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Emission measurements of multi-walled carbon nanotube release during production

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Introduction
The fields in which carbon nanotubes (CNTs) are found useful are rapidly growing, causing an increased demand worldwide. The industry is looking for ways to improve their production and thus increase the amount of CNTs being handled. This, together with the fear that exposure to CNT particles may cause similar health effects as asbestos (Donaldsson, 2006), create a need for accurate methods of emission assessments. We present results from field measurement utilizing a range of measurement techniques to assess emissions at a small-scale CNT producer that utilize the arc-discharge method for production of multi-walled CNTs.

Methods
Different tasks in the production were measured as well as full-shift personal measurement. Air samples were collected both in the emission zone and in the respiratory zone of the workers. By using cyclones (BGI4L, BGI) respirable (<5 µm aerodynamic diameter) dust fractions, were collected on polycarbonate (37 mm, 0.4 µm pores) filters. Filters were analysed using scanning electron microscopy (SEM) and online instruments were used both in the emission zone (<10 cm from the source) and in the background (3 m from the closest source).

Table 1. SEM results from filter measurements.

<table>
<thead>
<tr>
<th>Task</th>
<th>Total ± σ (0.01-5 µm) (cm³)</th>
<th>CNT containing particles ± σ (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieving, mechanical work-up and packaging</td>
<td>324±4</td>
<td>11±1</td>
</tr>
<tr>
<td>Cleaving of deposits</td>
<td>410±10</td>
<td>3.4±0.9</td>
</tr>
<tr>
<td>Opening of the reactor</td>
<td>1095±43</td>
<td>N.D.</td>
</tr>
<tr>
<td>Functionalization Part I</td>
<td>162±4</td>
<td>1±0.4</td>
</tr>
<tr>
<td>Personal Exposure Measurement</td>
<td>120±2</td>
<td>2.0±0.2</td>
</tr>
</tbody>
</table>

The CNT concentration was estimated to 11 CNT containing particles/cm³ during the task performed in Figure 1 (Cleaving of deposits). CNT concentration in the personal exposure measurement was measured to 2 CNT containing particles/cm³. The combination of online instrumentation and SEM analysis gave a deep understanding of when emissions occur and a detailed description of what kind of particles that were emitted. The results show that several tasks in the production could cause workplace exposure occur.

Conclusions
Emissions of CNTs were detected in 9 out of 16 samples (selected results in Table 1). CNT structures were found in all personal exposure measurements. The CNT structures found in the respirable fraction did seldom exceed a length of 5 µm and CNT structures classified as fibres (aspect ratio >3:1 (Figure 1)) were in most cases shorter than 3 µm. The fraction of CNT structures compared to other particles was small. Emissions during activities occurred as peaks (Figure 1).

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