# Effect of physical exertion on the deposition of traffic related aerosols in the children´s respiratory system

**Kati Oravisjärvi[1*], Mari Pietikäinen[1], Arja Rautio[2], Mauri Haataja[3], Arto Voutilainen[4], Juhani Ruuskanen[5] and Riitta L. Keiski[1]**

[1]Department of Process and Environmental Engineering, University of Oulu, Finland
[2]Centre for Arctic Medicine, Thule Institute, University of Oulu, Finland
[3]Department of Mechanical Engineering, University of Oulu, Finland
[4]Department of Physics, University of Kuopio, Finland
[5]Department of Environmental Sciences, University of Kuopio, Finland
[*]contact person (e-mail: kati.oravisjarvi@oulu.fi)

Particles emitted from diesel fuelled engines have been a great concern in the past years due to their high amount in the vicinity of roads and adverse health effects caused especially for children, elderly people, and people with pulmonary and cardiovascular diseases (Dockery et al. 1993). Although ambient air pollution contributes to adverse health effects, the highest exposures of air contaminants may occur in microenvironments, like vehicles. Some studies have reported that passengers are exposed to elevated concentrations of respirable particulates during transit bus commutes (Gee and Raper 1999, Praml and Schierl 2000).

In this study, lung deposition of diesel particles in children was studied by using a lung deposition model. Children are more vulnerable to air pollution than adults, because of higher metabolism per body weight and they are often more active during the day. Also airways and lung function in children are under development and therefore toxic substances may cause permanent impairments of the respiratory system. The study subject was selected to be either a 10-year-old or a 5-year-old child, who was performing light exercise (e.g. walking in a road near the bus) or sitting in a car behind a moving bus. The values were compared to previous calculated values of an adult male (Pietikäinen et al. 2009). The used lung deposition model is MATLAB-based with inhouse scripts. The model is originally based on a lung deposition model ICRP 66 published by the International Commission on Radiological Protection (ICRP) (ICRP 1994). For modeling purposes, the human respiratory system is divided into five main deposition regions from nasal region to gas-exchange region: the anterior nasal region (ET1), the main extra thoracic region (ET2, including the posterior nasal region, mouth, pharynx and larynx), the bronchial region (BB, consisting of the trachea and bronchi), the bronchiolar region (bb, consisting of the bronchioles), and the alveolar interstitial region (AI, consisting of the alveolar ducts and sacks).

Particulate number size distributions of a city diesel bus were performed at Technical Research Centre of Finland (VTT) in Espoo on a heavy-duty chassis dynamometer. The Braunschweig City Driving Cycle, which is simulating urban bus driving with frequent stops was used for the evaluation of particulate emissions. The used city diesel bus represented the Euro 2 technology, with a partial diesel particulate filter (pDPF) on it. The catalyst had been aged so that the results are comparable with the real situation. The type of the engine was Volvo DH10. Particulate number size distributions were measured using an Electric Low Pressure Impactor (ELPI) measurement system (Dekati Ltd., Tampere, Finland) in the size range of 7 nm to 10 µm. The exposure time to diesel exhaust particulates was 1740 seconds (29 minutes), which is the same time as the schedule of the used test cycle in diesel exhaust measurements. The exposure time was the same in both physical activities.

Results were given as particle numbers deposited in respiratory system and different regions. Most of the measured number concentrations of diesel particles were smaller than 200 nm in their aerodynamic diameter. The part of inhaled particulates comes out from the respiratory system by exhalation and clearance effects (coughing, wiping and swallowing) and only approximately half or less of the inhaled particles stay in the respiratory system. The deposition of particulates depends also on the way of breathing: nose or mouth breathing and the intensity of breathing. In this study results indicated that 8 % and 9 % of inhaled diesel particulates stayed in the respiratory system of 5- and 10-year old children in sitting and 10 % and 27 % in light exercise. The highest amounts of diesel particulates deposited in children's respiratory system during light exercise. The deposition increased more than two- to three-fold during the sitting to light exercise. The majority of deposited particles emitted from diesel engine penetrate deep into the unciliated regions and gas-exchange region of human lungs in breathing conditions of sitting and light exercise. The percentages of particles deposited in the alveolar-interstitial region of a 10-year old child were 55.7 % in sitting and 66.0 % light exercise. The comparable values of a 5-year old child were 57.5 % in sitting and 61.8 % in light exercise. The amount of deposited particles into 5- or 10-year old children's respiratory system are ½ and ¾ in sitting and ¼ and ¾ in light exercise, respectively, compared with the standard adult (in this case an adult male) (Figure 1).

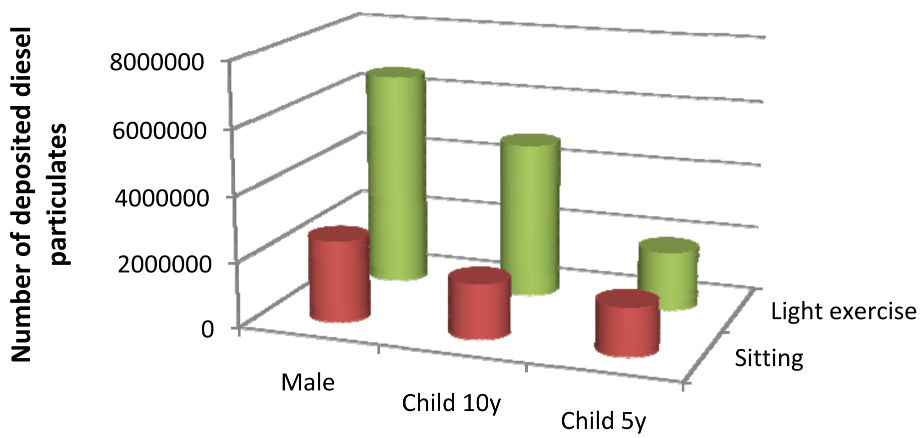


***Figure 1.*** *Number of diesel particulates deposited into respiratory system of 10- and 5-year old children and an adult male during different breathing conditions.*

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## Introduction

Particles emitted from diesel fuelled engines have been a great concern in the past years due to their high amount in the vicinity of roads and adverse health effects. Although ambient air pollution contributes to harmful health effects, the highest exposures of air contaminants may occur in microenvironments, like vehicles. Some studies have reported that passengers are exposed to elevated concentrations of respirable particulates during transit bus commutes. In this study, lung deposition of diesel particles in children were studied.

## Experimental

### *Particulate measurements*

Diesel particulate measurements were carried out for Euro 2 city bus with a partial diesel particulate filter (pDPF) on it. The catalyst had been aged that the results are comparable with the real situation. Particulate number size distributions were measured by using an ELPI (Electric Low Pressure Impactor) in the size range from 7 nm to 10 µm (Fig 1). Particulate emissions were evaluated by the Braunschweig City Driving Cycle.

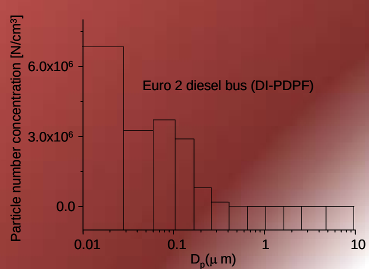


*Figure 1. Measured diesel particulate number concentrations from Euro 2 diesel city bus with pDPF catalyst during Braunschweig City Driving Cycle.*

### *Human lung deposition model*

Estimation of deposited particulates in human respiratory system was computed with a lung deposition model. Exposure assessment was made for 5- and 10-year old children, who were performing light exercise (e.g. walking on a road near the bus) or sitting in a car behind a moving bus. The exposure time for diesel particles was the same as in the used test cycle, 1740 s. Human respiratory tract was divided into five main deposition regions from nasal region to gas-exchange region in the model.

## Results

The part of the inhaled particulates comes out from the respiratory system by exhalation and clearance effects. The deposition of particulates depends also on the way of breathing: nose or mouth and the intensity of breathing.

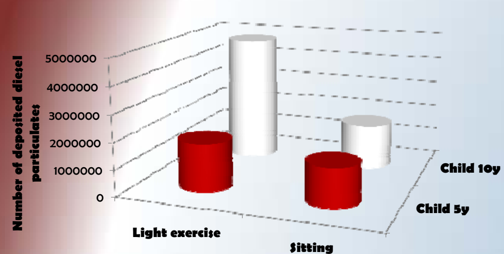


*Figure 2. Number of diesel particulates deposited into respiratory system of 5- and 10-year old children during sitting and light exercise.*

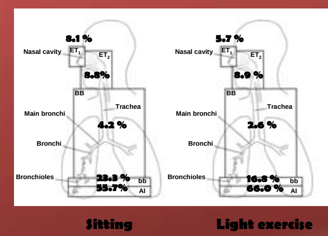


*Figure 3. Percentages of deposited dieselbus particulates for each region of the lung of a 10-year old child.*

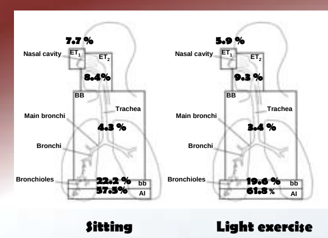


*Figure 4. Percentages of deposited dieselbus particulates for each region of the lung of a 5-year old child.*

8 % and 9 % of inhaled particulates stayed in the respiratory system of 5- and 10-year old children in sitting and 10 % and 27 % in light exercise (Fig. 2). The majority of deposited particles (especially the smallest particles) penetrate deep into the unciliated regions and gas-exchange region of human lungs in breathing conditions of sitting and light exercise (Fig. 3,4,5). The percentages of particles deposited in the alveolar-interstitial region of a 10-year old child were 56 % in sitting and 66 % light exercise. The comparable values of a 5-year old child were 57 % in sitting and 62 % in light exercise.

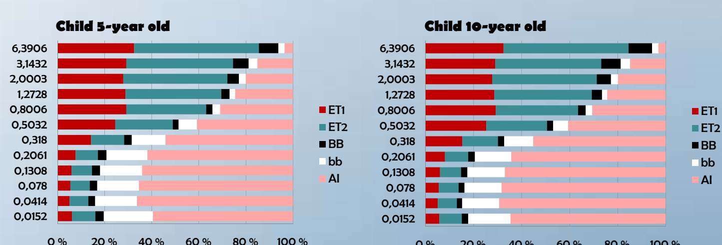


*Figure 5. Percentages of deposited diesel particulates into respiratory system of 5- and 10-year old children during light exercise.*

## Conclusions

The health risk of inhaled diesel particulates for 5- and 10-years old school children is different. This is based on the differences in the deposition of diesel particulates and structure of children's respiratory system.


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**Contact information**

*Kati Oravisjärvi*
*Department of Process and Environmental Engineering*
*P.O. Box 4300, FI-90014 University of Oulu, Finland*
*tel. +358 8 553 2388, fax: +358 8 553 2369*
*E-mail: kati.oravisjarvi@oulu.fi, http://pyo.oulu.fi*

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