Assessment of the lung deposition of particulates originating from diesel and CNG fuelled engines

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Ambient air particulate pollution is associated with increased pulmonary and cardiovascular morbidity and mortality. Especially, fine and ultrafine particulates, which exist in emissions of transportation (Kittelson, 1998; Ristovski, 2000; Burtscher, 2005), can cross the epithelial barrier of the lung cells and get to the systemic circulation (Oberdörster, 2002) causing harmful effects to human health.

In this study, lung deposition estimates of particulate emissions of diesel and natural gas fuelled buses were calculated using *in silico* methodology. Particulate emissions as particulate number size distributions of two conventional Euro 2 diesel buses and one Euro 3 gas bus were measured by Technical Research Centre of Finland. The diesel buses used were the first with an oxidation catalyst on the vehicle (DI-OC), and the second with a partial diesel particulate filter catalyst on the vehicle (DI-pDPF). The third bus used was a gas bus with an oxidation catalyst on the vehicle (CNG-OC). For the evaluation of particulate emissions of these vehicles a transient chassis dynamometer test cycle (the Braunschweig city driving cycle, duration 1740 s) was used. Particulate number size distributions were measured using an Electric Low Pressure Impactor (ELPI), which measures the particulates in the size range of 7 nm to 10 µm. Estimates for the deposited particulates were computed with a lung deposition model ICRP 66 using in-house MATLAB scripts (ICRP, 1994). Results were given as particulate numbers deposited in five different regions of the lung (ET_1: the anterior nasal region, ET_2: the main extrathoracic region (including the posterior nasal region, mouth, pharynx and larynx), BB: the bronchial region (consisting of the trachea and bronchi), bb: the bronchiolar region (consisting of the bronchioles), and AI: the alveolar interstitial region (consisting of the alveolar ducts and sacks)).

The total amounts of the emitted diesel particulates were around 90-fold for DI-OC and 60-fold for DI-pDPF compared to the total amount of emitted CNG particulates. In the modeling it is assumed that the amount of inhaled particulates is the same as emitted from the vehicle. Exposure assessment by modeling was made for a male, who is either performing light exercise or sitting, e.g. walking in a city near a traffic road or sitting in a car behind the bus in motion with an assumption that the transition of particulates from outside to inside a car is 100 %.

Based on the results, in similar conditions the total exposure of a male performing both light exercise and sitting to particulates originating from conventional diesel fuelled engines DI-OC and DI-pDPF was around 65- and 40-fold, respectively, compared to the exposure to particulates originating from the CNG fuelled engine (Figure 1). The total fractions of deposited particulates of all the particulates exposed to are in sitting 15 % for DI-OC, 14 % for DI-pDPF and 20 % for CNG-OC, and compared to that, the numbers of deposited particulates in light exercise were more than 2.5-fold for all the vehicles. The highest deposition values were observed in the alveolar interstitial region of the lung regardless of the fuel used or subject's activity level. Percentages of particulates deposited in the alveolar-interstitial region of the lung were 67 % for DI-OC and DI-pDPF and 66 % for CNG-OC in light exercise, and 58 % for DI-OC and DI-pDPF and 55 % for CNG-OC in sitting of all the deposited particulates.

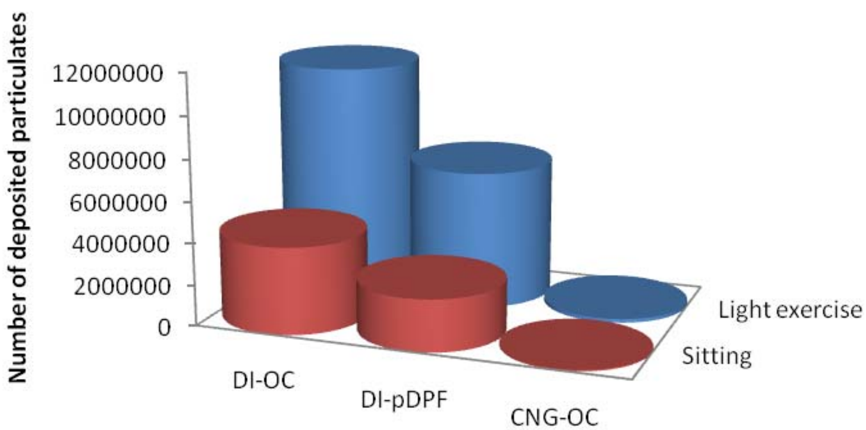

Figure 1. Estimates of the total amounts of deposited particulates as numbers into male's lung, when either sitting or performing light exercise.

In conclusion, the results suggest that the health risk of particulate deposition of an adult male is different depending on subject's activity level and whether the particulates originate from conventional diesel fuelled engines or natural gas fuelled engines.

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ASSESSMENT OF THE LUNG DEPOSITION OF PARTICULATES ORIGINATING FROM DIESEL AND CNG FUELLED ENGINES

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Introduction

Ambient air particulate pollution is associated with increased pulmonary and cardiovascular morbidity and mortality. Especially, fine and ultrafine particulates, which exist in emissions of transportation (Kittelson, 1998; Ristovski, 2000; Burtscher, 2005), can cross the epithelial barrier of the lung cells and get to the systemic circulation (Oberdörster, 2002) causing harmful effects to human health. In this study, lung deposition of particulate emissions of diesel and natural gas fuelled buses were estimated.

Methods

Particulate measurements

Particulate number size distributions of *two conventional diesel buses* with an oxidation catalyst (DI-OC) on one and a partial-DPF catalyst (DI-pDPF) on the other vehicle, and *one natural gas bus* with an oxidation catalyst (CNG-OC) on the vehicle were measured using an ELPI (Electric Low Pressure Impactor) (Figure 1). For the evaluation of particulate emissions of the vehicles the European Braunschweig city driving cycle was used.

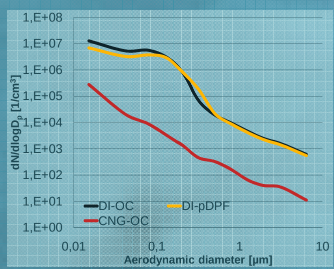

Figure 1. Particulate number size distributions for diesel and natural gas buses.

Lung deposition model

Estimates for the lung deposition of the particulates in different regions of male's lungs were computed using a model based on the ICRP 66 Human lung deposition model (ICRP, 1994). Used parameters for an adult male are shown in Table 1.

Table 1. Physiological parameters for an adult male when sitting or performing light exercise (ICRP, 1994).

Ventilation rate 0.54 / 1.5 m^3/h	Fraction breathed through nose 1.0 / 0.7	Bronchiolar dead space 47 cm^3
Breathing frequency 12 / 20 1/min	Functional residual capacity, FRC 3301 cm^3	Height 176 cm
Tidal volume 750 / 1250 cm^3	Extrathoracic dead space 50 cm^3	Tracheal diameter 1.65 cm
Volumetric flow rate 300 / 833 cm^3/s	Bronchial dead space 49 cm^3	First Bronchiolar diameter 0.165 cm

RESULTS

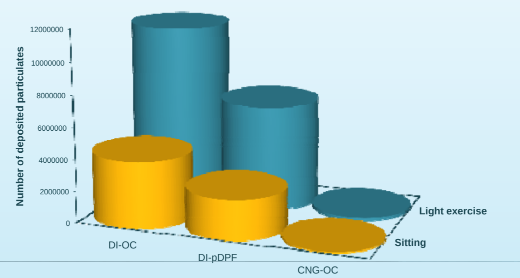

Figure 2. Number of deposited particulates into the respiratory system of an adult male.

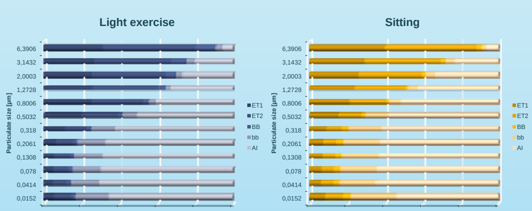

Figure 4. Distribution of different size deposited DI-OC particulates in five regions of male's lungs.

Total exposure of a male performing both light exercise and sitting to particulates originating from conventional diesel fuelled engines DI-OC and DI-pDPF compared to particulates originating from the CNG fuelled engine, was around 65- and 40-fold, respectively (Figure 2). The total fractions of deposited particulates of all the particulates exposed to were 15 % for DI-OC, 14 % for DI-pDPF and 20 % for CNG-OC in sitting, and 41 % for DI-OC, 37 % for DI-pDPF and 56 % for CNG-OC in light exercise. The highest deposition values were observed in the alveolar interstitial region of the lungs regardless of the fuel used or subject's activity level (Figure 3). The smallest particulates penetrate to the deepest parts of the lungs (Figure 4).

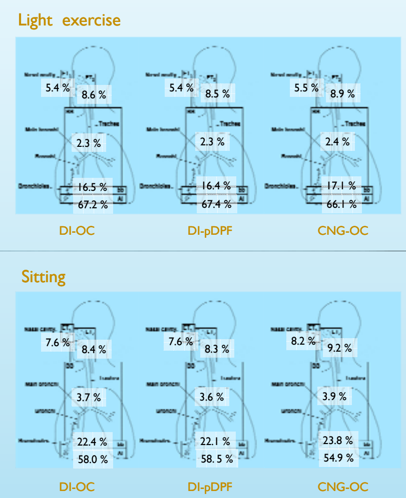

Figure 3. Percentages of deposited diesel (DI-OC and DI-pDPF) and CNG (CNG-OC) particulates for each region of male's lungs when either sitting or performing light exercise. ET_1 = anterior nose, ET_2 = main extrathoracic region, BB = bronchial region, bb = bronchiolar region, AI = alveolar-interstitial region.

Conclusions

Health risk of particulate deposition of an adult male is different depending on subject's activity level and whether the particulates originate from conventional diesel fuelled engines or natural gas fuelled engine. The highest health risk is caused by particulates originated from DI-OC engine during light exercise.

Acknowledgements
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