SUMMARY REPORT

Co-combustion

of BUILDING INSULATION Foams with municipal solid waste

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APME
ASSOCIATION OF PLASTICS MANUFACTURERS IN EUROPE

Exiba
EUROPEAN EXTRUDED POLYSTYRENE INSULATION BOARD ASSOCIATION

Isopa
EUROPEAN ISOCYANATE PRODUCERS ASSOCIATION

Background and summary

The aim of this report is to assess the extent to which insulation foams from the building and construction industry can be safely and efficiently co-combusted with municipal solid waste. Co-combustion with MSW is seen as the most environmentally friendly option, as crushing or compressing the foam to reduce its density for disposal by landfill can be problematic due to the presence of the ozone depleting blowing agents (Chlorofluorocarbons) in old foams that would be released during the process. Using the co-combustion route, CFC's are safely destroyed, the energy content of the foam can be recovered and landfill avoided. The use of local MSW combustors* is also recommended in order to eliminate the need for long distance transportation.

The process by which CFC's are destroyed during combustion is generally well understood. However, what happens to the flame retardants also contained in these foams (added to fulfil fire safety requirements) is less well known. It is largely for this reason that APME, EXIBA, ISOPA, FZK and BING sponsored this research programme.

The foams used by the building and construction industry are manufactured from different polymers, including polyurethane (PUR) and expanded and extruded polystyrene (EPS and XPS). In most cases the flame retardants used in these foams are brominated or chlorinated organic compounds. The two foams used in the test campaign were XPS and PUR. The flame retardant used for XPS was hexabromocyclododecane (HBCD). For PUR, the foam tested had been formulated with P, Cl and Br (from a brominated polyol).

It was found that the bromides and mixed halogenated dibenzo-p-dioxins and dibenzofurans formed during the combustion of these flame retardants in the foam neither add substantially to the overall hazard of the raw gas of a Municipal Solid Waste Combustor (MSWC), nor to that of air emissions.

Objectives

To study:

- the effects of the destruction of CFC-11 and CFC-12
- the changes occurring to HCl,HF and HBr concentrations in the flue gas and their neutralisation efficiency in a two stage wet scrubbing system
- the effects of the volatilisation of heavy metals caused by the increased levels of halogen in the feed and
- the potential additional formation of brominated and / or mixed halogenated dibenzo-p-dioxins and dibenzofurans.

Test programme

Two test programmes were carried out in the test incinerator, TAMARA in 1993 and 1994 for XPS and PUR respectively. The test programmes for XPS and PUR were designed to last a total of three complete weeks of TAMARA operation.

The XPS tests were run at two temperature levels (850°C and 950°C) with a constant foam addition of 3 wt %. The PUR tests were run at a constant temperature (900°C) with two foam additions of PUR A and PUR B at 1 and 2 wt % foam addition.

The test incinerator TAMARA

TAMARA was built for the Forschungs Zentrum Karlsruhe (FZK) during 1985/87. It is a mass burner with a nominal throughput of 250 kg / h of preconditioned waste.

Test material and base fuel

The XPS foam and granulate was supplied by EXIBA member companies in a form compatible with their specifications. The PUR rigid foams were supplied by a BING (The Federation of European Rigid Polyurethane Foam Associations) member company. These were formulated to represent the expected "European average composition" of PUR insulating foam and contained the CFC 11 blowing agent used up to 1994 and a mix of flame retardants based on phosphorous, chlorine and bromine. Their properties can be seen in Table 1 below.

Table 1.
Analysis of elements in XPS A with CFC 12 and XPS B with HCFC 22, PUR A and B used as co-fuel and the typical compostable and RDF fractions of the TAMARA fuel.

mg/kg	XPS A	XPS B	PUR A	PUR B	compostable fraction	RDF
Br	25 050	25 560	22 200	41 700	247	256
Cl	37 900	36 750	76 000	72 000	5 570	6 700
F	18 960	38 330	7 700	6 850	410	275
P	n.a.	n.a.	7 120	6 820	1 900	1 870
S	<100	<100	n.a.	n.a.	6 970	3 150
As	<10	<10	<1	<1	15	12
Cd	<5	<5	<2	<2	5.0	2.5
Cr	85	69	<1	<1	235	133
Cu	49	53	1.5	1.5	180	173
Ni	103	88	2.5	2.3	155	60
Mn	<20	43	1.2	1.2	339	136
Pb	<10	<10	2	1.9	406	490
Sb	<10	<10	<10	<10	14	18
Sn	<10	<10	<10	<10	44	41
Zn	45	41	8.5	9	641	591
Hu GJ/t	ca. 40	ca. 40	ca. 27	ca. 27	6	14.5

n.a. = not available

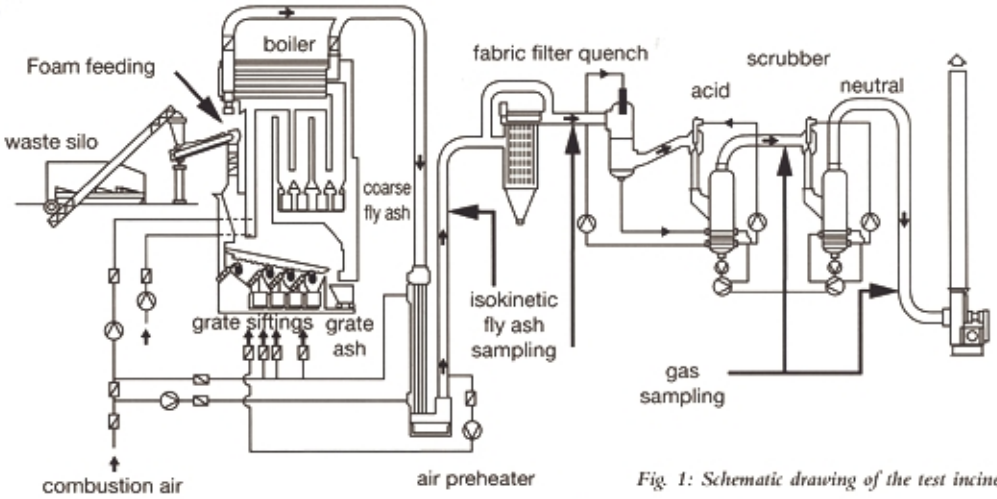

Fig. 1: Schematic drawing of the test incinerator TAMARA

Combustion conditions / raw gas

The following figure shows, as demonstrated by the small spread of raw gas composition, a good operational performance.

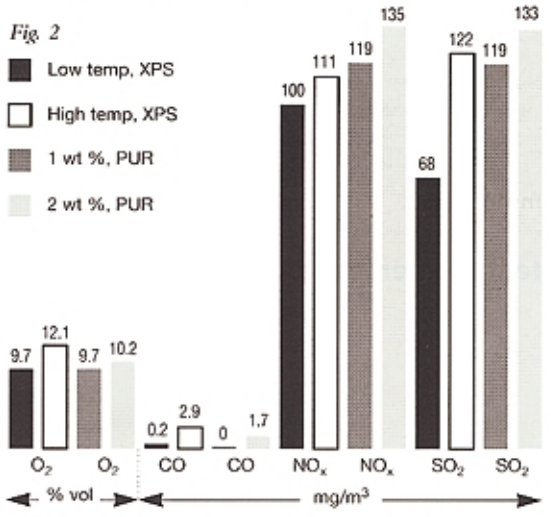

Fig. 2

Acid gas removal

TAMARA is equipped with a separate quench followed by an acid (pH=1) and a neutral scrubber (pH=7) both of which are modified Venturi scrubbers. Between both scrubbers and downstream from the neutral scrubber, special sampling units were installed.

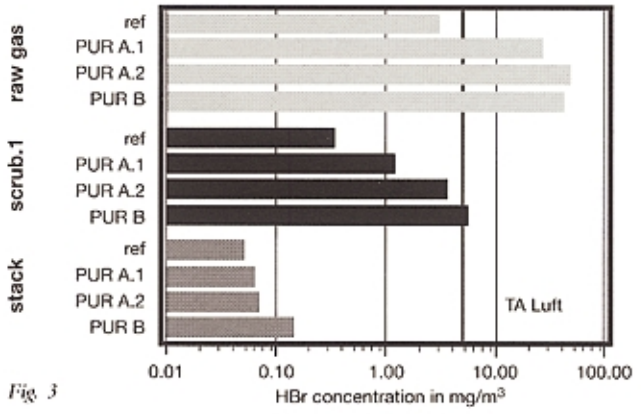

Fig. 3

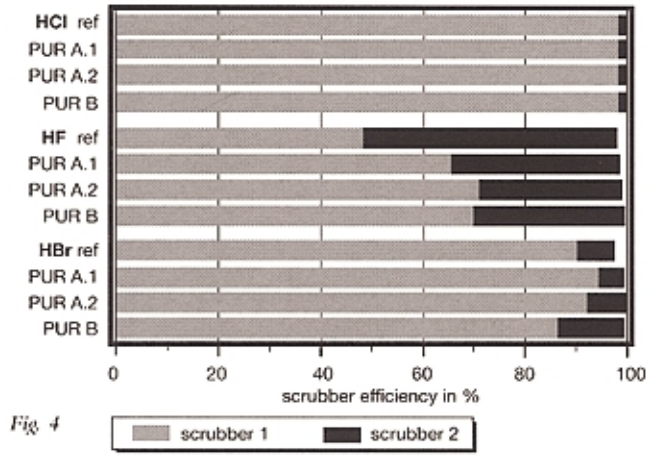

Fig. 4

HCl Abatement: After passing the second scrubber, HCl values far below 1 mg/m³ were achieved, easily meeting the German emission directive (17.BimSchV.) set at 10 mg/m³.

HF Abatement: Clean gas levels of < 0.2 mg/m³ were measured for HF, which is well below the German emission directive limit of 1mg/m³.

HBr Abatement: The HBr gas concentrations were below 0.2 mg/m³, which is well below the limit set by the old German emission directive (TA Luft 86).

Thermal behaviour

The thermal behaviour of chlorine is very well known. The behaviour of F and Br is shown in Figs. 5 and 6. A strong correlation was found between the HF levels in the gas phase and the F containing fuel feed. Also, the F concentration in the fly ash had far greater correlation with the F input than in the case of Cl. The amount of F staying in the bottom ash also remained fairly constant.

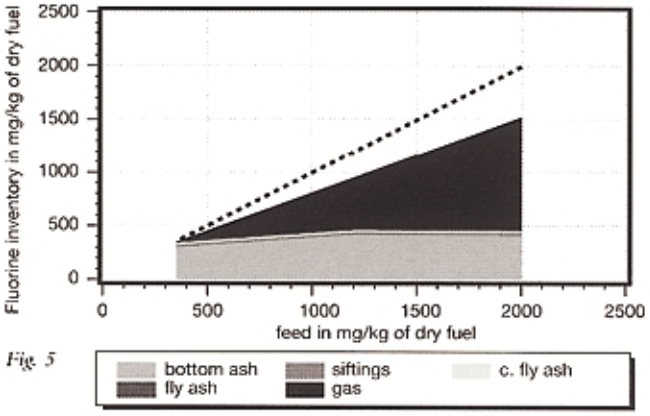

Fig. 5

As with F, there was also a strong correlation between the production of HBr and the Br fed into the system. This shows that the absolute distribution between the different compartments is a function of the Br input. Although the raw gas concentration was increased up to a factor of about 20, the absolute concentration stayed moderate. Thus no emission problems are expected.

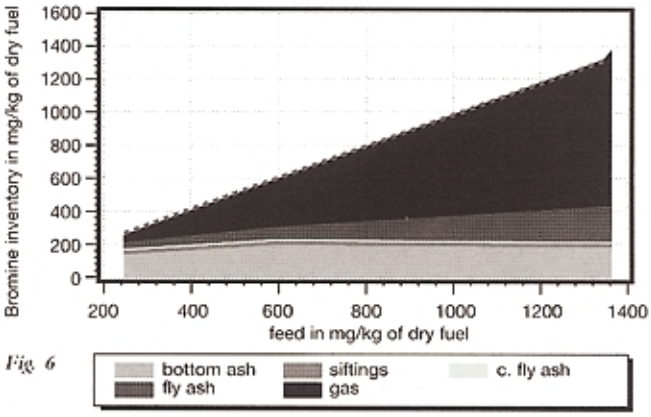

Fig. 6

Thermal destruction of (H)CFC

During the co-combustion experiments the influence of the combustion temperature on the CFC 12 destruction was demonstrated. The destruction efficiency calculated from the above given concentration leads to a guaranteed destruction of more than 99.9 % at 900 °C.

In contrast to CFC 12, the partially halogenated HCFC 22 and HCFC 142b were below the detection limit of 3 micro g/m³ in the raw gas of TAMARA during all test trials, reflecting the predicted ease of destruction.

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)

If foams containing flame retardants are incinerated in a MSWC, the possibility of the formation of chlorinated, brominated and mixed halogenated - Cl and Br substituted - dibenzo-p-dioxins and dibenzofurans has to be considered.

For evaluating the practical relevance of the results, the PCDD/Fs raw gas levels were compared with the respective values from modern full scale waste combustion plants. Results imply that PCDD/PCDF raw gas concentrations in modern MSWC's may vary within an operational window. The levels monitored in TAMARA fall into the range of the best data reported for full scale facilities. This confirms the technical relevance of the TAMARA test results.

An inter-laboratory comparison of analytical results for polybrominated and mixed halogenated dibenzo-p-dioxins and dibenzofurans was performed by two certified laboratories: GfA in Münster and ITU in Berlin.

The effect of the addition of foam on the formation of chlorinated and brominated dioxins and furans is well known. The effect on the formation of mixed brominated and chlorinated dioxins and furans was less well known and needed further study. The addition of brominated PUR foam did not change the distribution between the tetras and the octas dioxins and furans when plotted in a normalised form. Also, the concentration of PCDD and PCDF did not show any correlation with the Br input, as tested by the two laboratories. This homologue pattern can be seen in Figure 7. This visualisation indicates that, in general, the levels of all halogenated dibenzo-p-dioxins and dibenzofurans for both foams stayed well within the band width of PCDD and PCDF concentrations found in TAMARA. Similar results were obtained with XPS.

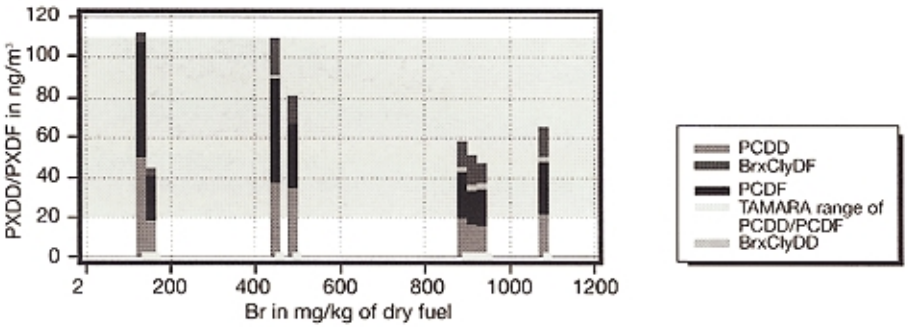

Fig. 7: Chlorinated and Brominated and mixed halogenated dibenzo-p-dioxins in all PUR test trials

Conclusions

The most important results of the tests are as follows:

- The overall burnout, particularly in the bottom ash and fly ash, was excellent during all test trials. The burnout correlated with the combustion temperature and the calorific heat value of the waste fuel. It was not negatively influenced by the addition of PUR and XPS foam.
- The tested foam materials added substantially to the Br content in the incinerator. An increase by a maximum factor of six was attained. The Br levels in the bottom ash stayed almost constant during all experiments and the additional Br load was more or less totally released into the raw gas.
- During the foam experiments considerable amounts of F were also introduced into the combustor which caused an increase in the F content by a factor of about 6 for XPS and 1.5 for PUR. Most of the additional F in the feed was found as HF in the flue gas.
- The Cl level in the feed was only increased by about 20% to 25% when the CFC 11 blown PUR and the (H)CFC blown XPS foams were added. The Cl, nevertheless promoted the volatilisation of some thermally mobile elements.
  The mobilisation of such metals prevents them from forming water soluble compounds in the bottom ash which is beneficial to co-combustion in terms of bottom ash quality.
- The enhanced levels of acid gases do not challenge a state-of-the-art air pollution control system such as a two stage wet scrubber. The HCl, HF and HBr clean gas values comply well with the most stringent air emission regulations.
- The CFC 12 used in former years as a blowing agent for foams is quite a stable compound. At a combustion temperature of around 900°C, over 99.9% thermal destruction is achieved for CFC 12. CFC 11 is already destroyed at lower temperatures. The partially halogenated HCFC 22 and 142b were never detected in the raw gas, because they break down even more easily.
- No significant increase in PCDD and PCDF raw gas levels in connection with the co-combustion of PUR or XPS could be detected. The brominated compounds PBDD and PBDF were generated at very low levels of pg/m³ in the case of PBDD and typically <1ng/m³ for PBDF. The production of mono- and dibrominated mixed halogenated dibenzo-p-dioxins, and dibenzofurans could also be detected at very low concentrations.
- Total halogenated dioxin/furan (PXDD/F) concentrations, however stayed within the variations observed for PCDD/F.

Recommendations

Assuming that Br containing congeners exhibit the same degree of toxicity as chlorinated ones and that abatement technologies work at a comparable efficiency, it can be concluded that the brominated and mixed halogenated dibenzo-p-dioxins and dibenzofurans neither add substantially to the overall hazard of the raw gas of a MSWC, nor to that of air emissions.

An assessment of all the results clearly shows that co-combustion in a modern MSWC is an environmentally recommended option for the disposal of foams. The disposal option is effective, makes full use of the energy of the plastic material, and offers an overall environmental benefit compared with other disposal options.

* The word "combustor" refers to equipment with energy recovery. (H)CFC and CFC destruction will take place whether or not energy is recovered.

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