Characterization of indoor and outdoor particles in a mechanically ventilated office building

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SUMMARY
One key feature of a healthy working environment is good air quality. In this work we measured the infiltration of outdoor air particles into a mechanically ventilated 4th floor office. The floor was unoccupied for the duration of the measurements, thus indoor particle sources were limited. We determined the indoor/outdoor ratio of sub-1 µm particles for several metrics and discovered that the ratio was higher for mass and lung-deposited surface area (LDSA) concentrations than for number concentration. We also noted that the contribution of black carbon particles to total indoor particulate mass was affected by traffic.

KEYWORDS
I/O-ratio, LDSA, black carbon, PM_1

1 INTRODUCTION
Airborne particulate matter is a major risk to human health (Kim et al., 2015). Many people spend much of their time in indoor spaces and indoor particulate pollution is of growing concern. Particles in offices are mostly of outdoor origin, as there are no major indoor sources. We measured the indoor and outdoor concentrations of particulate matter in a city centre office to study the infiltration of ambient particles into indoor air.

2 MATERIALS/METHODS
The measurements were conducted in a mechanically ventilated office building in Helsinki in March 2021. The office room was in the unoccupied 4th floor of the building and the supply air was filtered using ISO ePM1 60 % class bag filters. Indoor and outdoor particle number size distributions were measured with two electrical low-pressure impactors (ELPI+ by Dekati Ltd.). Only particles with an aerodynamic diameter of 1 µm or less were included when calculating total concentrations. The mass distributions were calculated assuming spherical particles with unit density. LDSA distributions were obtained from the ELPI+ data according to Lepistö et al. (2020). Black carbon mass concentration was measured indoors using an aethalometer (AE33 by Magee Scientific). We also measured the indoor $PM_{2.5}$ mass concentration according to the ISO-16000/37 standard using an eFilter (by Dekati Ltd.). The standard includes a 24-hour filter measurement with a supplementary 1 Hz resolution electrical measurement.

3 RESULTS
Figures 1 (a-d) show the hourly mean number, LDSA and mass concentrations indoors and outdoors and the I/O ratios for these metrics. The concentrations were moderate during the measurement period, with the highest hourly outdoor concentrations reaching 16 300 1/cm^3, 21.9 µm^2/cm^3 and 14.76 µg/m^3 for number, LDSA and mass respectively. The $PM_{2.5}$ mass

concentration obtained with the 24-hour filter measurement (mean 3.4 µg/m^3) is presented in Figure 1 (c). Mean I/O ratios were under 0.26 for all metrics, and only particle mass reached an hourly mean I/O ratio above 1. Figure 1 (e) shows the mean and median ratio of black carbon mass to total PM_1 mass and the mean eFilter current as diurnal cycles.

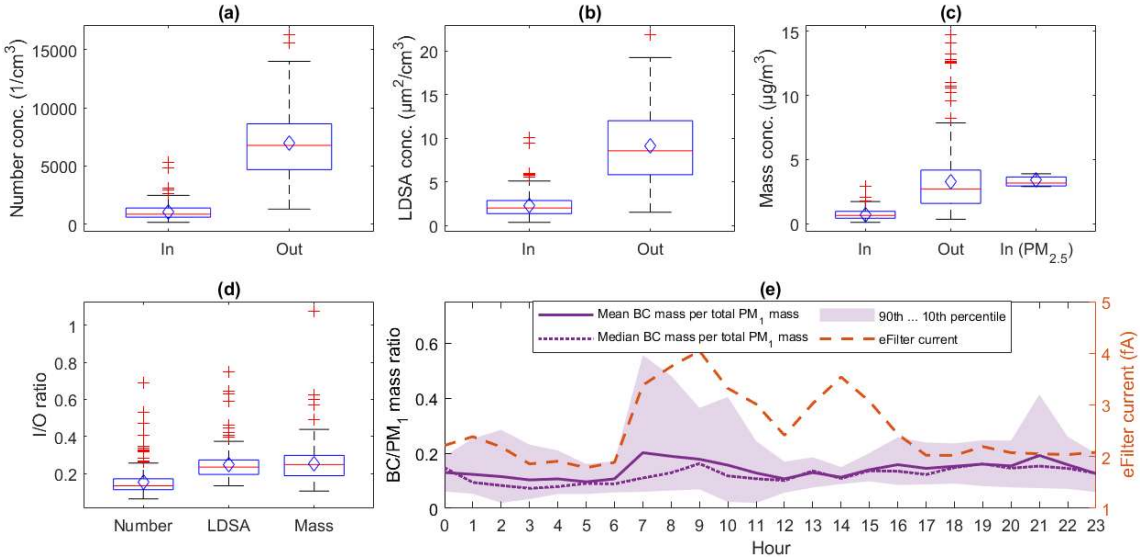

Figure 1. Top row: hourly mean number concentration (a), LDSA concentration (b) and mass concentration (c) in indoor and outdoor air. The red line indicates the median and the blue diamond the mean. The boxes indicate the region from 75th to 25th percentile, the red '+' markers are outlier values, and the whiskers extend to the most extreme values not considered as outliers. Bottom row: hourly mean I/O ratio of number, LDSA and mass concentrations (d) and the diurnal cycles of median and mean black carbon mass contribution to total PM_1 mass and the mean eFilter current (e).

4 DISCUSSION AND CONCLUSIONS

The low I/O ratios confirm that no significant indoor sources were present in the office and indoor particulate matter was mainly of outdoor origin. Particles near the most penetrating particle size of building shells and supply air filters (around 200-300 nm) contribute more to surface and mass than number concentration concentrations, which explains the observed higher I/O ratios for LDSA and mass than for number concentrations. Elevated BC/PM_1 mass ratios were observed during the morning rush hour, suggesting that traffic-related black carbon particles can infiltrate into indoor office environments. The high time resolution supplementary measurement allows for improved source appointment and spatial resolution when making ISO-16000/37 compliant indoor $PM_{2.5}$ measurements.

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