07	0.2	0.1	0.4	0.6	0.5	0.05	0.04	0.6
PCB											
Gas, ng/Nm^3	4.4	1.1	3.7	3.1	11	1.8	3.4	1.9	3.0	0.3	3.9
Dust, ng/Nm^3	3.9	5.0	5.0	2.8	9.6	6.2	5.5	2.4	6.5	3.2	10
Σ	8.3	6.1	8.7	5.9	21	8.0	8.9	4.3	9.5	3.5	14
Ash, ng/g	8.4	9.4	13	9.6	14	15	9.5	9.2	8.3	7.0	-
PAH											
Gas, μg/Nm^3	107	80	20	125	270	182	28	44	324	76	185
Dust, μg/Nm^3	1.8	0.2	46	3.8	195	34	7.0	0.1	25	0.2	53
Σ	109	80	66	129	465	216	35	44	349	76	238
Ash, μg/g	6.3	0.9	2.4	4.3	19	1.9	0.2	3.1	0.9	2.7	-
CHLOROBENZENE											
Gas, μg/Nm^3	0.7	0.3	0.4	0.6	25	0.2	0.3	0.1	<0.005	<0.005	2.0
Dust, μg/Nm^3	23	0.8	32	0.8	20	3.2	2.9	0.1	3.0	0.4	0.8
Σ	24	1.1	32	1.4	45	3.4	3.2	0.2	3.0	0.4	2.8
Ash, μg/g	0.2	0.2	0.4	0.9	2.0	3.8	0.2	0.9	<0.005	0.2	-
CHLOROPHENOL											
Gas, μg/Nm^3	1.5	1.1	0.8	0.8	0.6	0.1	7.7	2.7	4.1	1.4	0.7
Dust, μg/Nm^3	9.7	10.5	0.1	0.1	1.9	0.3	0.1	0.8	0.4	0.9	1.8
Σ	11	12	0.9	0.9	2.5	0.4	7.8	3.5	4.5	2.3	2.5
Ash, μg/g	2.6	0.5	3.2	8.4	0.5	1.3	3.3	0.8	0.9	2.3	-

* before electrostatic precipitator All results in dry gas

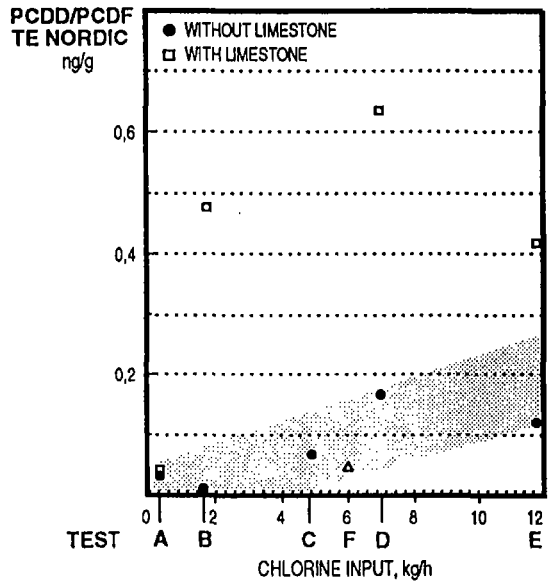

Figure 3. Dioxines and furanes in fly ash

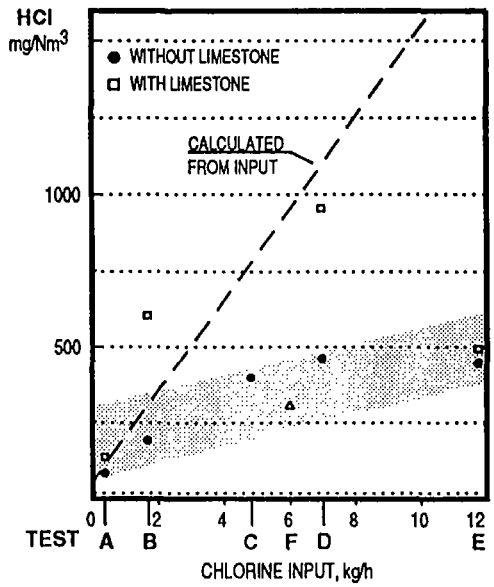

Figure 4. Hydrogen chloride in flue gas

PCDD/PCDFs in fly ash from the electrostatic precipitator are given in figure 3. They show a good correlation to HCl concentrations in flue gas (figure 4). The HCl concentration in flue gas does not follow the feed because of capturing by fly ash and lime. In tests D_2 and B_2 chlorine is obviously released due to increasing sulphur content in the feed.

Metal concentrations in fly ash did not change significantly during tests without limestone. Limestone addition gave increased concentrations of Ca, Cl and Sn. Cu concentrations were virtually constant in all tests. The EPA leachate test gave acceptable results for ashes from all tests.

Conclusions

PCDD/PCDF TE-stack concentrations were below 0.1 ng/Nm^3 during all the tests using a combined plastics/coal fuel feed and the S/Cl ratio in the fuel did not significantly affect emissions. It proved possible to reduce the relatively high figure recorded for Test E by increasing the amount of secondary air.

The slightly increased levels of PCDD/PCDF TEs observed following limestone injection could result from the binding of sulphur from flue gas and from the increased Ca-, Cl- and Sn- concentrations in the fly ash.

The PCDD/PCDF TEs in fly ash closely correlated to the HCl concentration and Cl/S ratio in flue gas. HCl did not directly correlate to chlorine in the feed stock (including PS/PVC in test F_2) because of interaction with the bed material. PCDD/PCDFs are not water soluble so the disposal of ashes should not be of special concern.

The tests showed that mixed plastics can be burned with coal at levels up to 70% of the thermal value of the fuel feed. As plastics do not contain sulphur or nitrogen, emissions from a co-fuel of this type are lower than from pure coal. Plastics possess a higher hydrogen/carbon ratio and thermal value than coal. As a result, carbon dioxide emissions per thermal unit are 30% lower using mixed plastics than when burning coal.

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