Deposition of inhaled particles from diesel fuelled engines into human lungs: Comparison between men and women in different activity levels

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Particulates emitted by diesel engines range between 1 nm and 10 μm, over 90 % being smaller than 1 μm. Particulates of this size have been found to be associated with several adverse health effects, such as pulmonary and cardiovascular diseases (Kittelson et al. 2002). Diesel particles contain soot, sulphate compounds and hydrocarbons such as polyaromatic hydrocarbons (PAH), which have been found to be carcinogenic (Cohen and Nikula 1999, Kittelson 1998). Hydrocarbons, as lipid soluble compounds, can cross the epithelial barrier of the lung cells and get to the circulation and influence the whole organ system, more easily than water soluble sulphates.

In this study, lung deposition of diesel particulate emissions in males and females was studied *in silico*. Particulate emissions and their particle number size distributions were measured in a Euro 2 diesel bus (9.6 l) with a partial diesel particulate filter (pDPF) on it in the Technical Research Centre of Finland (VTT). This kind of a catalyst gives particulate reduction at around 40–70 %. Estimation of deposited particles was computed with a special lung deposition model using in house MATLAB scripts. Physiological parameters were standardized by a “virtual human”, adult male or female. The chosen activity levels were sleeping, sitting and light exercise. Exposures particle concentration was assumed to be equal to the outcome from the exhaust pipe. Particle transformation in air was ignored. Exposure time was chosen to be the same as in the European

Braunschweig cycle, a transient chassis dynamometer test cycle (DieselNet). Respiratory tract was divided into five main deposition regions: anterior nasal region (ET1), main extrathoracic region (ET2, including posterior nasal region, mouth, pharynx and larynx), brochial region (BB, consisting of trachea and bronchi), bronchiolar region (bb, consisting of bronchioles), and alveolar interstitial region (AI, consisting of alveolar ducts and sacks) (ICRP 1994). Results were given as particle numbers deposited in different regions of lungs.

Most of the measured number concentrations of diesel particles were smaller than 200 nm in their aerodynamic diameter. Results indicated that a majority of inhaled particles emitted from a diesel engine penetrate deep into the unciliated regions and gas-exchange region of lungs. In addition, approximately half of the inhaled particles stay in the lungs. The inhaled dose of particulates was different in female and male lungs. The dose in male lungs was 19 % higher in sleeping, 48 % higher in the sitting position and in light exercise 43 % higher than with females. These differences of inhaled dose results from differences of breathing parameters (ventilation rate 20-40 % higher in males than females) and deposition probabilities, and differences of anatomy and physiology of lungs in males and females. Percentages of particles deposited in the alveolar-interstitial region of male and female lungs in different activity levels were 55.2 % and 50.1 % in sleeping, 58.5 % and 51.5 % in sitting and 67.4 % and 65.7 %, respectively, in light exercise of all deposited particles. Based on the results at similar exposure conditions, the lung dose of diesel particulates is different between males and females and can cause also different health risks to genders *in vivo*.

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Deposition of Inhaled Particles from Diesel Fuelled Engines: Comparison Between Men and Women into Different Acitivity Levels

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- Particulate measurements
- Human lung deposition model

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- Different activity levels: sleeping, sitting and light exercise
- Female and male

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Introduction

- Small particles are an important research focus area, because of their health effects (ect. lung and heart diseases)
- In our study the lung deposition of particulate emissions of diesel vehicles was studied by using a modified model based on ICRP lung deposition model

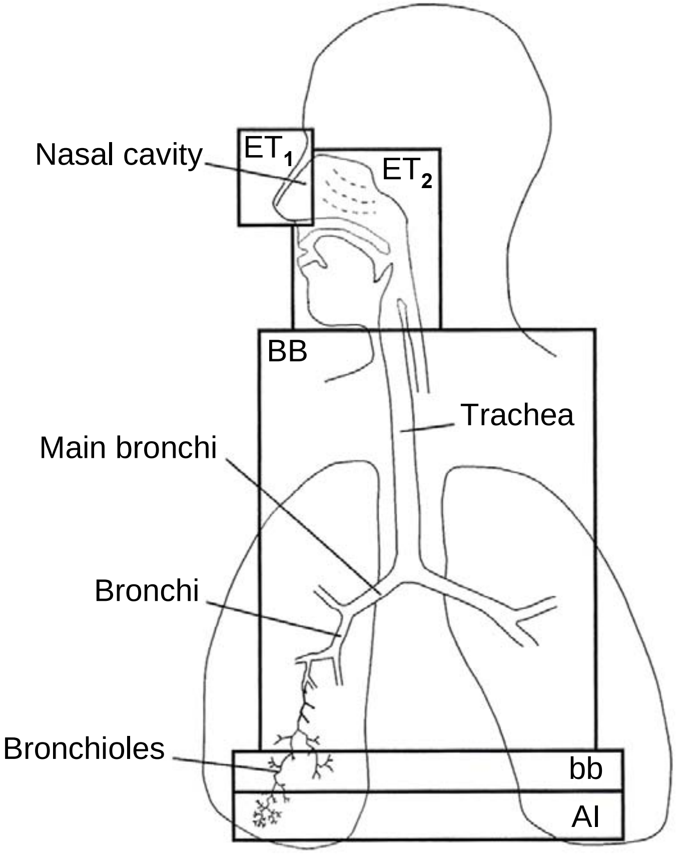
Methods

<u>Particulate measurements</u>

- Measured by (VTT) Technical Research Centre of Finland
- Euro 2 diesel bus with a partial-DPF catalyst
- European Braunschweig cycle
- Number size distributions were measured using an (ELPI) Electric Low Pressure Impactor

In silico methods

- Human Lung Deposition model with in house MATLAB scripts
- The lung system was divided into five different regions (ICRP, 1994)



Physiological parameters of Human Lung Deposition model (adult male or female) (ICRP, 1994)

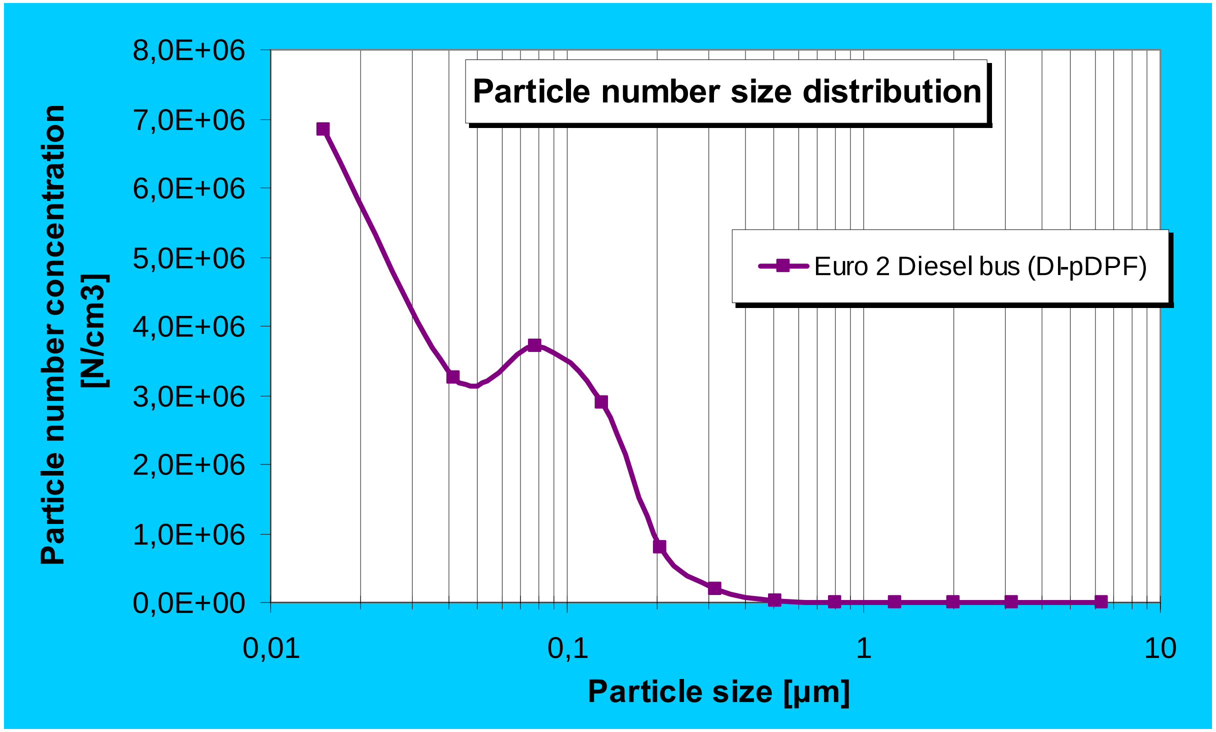
Parameter	**Male**	**Female**
Functional residual capacity, FRC [cm^3]	3301	2681
Extrathoracic dead space [cm^3]	50	40
Bronchial dead space [cm^3]	49	40
Bronchiolar dead space [cm^3]	47	44
Height [cm]	176	163
Tracheal diameter [cm]	1.65	1.53
First bronchiolar diameter [cm]	0.165	0.159

- Three different activity levels: sleeping, sitting and light exercise (ICRP 1994)

Parameter	Sleeping		Sitting		Light exercise	
	Male	Female	Male	Female	Male	Female
Ventilation rate [m^3/h]	0.45	0.32	0.54	0.39	1.5	1.25
Breathing frequency [1/min]	12	12	12	14	20	21
Tidal volume [cm^3]	625	444	750	464	1250	992
Volumetric flow rate [cm^3/s]	250	178	300	217	833	694
Fraction breathed through nose	1	1	1	1	0.7	0.7

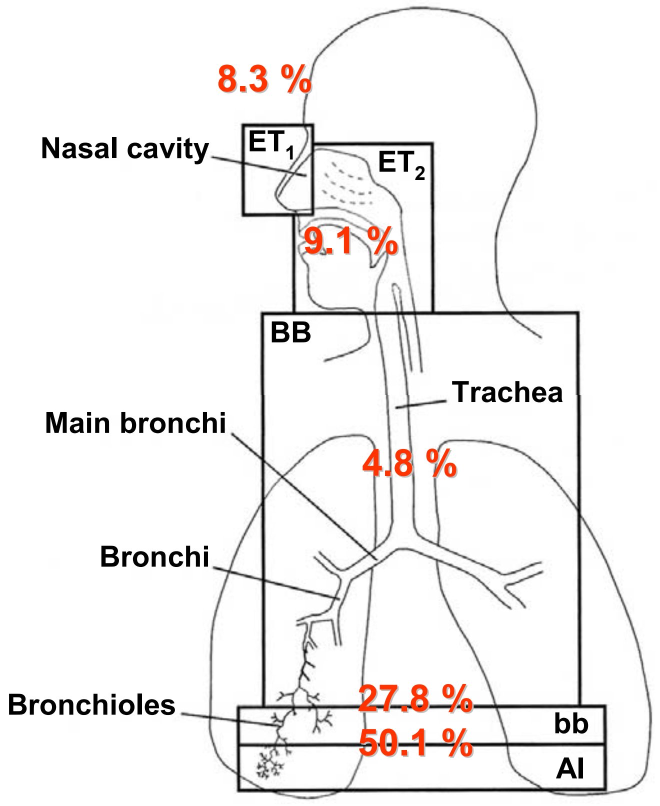
Results

- Most particles smaller than 200 nm
- Majority of the measured particle sizes can easily penetrate deep into the uniciliated regions of the lungs

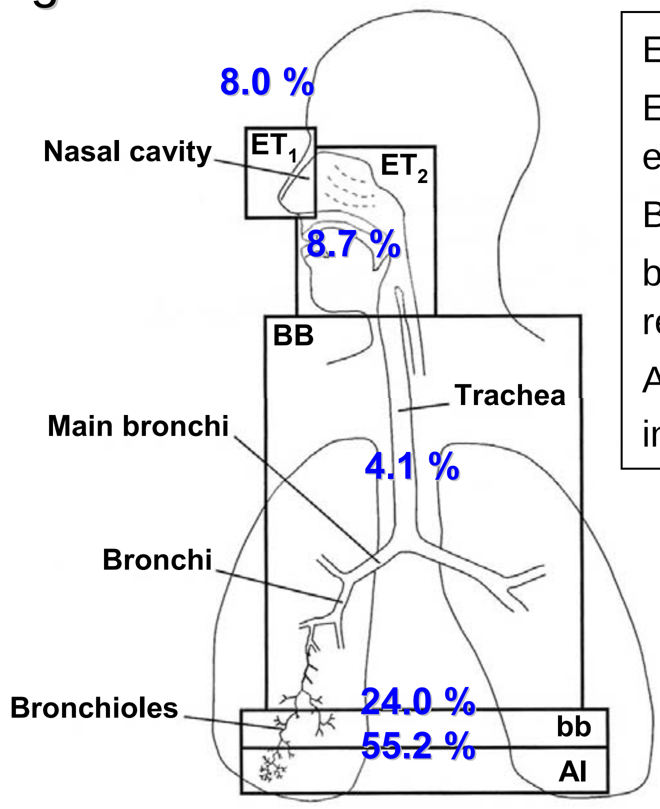


- Inhaled dose of particulates was different in female and male
- In sleeping the total amount of deposited particles was 19 % higher in male than female

Sleeping



Female



Male

ET_1 = anterior nose

ET_2 = main extrathoracic region

BB = bronchial region

bb = bronchiolar region

AI = alveolar-interstitial region

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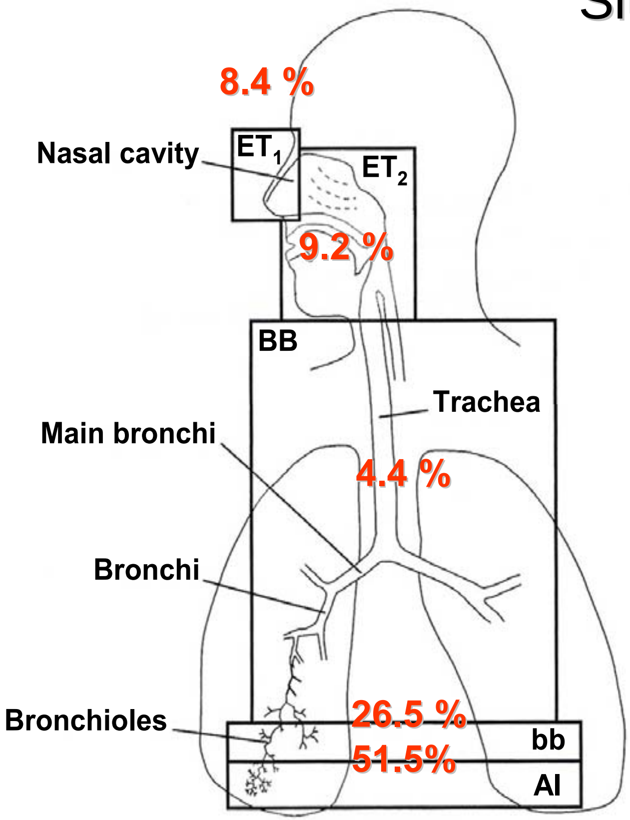
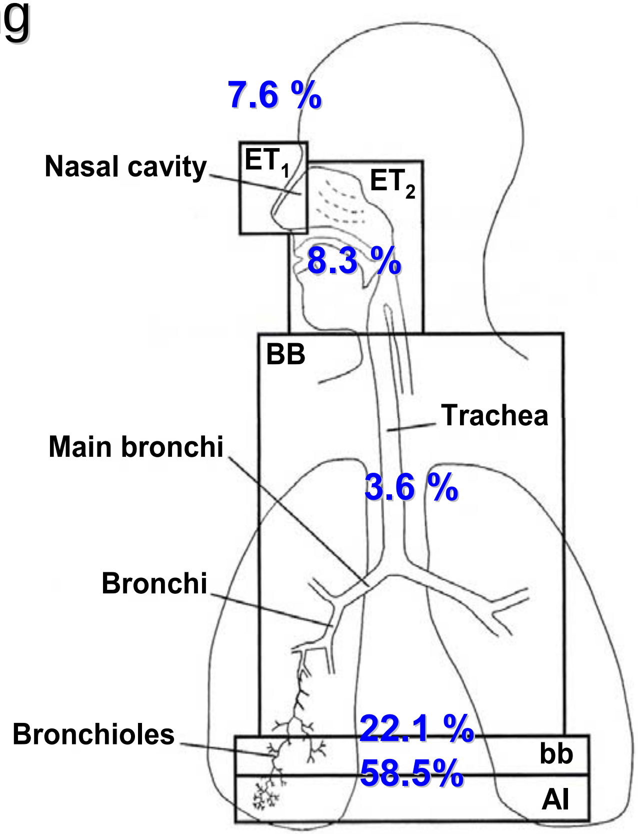
- In the sitting position the total amount of deposited particles was 48 % higher in male than female

Sitting



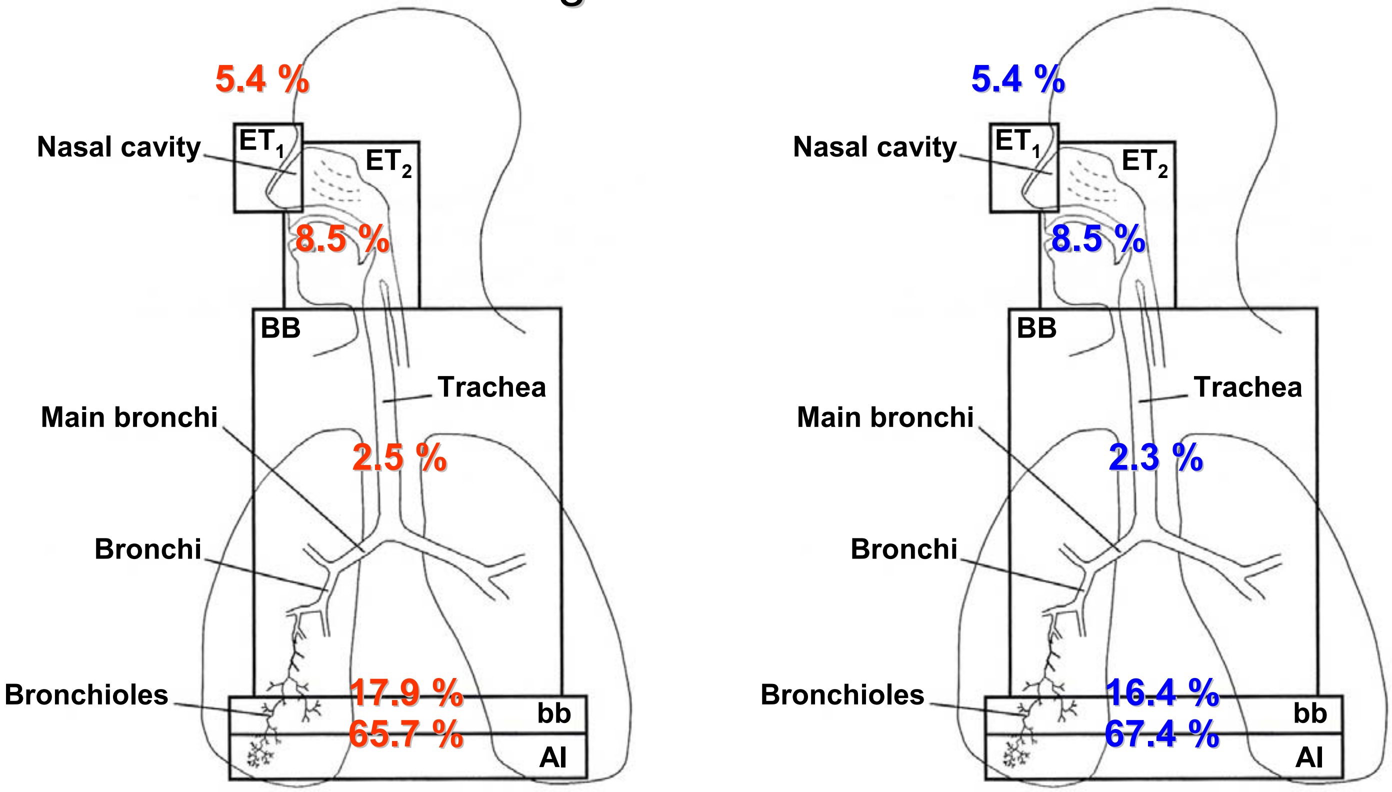
Female



Male

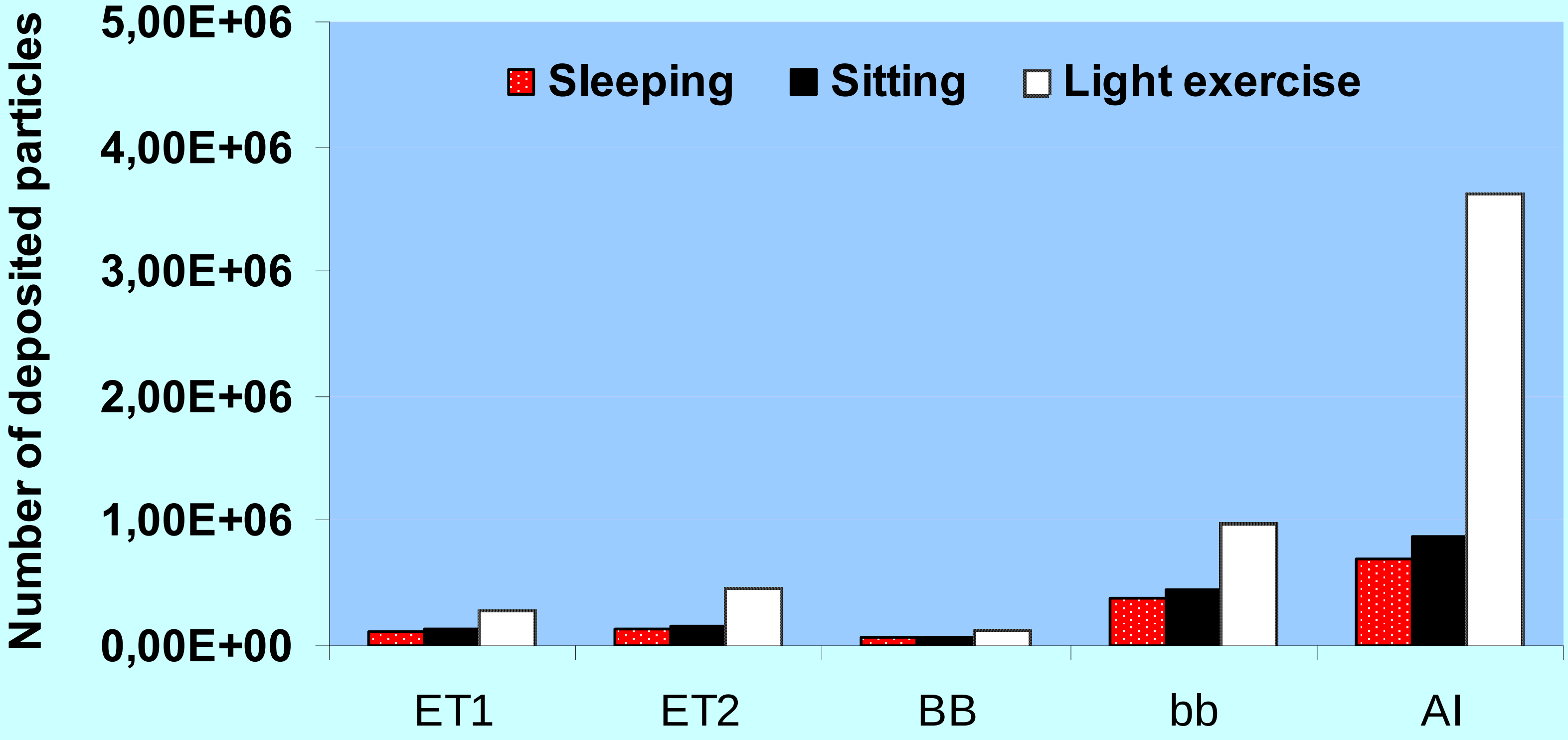
- In light exercise the total amount of deposited particles was 43 % higher in male than female
- Differences of doses depend breathing parameters, deposition propabilities, and anatomy and physiology

Light exercise

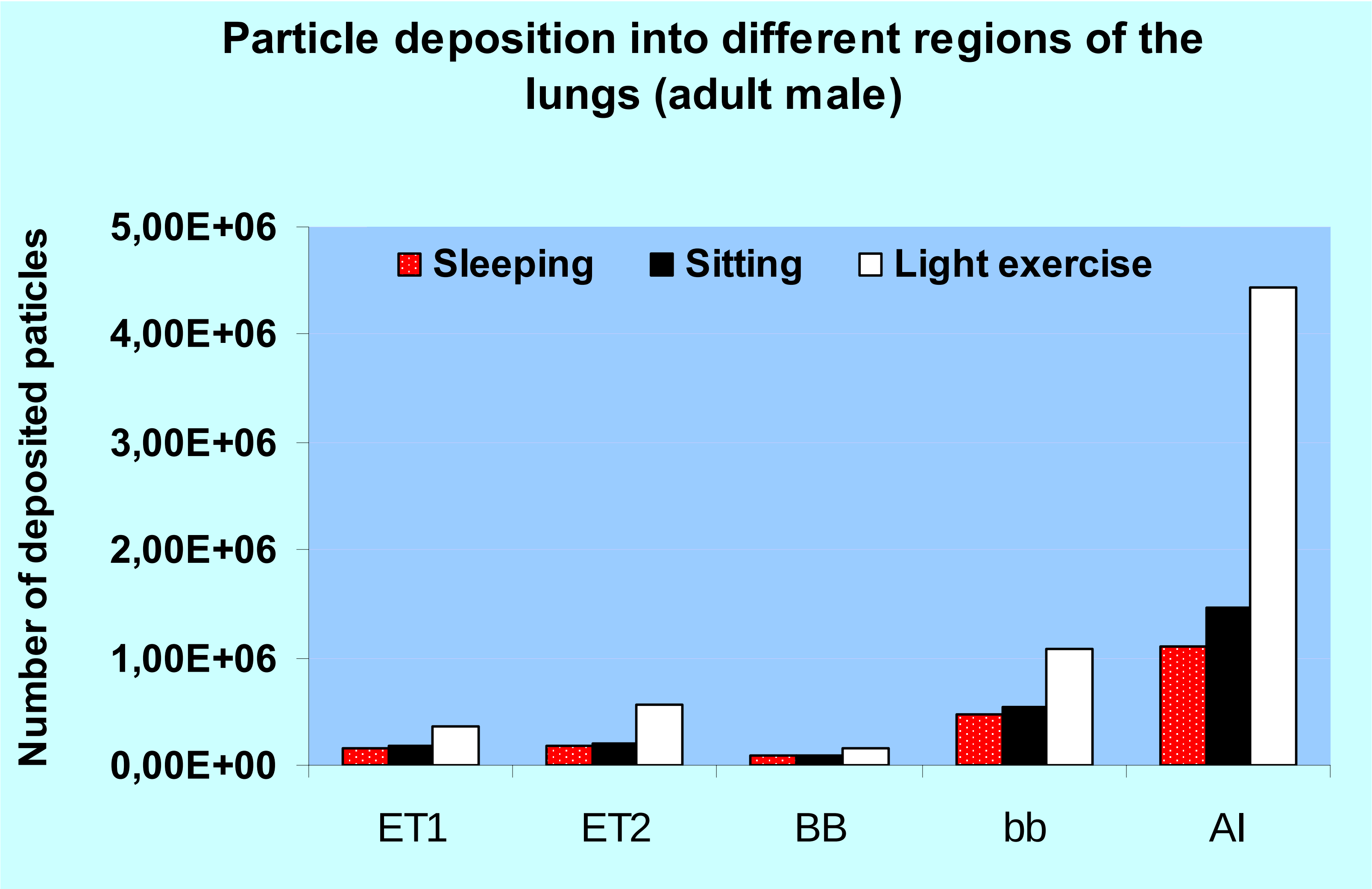


Female Male

Particle deposition into different regions of the lungs (adult female)



ET_1 = anterior nose, ET_2 = main extrathoracic region, BB = bronchial region, bb = bronchiolar region, AI = alveolar-interstitial region



ET1 = anterior nose, ET2 = main extrathoracic region, BB = bronchial region, bb = bronchiolar region, AI = alveolar-interstitial region

Conclusions

- At similar exposure conditions, the lung dose of diesel particulates, is different between males and females and this result may cause different health risks between genders
- A need for more research in special groups, e.g. children

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Thank you for your attention!

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