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THE FATE AND MASS BALANCE OF PCB IN MUNICIPAL SOLID WASTE INCINERATORS (MSWIS)

A.A. Jensen[1]

[1]*Nordic Institute for Product Sustainability, Environmental Chemistry and Toxicology (NIPSECT)*

Introduction

Polychlorinated biphenyls (PCBs) are common contaminants in the environment, wildlife, food, and humans. Most wastes in the society will also be contaminated PCBs, and if the PCB levels exceed 50 mg/ kg waste (50 ppm), it is considered hazardous waste to be disposed of in chemical waste incinerator plants operating at temperatures >1000oC. A BIPRO rapport submitted to the EU estimated that municipal solid waste (MSW) in whole EU contained 87 tons PCB/year, of which 5 tons PCB was disposed to municipal solid waste incinerators (MSWIs).[1] About 3 mio. tons MSW was produced in Denmark in 2012, and about 30% hereof was disposed to conventional MSWIs operating at >850oC and equipped with modern flue gas cleaning systems, including dioxin filters.[2]

In general, household waste and other MSW-wastes are supposed to contain very low PCB levels (<1 ppm) and most PCBs in waste will be non-dioxin-like-PCBs (ndl-PCB).The BIPRO 2005-study estimated that European MSW contained <0.4 mg PCB/kg (ppm) wet weight (w.w.) calculated as the sum of the 6 DIN congeners PCB_6 (PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180) multiplied with a factor of 5. MSW are seldom routinely checked for PCB, thus good baseline data are missing. An earlier survey of three German MSWIs reported an average PCB-concentration in the received wastes of 0.2 ppm dry weight (d.w.).[3] In Japanese MSWs measured PCB levels were even lower as <0.03 ppm w.w. for total-PCB and <0.001 ppm for dl-PCB.[4-5] Some waste types, such as waste wood and shredder waste, may contain much more PCB than normal MSW. Average PCB level in Danish shredder wastes is 5 ppm d.w. but levels may be approaching or exceeding 50 ppm PCB.[6-7] In Germany the PCB in waste wood has been reported up to 5 ppm.[1] Minor fractions of such wastes may be part of MSW or co-incinerated intentionally.

In order to be able to evaluate applications for co-incineration of shredder waste with MSW, the Danish EPA (DEPA) initiated this literature study of the fate and mass balance of low levels of PCB (<50 ppm) in wastes disposed in conventional Danish MSWIs.

Materials and methods

A thorough literature search and literature collection regards the fate and mass balance of < 50 ppm PCB in common waste burned in a conventional municipal solid waste incinerator was initiated with the help of common databanks and databases. Additional data on PCB contents of waste and air emissions were obtained from a few Danish MSWIs. All collected data covering a time period of almost 40 years were mapped, evaluated and compared, and the results were published in Danish language in a DEPA report.[8]

Results and discussion:

PCB is non-flammable and non-combustionable. However, most low levels of PCB in MSW was 90-99 % destroyed after a few seconds residence time at the high temperatures (>850 °C) in the furnace.[5] Very little PCB survived the combustion process and ended up vaporized in the raw flue gasses. Some of the PCB in waste ended up in the bottom ash, which is the non-combustion part of the waste consisting of around 15-20% of the input waste, the more PCB in bottom ash, the higher PCB level in the waste. The PCB patterns of the input wastes, of the bottom ashes and of the commercial PCB preparations were rather similar with ndl-PCBs as the dominating congeners.[9]

Gradually, during the cooling of the flue gas dioxin-like PCBs (dl-PCB) are formed de novo in the raw flue gas and on boiler- or fly ashes. The formation was highest at temperatures about 350°C. The faster the raw flue gas was cooled to below 250°C, the lesser dl-PCBs were formed. Calculated as toxicity equivalents (TEQs) the PCB concentration in the flue gas typically increased 10 times compared with the PCB-TEQ content in the waste. Among the formed dl-PCB congeners PCB126, PCB77 and PCB169

dominated. That is also the most toxic PCB congeners. Thus PCB patterns of the raw flue gas and the ashes were very much different from the PCB pattern of the waste burned. A constant and steady incineration process diminishes the formation of both dl-PCB and dioxins. Because of a memory effect emissions may increase 2-10 folds at start-up and shut down.[10]

Only in Germany the PCB-TEQ sum is included in the dioxin-TEQ emission standard of 0.1 ng/m^3.[11] However, it doesn't matter so much; because the formation of PCB-TEQ only is 4% of the dioxin-TEQ formation, less escape the flue gas cleaning and much more is collected in the ashes (see Table 1).
The modern and efficient flue gas cleaning equipment with dioxin bag filter and active coal was able to remove > 99 % of the dl-PCB from the flue gases. During the flue gas cleaning, the PCB patterns were rather unchanged. Thus, in a modern MSWI only <1 % of the dl-PCB in the raw flue gas will be emitted to ambient air, and >99 % will end up in the various ash fractions, mainly fly ashes, which means that the emission of PCB to the environment will be insignificant, if the collected ash fractions are handled with care. A PCB pattern of a stack emission from a Spanish MSWI is shown in Figure 1.

The mass distribution of PCB and PCDD/F to ashes and stack emission from a Taiwanese MSWI with semi-dry cleaning system showed that a larger mass ends up in the bag filter for PCB than for dioxins and more PCB was emitted to the stack. Various ashes were for both substances the largest mass.[13]
In Sweden, a study of co-incineration of 20% shredder waste in an MSWI showed a 3-fold increase in PCB in flue gases compared with incineration of MSW only.[14] The day after cessation of co-incineration PCB levels were still somewhat higher than before the co-incineration started.

This literature survey showed that globally there are many different technologies and operation conditions applied for municipal waste incineration. These technologies have improved by time. Furthermore, the methods of PCB determination, quantitation and TEQ-calculation in waste and ashes differed in the published studies, making comparisons difficult and uncertain.

The conclusion was that in order to reduce the emission of dl-PCB from MSWIs, the burned waste should contain as little PCB as possible. For example, addition of 10% shredder waste to the MSW will increase the PCB concentration of the waste and increase the PCB concentration in the bottom ash and raw flue gas 2-5-fold. A regular and constant operation of the incineration plant will also be important, because start-up and close-down of operations by memory effects diminished the destruction of PCB in the furnace and increased new-formations and emissions of dl-PCB.

If a MSWI has an optimal and steady-state combustion, a rapid and efficient cooling of the raw flue gas to less than 250 °C, and if the flue gas cleaning equipment will be completely efficient, it seems not to be problematic to incinerate wastes containing up to 10 mg PCB/kg (10 ppm) at a conventional MSWI. This concentration level has also been used as an accept limit value at some German MSWIs.[15] Unfortunately, reliable studies of incineration in MSWIs of waste with higher PCB concentrations than 10 ppm are lacking.

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Table 1: Concentrations (w.w.) of PCB and dioxins in MSW, flue gas, emissions and solid residues in Kypto, Japan.[4]

	Concentration in MSW ng/g	Raw flue gas after combustion ng/Nm^3	Flue gas after bag filter ng/Nm^3	Emission in chimney ng/Nm^3	Concentration in bottom ash ng/g	Concentration in fly ash ng/g
Total PCB	10.7	39	3.2	18	0.06	2.1
dl-PCB	0.75	6.0	0.20	1.5	0.00085	0.032
dl-PCB TEQ	0.00048	0.079	0.002	0.003	0.62	10
PCDD/F	0.6	80	3.3	2.7	0.71	26
PCDD/F TEQ	0.0019	1.2	0.065	0.036	0.012	0.46
Calculated TEQ-ratio Dioxin /PCB	3.9	15.2	32.5	12	0.02	0.05

Figure 1: A dl-PCB pattern of a stack emission from a Spanish MSWI.[12]