Combustion of CNT-containing composite materials in a laboratory scale incinerator

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Currently, there is growing interest in industry for nanoparticles and nanocomposites due to their wide range of applications. Since a large amount of the composite materials will finally be incinerated once their functional life has come to an end, it is important to know whether municipal waste incinerators have the ability to completely remove the additives from the flue gases or solid residues (slag), thus avoiding their emission to the environment.

An increasing number of experimental and commercial composite materials use carbon nanotubes (CNTs) in order to improve material properties like electrical conductivity or mechanical strength. The aim of the study presented here was to investigate whether CNTs may be released under the simulated conditions in a municipal waste incinerator due to incomplete combustion as part of the (fly) ash or slag. The operating parameters were chosen in order to fulfill the minimum requirements for municipal waste incinerators set forth in the 17th Ordinance on the Implementation of the Federal Immission Control Act ("17th BImSchV").

To simulate a municipal waste incinerator in the lab, two tube furnaces (Carbolite, models CTF 12/65/550 and TZF 12/65/550) were used in series, connected with a quartz glass tube. A ceramic crucible was used as sample container and means of transport of the composite material in the first furnace. While the first furnace was used to mimic the incineration of the composite material, the second furnace was used to simulate thermal after treatment of the exhaust gases. A primary air flow (compressed air with 21 % oxygen content, 14 l/min) was fed to the quartz tube from the entrance of the first furnace. A secondary air flow (7 l/min) was added to the second furnace to maintain the minimum legal requirements regarding the minimal O_2 concentration of 6 % and the 2 s residence time at 850 °C for thermal after treatment.

Three different composite materials, i. e. polycarbonate (PC), polyamide (PA) and polyethylene (PE) with different CNT amounts (0 wt%, 5 wt% and 7.5 wt%, Baytubes C150P® with a typical diameter of approximately 20 nm – 30 nm and a typical length after post-production treatment below 5 µm) were investigated. The particle size distribution in the exhaust gas that resulted during incineration of the composite materials was measured using a Fast Mobility Particle Sizer (FMPS, Model 3091, TSI Inc). Furthermore, the released fragments were electrostatically sampled with a Nanometer Aerosol Sampler (NAS, Model 3089, TSI Inc) and analysed using scanning electron microscopy (SEM, JEOL 7500F). The oxygen content was measured with 1 s time resolution towards the end of the second furnace together with other gas components using a multi component gas analyzer (NGA 2000 MLT 5).

The particle size distributions were comparable for all materials, with count median diameters (CMD) in the range 113 nm to 132 nm and total number concentrations in the range 1.07×10^7 #/cm³ to 2.11×10^7 #/cm³ (Table 1). The composite materials with different amounts of CNTs showed slightly lower number concentrations and larger CMD.

Table 1. Measured total number concentration and count median diameter (CMD) of the particle size distribution along with standard deviations.

Material (10 reruns for each material)	Conc. (#/cm^3) $\times10^6$	SD	CMD (nm)	SD
PC no CNT	21.1	1.4	131	0.8
PC + 5% CNT	14.8	2.1	132	1.1
PC + 7.5% CNT	15.9	1.8	132	1.1
PA no CNT	18.3	1.1	113	1.5
PA + 5% CNT	10.7	1.6	127	1.7
PA + 7.5% CNT	10.7	1.9	124	2.5
PE no CNT	19.9	3.4	121	4.1
PE + 5% CNT	15.1	2.7	128	1.2
PE + 7.5% CNT	15.5	1.9	128	1.7

The FMPS results showed no indication for largely different number size distributions for materials with and without CNTs. Also the SEM images of the NAS samples did not show any evidence for airborne free CNTs. Considering that the flue gases from an incinerator get filtered before they are released into the atmosphere, it can be concluded that a release of CNT from municipal waste incinerators into the atmosphere is rather unlikely.

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