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REPORT ON INCINERATION OF PRODUCTS CONTAINING BROMINATED FLAME RETARDANTS

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FOREWORD

This paper was originally provided at the March 1997 meeting of the Waste Management Policy Group, as a response to the recommendation from the Joint Meeting of the Chemicals Group and Management Committee to investigate waste management practices in the OECD Member countries, with respect to products containing Brominated Flame Retardants.

In March 1997 the WMPG reviewed the paper the resulting from this study and asked the Secretariat to collect further information, with a view to improving the geographical coverage of the report.

This final report incorporates the new information received by the Secretariat. The amount and nature of the additional information received, however, was insufficient to significantly improve the coverage of this report.

Delegates to the Waste Management Policy Group have had the opportunity to review this document and have agreed that it should be de-classified. This document is published under the authority of the Secretary-General of the OECD.

INTRODUCTION

Certain polymers, such as synthetic fibres and plastics, are combustible and therefore are treated with flame retardants to meet fire safety standards. Brominated chemicals are the most widely used flame retardants for these materials. Brominated Flame Retardants (BFRs) are used in particular in electrical and electronic appliances, coatings, in automotive parts, coated textiles, furniture, building materials and in cushioning, packaging and padding materials.

OECD countries account for 55 percent of world bromine production, estimated at 438 000 tonnes in 1990. Much of the remainder is produced in Israel and the former USSR. Production is very concentrated, being split between less than a dozen production companies in the world. The total demand for brominated flame retardant chemicals is estimated at 150 000 tonnes per annum.

The three most studied groups of families of BFRs are polybrominated biphenyls (PBBs), polybrominated diphenyl oxides (PBDOs), and tetrabromobisphenol A (TBBPA).

One of the main reasons for the current controversy surrounding BFRs, in particular PBBs and PBDOs, is the possible formation of polybrominated dibenzo-dioxins and furans during combustion of both the BFRs themselves and flame retarded materials. Incineration of flame retarded plastics present in municipal solid waste is of particular concern.

The plastic fraction of municipal solid waste varies between 4 and 13 percent in OECD countries, the average being around 7 percent. The main part of the plastics is formed by polyethylene and polypropylene.

RISK REDUCTION TECHNIQUES

According to the International Programme on Chemical Safety (IPCS), properly controlled incineration of materials containing BFRs does not lead to the emission of significant quantities of brominated dioxins and furans. Incineration should only be carried out in properly constituted incinerators, running at consistently optimal conditions [1].

Several techniques are applied or investigated to reduce the emission of dioxins and furans. First of all there are primary measures like improved process control, temperature and residence time control of the flue gases, and high temperature dust removal. Secondly, there are two ways to remove these materials once they have been formed: adsorption on active cokes and catalytic oxidation. The main advantage of the active cokes technology is the ability of capturing very efficiently almost every pollutant, not only dioxins and furans, but also other halogenated hydrocarbons (e.g. PCBs, etc.), particulates, heavy metals (including the volatile ones like Hg) and acid gases, and, with less efficiency, NO_x. The active cokes technology, therefore, is very well suited to serve as a final security check. Investment costs are considerable, however, and the management of the contaminated cokes residue is difficult [2].

Such techniques allow control of dioxins and furans emission levels to less than 0.1 ng/m^3 flue gas. These trace levels in emissions from municipal solid waste incinerators are considered completely harmless by the “Beratungskommission Toxikologie of the Deutsche Gesellschaft für Pharmakologie und Toxikologie” [3].

Environment Canada launched the National Incineration Testing and Evaluation Programme (NITEP) in 1984 to address the threats to health and the environment of garbage incineration on a large scale. NITEP’s primary goal was to define the best design and operating conditions to minimise harmful emissions from municipal waste incinerators. A major part of NITEP’s work entailed running a battery of tests on modern, state-of-the-art energy-from-waste incinerators, which represented technology that would be more likely used in the future. Three different types of energy-from-waste systems were evaluated: a two-stage combustion incinerator; a modernised mass-burning incinerator; and a refuse-derived fuel incinerator. A large number of pollutants were considered, including dioxins and furans. Parameters measured included operating temperatures, garbage feed rates, combustion air flow rates, flue gas temperatures and other process variables. Dioxins and furans were measured both in the garbage entering the incinerator and the ashes and gases emitted by the incinerator. In general, test results indicated that, when the incinerator is outfitted with a state-of-the-art air pollution control system, its emissions can be controlled to a significant degree. Total dioxin and furan emissions were much lower than 0.5 ng/m^3 under all combustion conditions tested. The scrubber/fabric filter air pollution control system was able to remove more than 99 percent (almost undetectable levels) of dioxins and furans. Canada’s “Operating and Emission Guidelines for Municipal Solid Waste Incinerators”, which recommend a limit of 0.5 ng/m^3 for total polychlorinated-dibenzo-dioxins and furans (PCDD/F) and specify a residence time of no less than one second at a temperature of 1 000° C, rely upon NITEP data [4] [5].

Intensive investigations have also been carried out, especially at the initiative of the Association of Plastics Manufacturers in Europe, to assess the role of plastics in dioxin and furan formation in the incineration of municipal solid waste or during the co-combustion of plastic waste with other fuels. In tests involving the addition of up to 15 percent by weight of mixed plastic waste to the original municipal waste it was found that the addition of mixed waste plastics had no influence on the final gaseous dioxin and furan emissions and that the limit of 0.1 ng/m^3 could be met under normal operating conditions (temperature > 850°C, 8 to 10 % excess oxygen). Other tests involved the co-combustion of plastic packaging derived fuel as a source of energy in addition to traditional fuels in existing boiler plants, or the co-combustion of building insulation foams with municipal solid waste. In all cases no significant increase in dioxin and furan emissions could be detected [3] [6].

A detailed review of the regulatory approaches to, and experience with, the use of waste as supplementary fuel in cement kilns was carried out for the “Canadian Council of Ministers of the Environment”. This review suggests that cement kilns utilising waste fuels are able to achieve relatively low emissions of dioxins and furans in terms of toxic equivalents and that the emissions are influenced by process parameters such as the temperature of combustion gases at the inlet of the air pollution control device. On this basis limits of 0.5 ng/m^3 for existing plants, and 0.1 ng/m^3 for new plants are proposed in Canada [7].

REGULATORY APPROACHES

Various measures can be taken to reduce the risks associated with the emission of dioxins and furans from the incineration of municipal solid waste. Such measures concern either the BFR content of the waste fed into the incinerator, or the operating parameters of the incineration process. Emission limits for PCDD/F in the flue gases have also been prescribed.

A number of countries have restricted or prohibited the manufacture and use of some BFRs. These measures mainly concern the use of polybrominated biphenyls (PBBs) in textiles. In other countries the same results were obtained through voluntary action by industry. A summary of such actions is provided in Annex 1 [1].

Another type of measure which could be considered would consist of separating those products containing BFRs (or some of them) from the municipal waste before it is fed into the incinerator. No information was available concerning the use of this type of measure.

In recent years the standards of operation regarding incinerator operating temperatures, flue gas residence times and emissions to air have become more stringent. In June 1989 the European Community adopted two directives on the reduction of air pollution from municipal solid waste incineration plants (one for existing plants and one for new plants). The directive on existing plants introduced interim standards and a timetable for the compliance of these units with the standards specified for new plants. Most EC countries have now adopted at least the values given in these directives. Some countries, notably Germany and the Netherlands, have introduced more stringent requirements. The combustion conditions specified in these regulations are a minimum of 850°C in the combustion chamber, with a minimum of 2 seconds residence time for the resulting flue gases at the stated temperature, in the presence of at least 6 % oxygen. No figure is given for dioxins and furans in these EC directives. German and Dutch incinerators must meet a level of less than 0.1 ng/m^3 [8].

More recently, the 1994 EC directive on incineration of hazardous wastes 94/67/EC introduced a community-wide limit value of 0,1 ng/m^3 for dioxins and furans. However, this limit value was only to be regarded as a maximum guidance level, until a harmonised measurement method to determine the mass concentration of dioxins and furans could be established at EC level [9]. Commission Decision 97/283/EC of 21 April 1997 established such a harmonised measurement method. Consequently the 0.1 ng/m^3 limit value is now binding for all Member States [10].

Operating and emission guidelines for municipal solid waste incinerators have been issued by the Canadian Council of Ministers of the Environment. These guidelines specify a minimum temperature of 1000°C and a combustion gas residence time of no less than one second at this temperature. Total PCDD/F levels in the emissions should be limited to 0.5 ng/m^3 [5].

A summary of emission guidelines and operating parameters adopted in Member countries is provided in Annex 2.

PRESENT SITUATION

"The Dutch Institute of Environmental and Energy Technology" (TNO) has calculated the total emission of pollutants, including polychlorinated dioxins and furans, originating from the incineration of municipal solid waste in Europe [2]. These calculations are based on the number of incinerators installed in the European countries, their capacity, and their air pollution control equipment. A number of assumptions were made concerning the calculation of the emissions, the raw flue gas composition, and the performance of the different air pollution control devices. Emission factors were attributed to each specific equipment, representing what is generally achieved in practice rather than what is technically feasible with the stated equipment.

The results of these calculations are presented in Annex 3. They show a total emission of PCDD/F of 2 226 g/annum for the fourteen countries which were considered. In contrast, the total PCDD/F emission, which would be achieved if all installations met the limit of 0.1 ng/m^3, is 22 g/annum.

These calculations must be viewed with some caution, because of the number of assumptions which had to be made, especially with regard to the performance of the various air pollution control equipment. Also, a number of discrepancies exist between some of the basic data which were used for the calculations (e.g. the number of incinerators in operation) and the same data provided by other sources including another TNO publication on a similar subject[1]. This is particularly true for countries such as France, Italy, Norway and Spain.

CONCLUSIONS

The following statement, extracted from Ref. [8], is proposed for conclusion.

"In conclusion, based on the very limited amount of data available, a small amount of brominated and mixed brominated/chlorinated dioxins and furans are formed in municipal waste fly ash and presumably are to be found in even smaller amounts in the flue gas leaving the incinerator. It has been estimated that these materials may represent up to 10 % of the total PCDD and PCDF formed during the incineration of municipal waste.

In recent years a vast amount of research work has been carried out on chlorinated dioxins and furans. The formation mechanisms and methods for reducing emissions are better understood. The limits

1. Survey of municipal solid waste combustion in Europe - TNO report 92-304, August 1992.

set in Germany and the Netherlands, i.e. 0.1 ng/m3 and community-wide for hazardous waste within the EC are now considered to be achievable by a combination of the following technical steps:

- improved combustion conditions, i.e. temperature, residence time and oxygen levels;

- improved scrubbing systems for flue gases, i.e. better particulate matter separation, avoidance of dioxin reformation temperatures (250°C to 400°C) and also the introduction of activated carbon filters.

In addition, research work is also advancing on treating fly ash to remove any dioxins and furans present.

It may be assumed that these measures will be equally effective in reducing the formation and emission of brominated and mixed brominated/chlorinated dioxins. It should be noted that the highest formation rates for brominated dioxins and furans from PBBOs during the laboratory experiments were associated with low temperatures and pyrolytic conditions. Modern incinerators are specifically designed to avoid these conditions.

Future work both in the laboratory and at operating sites will be required before the above assumption can be confirmed."

Finally, it should be recognised that this draft report presents a partial view of the situation, due to the limited substantial and geographical coverage of the information provided and to limited budgetary resources available.

Annex 1

Country-specific Actions Taken or Proposed on PBBs	
Country	Actions
Australia	
Austria	Prohibits the manufacture, placing on the market, import and use of PBBs and products containing these substances.
Belgium	
Canada	Prohibits the manufacture, use, processing, offer for sale, selling or importation of PBBs for commercial, manufacturing or processing purposes.
Denmark	Implements EC Directive 89/677 banning the use of PBBs in textiles.
Finland	May not be used in textile articles intended to come into contact with the skin (in accordance with EC Directive 83/264).
France	Implements EC Directives concerning PBBs and their use on textiles.
Germany	
Greece	
Iceland	
Ireland	
Italy	
Japan	
Luxembourg	
Mexico	
Netherlands	Proposed resolution would prohibit the storage of PBBs or products or preparations containing these substances or making them available to third parties. (Exports are excluded from resolution.)
New Zealand	
Norway	
Portugal	
Spain	
Sweden	Ban on PBBs in textiles intended to come into contact with skin by implementation of EC Directive 76/769.
Switzerland	Prohibits manufacture, supply, import and use of PBBs and products containing these substances. Supply and import of capacitors and transformers containing PBBs is forbidden.
Turkey	
United Kingdom	
United States	No current production or use. Companies intending to resume manufacture must notify EPA 90 days in advance for approval.

Source: Ref. [1]

Annex 2

Emission guidelines and operating parameters for municipal waste incineration

Country	PCDD/F ng TEQ/N m^3	Temperature °C	Residence time Seconds	Oxygen conc. Vol %
Austria	0.1	-	-	-
Belgium	-	800	1	6
Canada	0.5	1 000	1	6/11[(1)]
Denmark	-	850	2	6
France	-	850	2	6
Germany	0.1	850	2	6
Italy	4000[(2)]	950	2	6
Netherlands	0.1	850	2	6
Norway	2	800	1.5	-
Sweden	0.1[(3)]	-	-	-
United Kingdom	1[(4)]	850	2	6
EC	-	850	2	6

NOTES (1) 3 % for refuse-derived-fuel incinerators.
(2) ng/N m^3 not expressed as TEQ.
(3) 2 ng/N m^3 for existing plants.
(4) operators should aim at 0.1 ng/N m^3 .

Source: Ref. [2] and [5].

Annex 3

Total emission of PCDD/F from municipal waste combustion in Europe

Country*	Number of incinerators	Fraction of total number with scrubbers %	Combustion capacity Ktonnes/a	Fraction of the total combustion capacity in Europe %	PCDD/F emission g/a	Fraction of the total PCDD/F emission in Europe %
Austria	2	100	340	0.8	0	0.01
Belgium	24	28	2240	5.2	148	6.64
Denmark	30	45	2310	5.4	103	4.65
Finland	1	0	70	0.2	5	0.24
France	225	17	11330	26.1	741	33.29
Germany[1)]	49	100	12020	27.9	417	18.73
Italy	28	38	1900	4.4	131	5.90
Luxembourg	1	100	170	0.4	7	0.31
Netherlands	10	60	3150	7.3	91	4.08
Norway	18	100	500	1.2	24	1.07
Spain	15	0	740	1.7	57	2.57
Sweden	21	82	1860	4.3	86	3.84
Switzerland[2)]	30	47	2840	6.6	133	5.96
United Kingdom[3)]	31	0	3670	8.5	283	12.70
Total Europe	485	39	43140	100.0	2226	100.0

* Greece, Ireland and Portugal do not have any municipal solid waste combustion facilities.

1) In the beginning of 1998 Germany had 54 incinerators, all of which (100%) were having scrubbers. The combustion capacity was 12 000 kt/a and the PCDD/F emission level was 3.3 g TEQ/a.

2) At the end of 1997 Switzerland had 28 incinerators, all of which (100%) had scrubbers. The combustion capacity was 2910 ktonnes/a and the PCDD/F emission level was 21 g TEQ/a.

3) At the end of 1997 the United Kingdom had only 5 incinerators, all of which (100 %) had scrubbers. The combustion capacity was 1 470 ktonnes/a and the PCDD/F emission level was 7 g TEQ/a.

Source: Ref. [2.]

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[9] "Council Directive 94/67/EC of 16 December 1994 on the incineration of hazardous waste". *Official Journal of the European Communities* 31/12/94 N° L365/34.

[10] "Commission Decision 94/283/EC of 21 April 1997 on harmonized measurement methods to determine the mass concentration of dioxins and furans in atmospheric emissions in accordance with Article 7(2) of Directive 94/67/EC on the incineration of hazardous waste". *Official Journal of the European Communities* 30/4/97 N° L113/11.