Respiratory tract deposition of diesel engine exhaust particles for healthy subjects and subjects with COPD

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Both epidemiological and toxicological studies have shown a correlation between adverse health responses and exposure to diesel exhaust particles. A key factor for determining the health effects is the deposition of the particles in the respiratory tract during breathing. It is therefore important to investigate the deposited fraction and dose for different aerosol sources during various conditions. It has been suggested that certain sub-populations are more susceptible to adverse health effects of airborne particles. One such group is those diagnosed with chronic obstructive pulmonary disease (COPD). The objective of this study was to examine the deposited fraction and dose of fresh diesel exhaust particles for healthy subjects and subjects with COPD.

The size-resolved deposited fraction and deposited dose of diesel engine exhaust particles were measured with the RESPI instrument (Löndahl et al. 2006). In RESPI particle concentrations in inhaled and exhaled air is measured with a scanning mobility particle sizer (SMPS). The measurements were done on 10 healthy subjects (5m/5f) and 10 subjects (7m/3f) with varying degree of COPD, from mild to moderate. One healthy male was excluded because of difficulties to breathe relaxed in the instrument. A Volvo diesel engine (Volvo TD40 GJE, 4.0 L, four cylinders, 1996) with no exhaust after-treatment was used with a typical MK1 diesel fuel (sulphur content ≤10 ppm). The engine was operated in a motor test bench to simulate different operating conditions. The deposited fraction was measured for two different diesel aerosols: idling and transient load conditions according to the standardized European Transient Cycle (ETC) protocol. The deposited fraction according to the International Comission for Radiological Protection model (ICRP, 1995) was calculated for each subject and compared to the measured values. The deposited dose was calculated (normalized to one hour exposure at 100 μg/m³ for both aerosols).

The average deposited fraction and dose for the two groups and aerosols are presented in Table 1. The study showed a statistically significant difference in deposited fraction between the groups. For both studied driving conditions, the deposited fraction is lower for the subjects with COPD compared to the healthy subjects, but the deposited dose is higher. The higher deposited dose for the subjects with COPD is expected as they breathed with a higher minute volume than the healthy subjects. The difference in deposited fraction between the two aerosols can most probably be explained by the different size distributions. The aerosol from the idle engine mode contained more nucleation mode particles for which the probability of deposition is high.

<table>
<thead>
<tr>
<th></th>
<th>Idle driving</th>
<th>Transient driving</th>
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<tbody>
<tr>
<td></td>
<td>DF</td>
<td>Dose (μg)</td>
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<tr>
<td>Healthy</td>
<td>0.65</td>
<td>13.2</td>
</tr>
<tr>
<td>COPD</td>
<td>0.57</td>
<td>16.6</td>
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When comparing the measured size-resolved deposited fractions with those of the ICRP model, the measured deposition for the healthy group agrees well with the ICRP model. The measured deposited fractions for the group with COPD show a different pattern compared to the ICRP model, which indicates that the change in lung morphology also may affect the deposition. The difference in deposited fraction between the healthy group and the group with COPD is most significant in the particle size range between 20 nm and 70 nm. In this size range, the ICRP model predicts that most particles are deposited in the alveolar region. COPD affects the alveolar region, for example with emphysema which cause a gradual destruction of the alveolar walls.

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