Measured LDSA concentrations indoors and outdoors at four schools/day-cares in Finland

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SUMMARY
Particles in ambient air can be harmful to human health, and children are a vulnerable population group. We measured the lung-depositing surface area (LDSA) of particles in four schools/daycares for two weeks to better understand particle sources and the current LDSA levels. Our results showed that indoor air LDSA concentration was highly correlated with outdoor LDSA concentration, but indoor sources were also noted in a few cases. The mean LDSA for all locations was 4.34 $\mu m^2/cm^3$.

KEYWORDS
ultrafine particles, lung-deposited surface area, I/O

1 INTRODUCTION
Particles in ambient can be hazardous to human health (e.g. Lelieveld et al., 2015). Recently, the World Health Organization (WHO) has extended their air quality guidelines to indoor air and given 1000 $1/cm^3$ (24-hour mean) as a limit to describe low particle number concentration (World Health Organization, 2021). Electrical particle sensors often report lung-deposited surface area, which is not yet recognized in the guidelines. However, assuming 100 nm spherical particles, the corresponding LDSA level is 5 $\mu m^2/cm^3$. In this study, we determined the LDSA concentrations at four schools/daycares to compare them to the WHO target.

2 MATERIALS & METHODS
The measurements for this study were conducted in four schools/day-cares in Western Finland during the autumn of 2021. Two schools were in suburban areas, and two were in city centers and at each school the measurements lasted two weeks. The average outdoor temperature during the measurements was 9.5 °C. Despite the ongoing pandemic, schools were operating relatively normally. All measurements were conducted in ground floor classrooms using two Partectors (manufactured by Naneos GmbH), one placed indoors and one outdoors.

3 RESULTS & DISCUSSION
Figure 1 shows the diurnal medians of LDSA at each measurement locations. Overall, the LDSA concentration indoors was nearly always lower than the outdoor concentration, and mostly under 5 $\mu m^2/cm^3$. However, for Suburban School 1, this limit was regularly exceeded at nighttime when the mechanical ventilation was switched off. Very high peaks also occurred during the day due to indoor sources (as no corresponding peaks were seen in the outdoor concentrations). At City School 2, the 5 $\mu m^2/cm^3$ target was exceeded by a little at 7-8 in the morning and again at around 13-14. The morning peak is also seen in the outdoor data and is

probably related to morning traffic. The afternoon peak does not have a clear correlation with outdoor concentrations, and could also be due to indoor sources, such as cooking or cleaning. Concentrations at City School 1 and Suburban School 2 were low throughout the day.

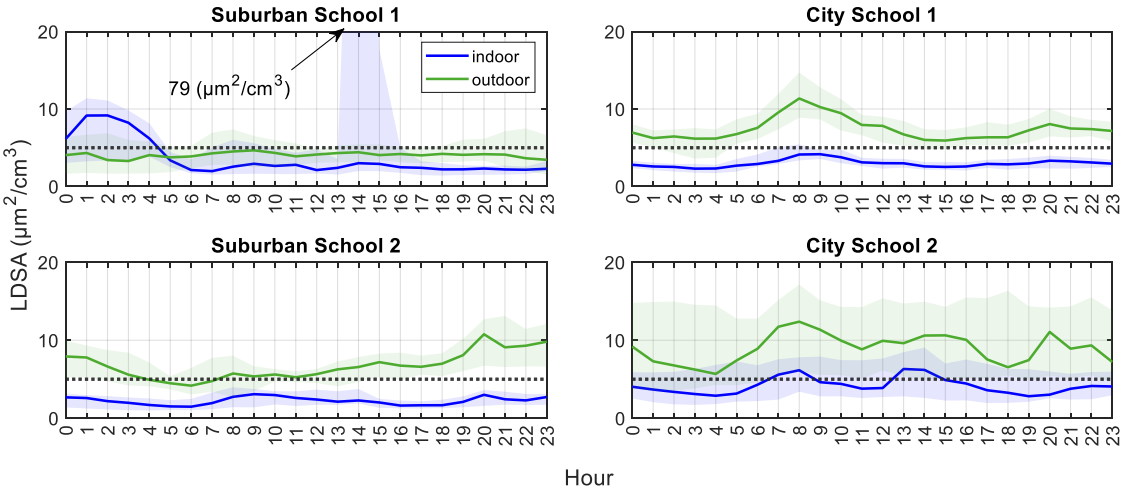

Figure 1: The median diurnal cycles of LDSA in the four school locations. The shaded area indicates the 25th to 75th percentile range and the horizontal dotted line shows the target level. Only weekday data is included.

To investigate the relationship between indoor and outdoor air concentrations, we calculated the ratio of indoor to outdoor LDSA (I/O) as well as the correlation coefficients. The overall I/O value for all locations was 0.44. Indoor LDSA was highly correlated ($R^2 > 0.5$) with outdoor LDSA at all locations except Suburban School 2 (R^2=0.14).

While the overall results for LDSA concentration were low, it is interesting to note that contrary to what we expected, the schools located in the city centers did not have higher indoor LDSA concentrations. For most locations, infiltration of outdoor air particles was the most significant LDSA contributor, but the results from Suburban School 1 show that when indoor sources are present, they may create very high concentrations.

5 CONCLUSIONS

This study was conducted using small, low-maintenance devices for particle measurements. Despite the simplicity of the measurement method, we were able to differentiate between outdoor and indoor sources, as well as changes caused by ventilation settings. Our results showed that on average LDSA concentrations are low, but traffic peaks and indoor sources do cause exceedances of the target level.

ACKNOWLEDGEMENT

This study was funded by the Business Finland project Future Spaces (grant number: 33250), with industry funding from Koja Ltd., A-Insinöörit Suunnittelu Ltd., Tampereen Tilapalvelut Ltd., TPI Control Ltd. and Dekati Ltd.

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