Human Exposure to Consumer Products: Analysis of Chlorinated Organic Compounds in Candles and Their Exhaust Fumes

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1 Introduction

In Germany about 90,000 tonnes of candles are being produced annually [1)]. The three materials used for candle production are paraffin, stearin, and beeswax. Paraffin contributes to more than 90 % of the total production volume, whereas stearin is used to some percentage, and beeswax with approx. 1,000 t/a contributes to less than 1 % [2)]. Occasionally it was assumed that toxicologically exhaust fumes of paraffin candles may cause a less favourable emission pattern than candles made of the „natural" materials stearin and beeswax which should therefore be preferred. So, investigations were performed to analyse raw materials as well as emissions from burning candles.

2 Materials and Method

Typical raw materials (wax and wicks) were analysed for PCDD/PCDF, chlorinated pesticides (α-, γ-HCH, *o,o'*- and *p,p'*-DDT), chlorophenols, and chlorobenzenes. Chamber experiments were performed to measure emissions of PCDD/PCDF from candle exhaust fumes.

2.1 Raw Materials

Uncoloured candles made of paraffin, stearin and beeswax and wicks were provided by the manufacturers. For each type of wax a certain brand of wick is being used to guarantee optimized combustion conditions. Wicks were extracted with toluene in a Soxhlet apparatus for 24 hours. Waxes were dissolved in hexane and extracts purified with a modified clean-up procedure.

2.2 Chamber Experiments and Sampling

A crucial point in the determination of emission concentrations is the simulation of realistic conditions for burning candles. Therefore, a special sampling device was developed which allowed the sampling of the exhaust fumes under defined burning conditions without turbulences. In the chamber (volume = 1.2 m^3) nine candles could be burnt at the same

time. For all experiments pre-cleaned air (passed through a polyurethane-foam filter) was used. The air exchange and flow rate in the chamber was adjusted to guarantee realistic burning conditions. After three sampling cycles (two hours each) a volume of about 30 m^3 of air was collected and adsorbed on a combined polyurethane-foam/XAD-filter for further analysis.
All emissions samples were also analysed for PAH and short-chain aldehydes, substances of special toxicological interest. These results are reported elsewhere [3].

2.3 Analysis

Analysis of PCDD/PCDF was performed with HRGC/HRMS (Varian HRGC 3400/Finnigan MAT 90 HRMS) using two columns of different polarity for the analysis of homologue groups (HP Ultra 2) and 2,3,7,8-substituted congeners (DB Dioxin). Quantification was done using isotope dilution method with an additional recovery standard for 2,3,7,8-Cl_4DD.
Chlorinated phenols were analysed for mono- through pentachlorinated and chlorobenzenes for mono- through hexachlorinated isomers. Results in Tables 1 and 2 are given as sum of these isomers. Pesticides were detected with HRGC/MSD (Hewlett-Packard GC5890/MSD 5970) using a HP Ultra 2 column. Quantification was made with an external standard solution containing all compounds of interest.
For reasons of quality control, blank values were determined for all compounds prior to the analysis.

3 Results

3.1 Raw Material

Concentrations of chlorinated organics in wax are reported in Table 1. It is remarkable that beeswax contained the highest levels of PCDD/PCDF and chlorophenols, both compounds present in ambient air. In contrast, levels of chlorobenzenes in stearin wax were more than a factor of two higher than in paraffin and beeswax.

Table 1: Concentration of PCDD/PCDF, chlorophenols and chlorobenzenes in wax materials

Wax material	PCDD/PCDF (ng I-TEQ/kg)	Σ Chlorophenols (µg/kg)	Σ Chlorobenzenes (µg/kg)
Paraffin wax	0.59	14.8	130
Stearin wax	1.62	32.3	330
Beeswax	10.99	256	120

As shown in Table 2 levels of PCDD/PCDF, chlorophenols, and chlorobenzenes in all types of wicks were significantly lower than in wax. No HCH-isomers could be detected and DDT-isomers were only present in wicks used for paraffin candles.

Table 2: PCDD/PCDF, chlorinated pesticides, chlorophenols and chlorobenzenes in different types of wicks

Compound	Dimension	Type of Wick Used for... Paraffin Candles	Stearin Candles	Beeswax Candles
α-HCH	(µg/kg)	< 0.5	<0.5	<0.5
γ-HCH	(µg/kg)	< 0.5	<0.5	<0.5
p,p'-DDT	(µg/kg)	6.0	<1.0	<1.0
o,o'-DDT	(µg/kg)	13.0	<1.0	<1.0
Σ Chlorophenols	(µg/kg)	1.23	0.94	0.74
Σ Chlorobenzenes	(µg/kg)	0.67	0.34	0.35
PCDD/PCDF	(ng I-TEQ/kg)	0.18	0.12	0.08

3.2 Emissions from Candle Exhaust Fumes

Chlorophenols and chlorobenzenes - known precursors for the formation PCDD/PCDF - could be detected in the raw material. Additionally, low levels of PCDD/PCDF were already present in the candle materials. Emission values are shown together with calculated emission factors in Table 3. Due to the very low emission concentrations, values were determined by the simultaneous burning of nine candles each.

Table 3: Blank-corrected emission values and emission factors of PCDD/PCDF from candles

Wax material	Emission Value (pg I-TEQ/m³ air)	Emission Factor (pg I-TEQ/g burnt wax)
Paraffin	0.020	0.015
Stearin	0.037	0.027
Beeswax	0.004	0.004

4 Discussion and Conclusions

4.1 Raw Materials

Apart from *o,o'*- and *p,p'*-DDT in wicks of paraffin candles, levels of chlorinated pesticides were below the detection limit. Chlorinated phenols, benzenes and polychlorinated dibenzo-*p*-dioxins and dibenzofurans were present only at very low concentrations.

Levels of chlorinated organics in synthetic wax (paraffin) and stearin were low. In contrast, levels of chlorophenols and PCDD/PCDF in beeswax were significantly higher. „Natural" raw material collected by bees to produce wax is exposed to ambient air. Obviously, the lipophilic matrix accumulates PCDD/PCDF and chlorophenols present in ambient air well above levels of background concentrations.

4.2 Emission Samples

Emission values of PCDD/PCDF from all types of candles were very low. Although beeswax contained the highest levels of PCDD/PCDF and chlorophenols the burning beeswax candle gave the lowest emission of dioxins. Possibly the higher combustion

temperature in the flame of beeswax candles effectively impedes the thermal formation of PCDD/PCDF in the flame but supports the destruction of dioxins being present in the wax.

4.3 Human Exposure

To quantify the exposure of PCDD/PCDF from the candle's emissions to humans two different scenarios were compared:

a) The simultaneuos use of 30 candles, corresponding to 600 g wax (e.g. at a christmas tree) being burnt within 4 hours in a living-room (volume 50 m^3) without air exchange.

b) The smoking of a single cigarette in same room (volume 50 m^3).

The amount of PCDD/PCDF emitted from these sources was calculated and compared to the average daily intake of dioxins via inhalation. Using the emission factors in Table 3 the amount of PCDD/PCDF released from the candles can be calculated. Dioxins emitted with cigarette smoke are reported in the literature [4]. A breathing volume of 0.8 m^3/h is a typical value for an adult person.

Table 4: Amount and concentration of PCDD/PCDF emitted from 30 candles and one cigarette, respectively and calculated additional inhalative uptake by humans after 4 hours

Source	Amount (pg I-TEQ)	Indoor Air Concentration (pg I-TEQ/m^3)	Additional Inhalative Uptake (pg I-TEQ/Person)
30 Paraffin candles	9	0.18	0.43
30 Stearin candles	16.2	0.32	0.77
30 Beeswax candles	2.4	0.05	0.12
1 Cigarette	0.1	0.002	0.005

The average uptake of PCDD/PCDF via inhalation in Germany is about 1.5 pg I-TEQ/Person and contributes to less than 2 % of the total daily intake (115 pg I-TEQ) of an adult person. The additional exposure to emissions from burning candles contributes to less than 0.7 % of the total daily intake via all paths. Keeping in mind that events as described above with the exceptional use of candles occur only very seldom the impact on human exposure from the use of candles is negligible.

Acknowledgements:
The skillfull help of Dr. Alsorachi from the Landesgewerbeanstalt (LGA) Nuremberg, Germany, in developing the chamber experiments is greatfully appreciated.

5 References

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