

Preliminary results of outdoor and indoor air quality and micrometeorological measurements in an inflatable football arena

Continuous measurements of air quality are needed in outdoor and indoor sports and recreation areas to raise awareness of the breathable air conditions and to help mitigate the accumulating health risks.

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Introduction. Climate change is expected to increasingly impact the indoor and outdoor conditions in the future (IPCC 2021). As regards football, it is urgent to promote climate neutrality and meet e.g., the UEFA2030 climate targets in mitigation and adaptation (UEFA 2022). In addition, it is evident that health risks in the breathable air, including both risks related to poor air quality and spreading of diseases such as COVID-19 should be mitigated proactively as well as possible.

Due to COVID-19 there was a fully unexpected lockdown of societies in 2020-2021 (Torkmahalleh et al. 2021). The Finnish Meteorological Institute (FMI) was asked by the football clubs to help investigate how COVID-19 is spreading in the air and what restrictions are essential in outdoor conditions as well as indoor inflatable arenas.

The air quality in football arenas has been a concern e.g., due to volatile compounds emitted by the artificial turf fields (Salonen et al. 2015) and more lately due to COVID-19 superspreading events. During COVID-19 pandemic it was noticed that aerosols containing SARS-CoV-2 are co-exhaled with CO₂ by people with COVID-19 infection. It was then found that CO₂ can also be used as a proxy of SARS-CoV-2 concentrations indoors (Peng and Jimenez 2021).

Very limited amount of information exists about the air quality in the modern inflatable football arenas. In the study by Salonen et al. (2015) health impacts related to compounds emitted by the artificial turf, particulate matter (PM) and microbial emissions have been concerns related to older indoor arenas and more than half of adolescent football players using the studied arenas reported at least one symptom or nuisance (e.g., sore throat, running nose). Most studies indicate PM_{2.5} at or below 12 µg/m³ is considered with little to no risk from exposure (IAHI 2022). According to IAHI (2022), peaks above 35 µg/m³/24 hours can cause issues for people with existing breathing issues such as asthma. Long-range transports (LRT) are an important source of pollution in ambient air, but their impact has not been studied as regards football arenas.

In this article we describe what efforts we have made in 2021-2022 and what we have learned as regards air quality outside and inside an inflatable football arena located in Järvenpää, southern Finland.

Experimental setup. In many ways the large inflatable arenas that are commonly used in the football are more resembling outdoor conditions than indoor due to their size, volume and effective ventilation. Our measurements were conducted in a modern inflatable football arena (volume of 144 000 m³) located in Järvenpää (Fig. 1).



Figure 1: Football arena measurement locations (green). Low-cost sensors measured in all locations, Licor instrument only in the middle. The ventilation system is located on right (marked as IV). Parking area is depicted with black "P-paikat", running training area with "Juoksurata", "Kulku" shows the door.

To study the air transmission and conditions in the football arena, we made preliminary air flow, temperature and relative humidity measurements using a hot-wire anemometer (VelociCalc 8347) in the football arena on April 16th 2021. The number of participants in trainings and games we received from JäPs (1.11.-27.11.2021). Furthermore, between June 2021 and February 2022, three SmartCitizen low-cost sensors developed in H2020 iScape-project (see <https://smartcitizen.me/> and www.iscapeproject.eu) were used to monitor PM₁, PM_{2.5}, PM₁₀, (refers to particles with diameter smaller than 1, 2.5 and 10 µm), eCO₂ (i.e., a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential), TVOC (total VOC) concentrations as well as light, noise, and meteorological parameters (Temperature (T), relative humidity (RH), pressure (P)) with time resolution of 1 min). The sensors were installed to western side of the arena, at the middle and to both ends of the arena (Fig. 1) at approximately 1.5-3 m height, depending on where it was safe and where electricity to install the sensor was available. Prior to measurements a co-location study was carried out to ensure the results of sensors are comparable (results not shown). One CO₂/H₂O analyzer (Licor LI-840A) was installed to the arena for two weeks in spring 2022 to compare to the results of the low-cost sensors. Luukki (Northern Espoo, 45 km from the Järvenpää) clean background air quality station used in the LRT investigations.

Results. In April 2021, the hot-wire anemometer measurements indicated that the largest air flows (> 7-10 m/s) were observed in the proximity of air vents and lowest (< 0,1 m/s) in the middle and in the corners of the side of the "Juoksurata". During the training hours (12:00-22:00) in November-March the mean temperature varied between -0,6 °C and 4,1 °C and the mean humidity between 63,6 % and 77,4 % with maximum and minimums much larger and smaller. In summertime a clear diurnal cycle was observed, with minimum in night-time and maximum in afternoons, similarly as in ambient air. This was expected as the air flow from outdoor to indoor is 70000 m³/h to inflate the arena.

Indoor, the measured $PM_{2.5}$ and PM_{10} concentrations were mostly low. However, random peaks of $PM_{2.5}$ above $12 \mu\text{g}/\text{m}^3$ and for PM_{10} of $50 \mu\text{g}/\text{m}^3$ (daily average safety limit) did occur (Fig. 2). To study the influence of outdoor air to air quality in the football arena, we studied how the two long-range transport (LRT) episodes (marked with Episode 1 and Episode 2) seen in HSY Luukki Air quality station as an increase in particulate matter concentrations are seen in the football arena (Fig. 2). During both LRT episodes a clear increase was seen, with nearly as large $PM_{2.5}$ and PM_{10} concentrations indoors as outdoors. During Episode 2 trainings took place (Fig. 3).

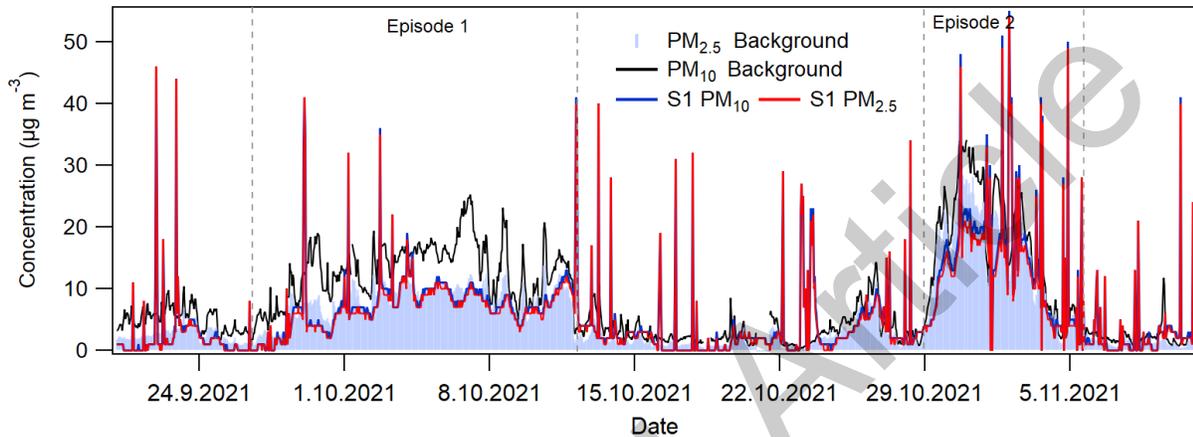


Figure 2: $PM_{2.5}$ and PM_{10} concentrations measured in the Luukki back-ground station and in Järvenpää football arena during LRT Episode 1 and Episode 2.

In the inflatable football arena in Järvenpää, the incoming air flow is $70000 \text{ m}^3/\text{h}$. When the incoming air flow is compared to human breathing (rough estimate: $90 \text{ l}/\text{min}$ in exercise, for 100 persons the breathing volume $540000 \text{ l}/\text{h}$ i.e. $540 \text{ m}^3/\text{h}$), the breathing volume is negligible ($<1\%$). We found that $e\text{CO}_2$ has some correlation with number of participants and noise. However, the $e\text{CO}_2$ was found to be influenced by other greenhouse gases such as water vapour. On the other hand, number of participants and noise with values exceeding 60 dB had clear correlation ($r=0,66$) in the arena. Thus, noise was considered to serve as a new indicator for assessing the number of people present in the football activities (Fig. 3). We note that the variation in CO_2 concentration was modest (between $420\text{-}650 \text{ ppm}$), likely due to strong ventilation.

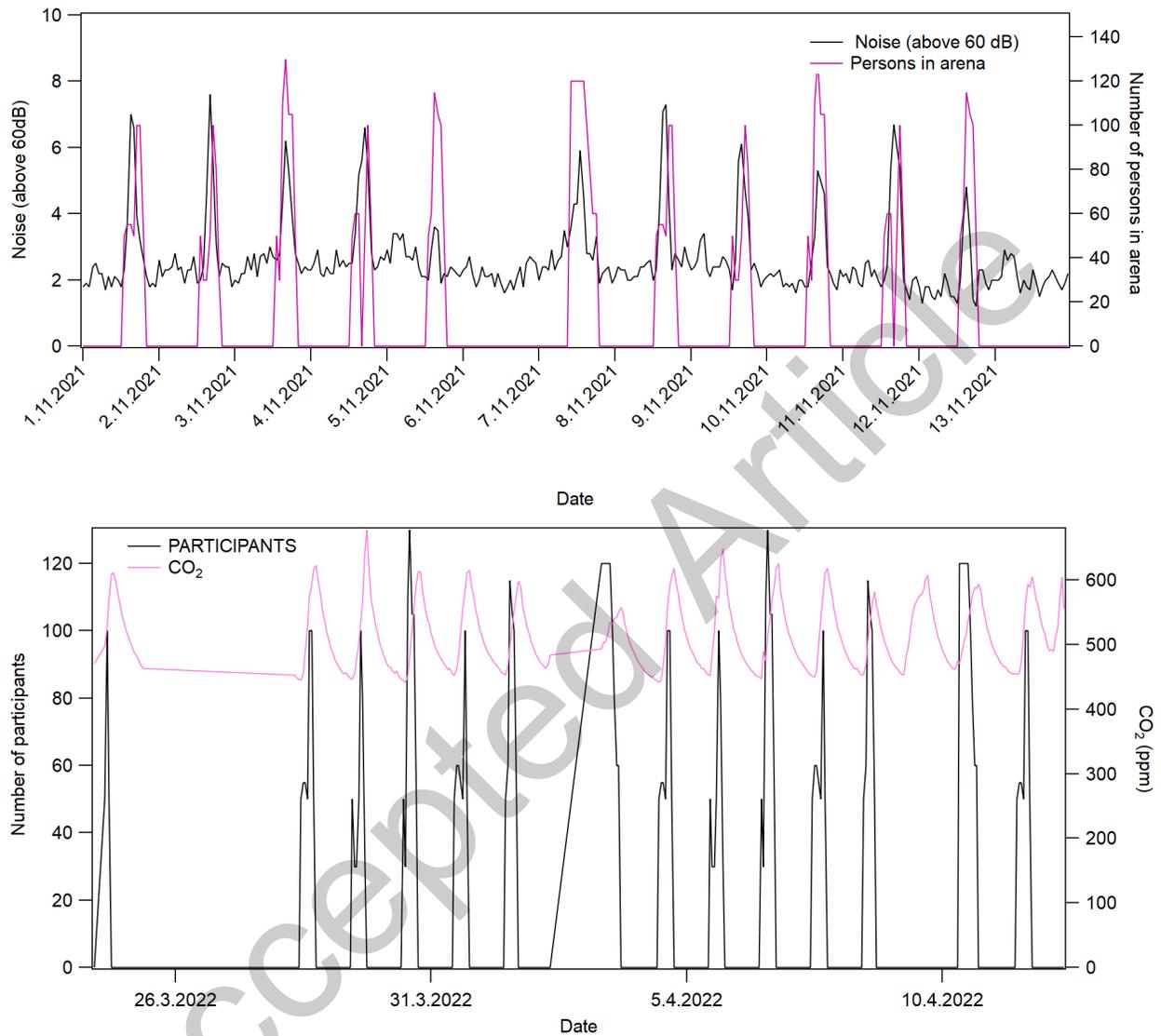


Figure 3: Noise above 60dB and number of participants (upper panel, low-cost sensor) (1.11.-13.11.2021) and number of participants vs CO₂ concentrations (lower panel, Licor analyzer) (26.3.-10.4.2022) in the arena.

Discussion and conclusions. Meteorological measurements conducted by the low-cost sensors show that the conditions in the arena vary a lot during the year, likely affecting the training conditions also. Although the PM sensors are not most reliable, they demonstrated that the PM concentrations were mainly low. However, random PM_{2.5} peaks above recommended safe 24-hourly levels ($12 \mu\text{g}/\text{m}^3$) did occur during the long-range transport episode and a local fire.

As regards the COVID-19 infection risk monitoring, we learned that the measured noise was correlated with the number of participants in the arena. The number of participants also correlated with CO₂, which we measured with Licor during two weeks in Spring 2022. Based on Peng and Jimenez (2021), we assume that our future research should focus on proving if noise can also be used as a proxy of SARS-CoV-2 concentrations indoors. We should also do simulations, as based on the preliminary assessment, we found spots where the air was not moving. In addition, we should focus on temperature and humidity conditions, since based on Ai et al. (2022) the risk of COVID-19 infection was found to be the highest at temperature below 5 °C and with low relative humidity. In

Please cite this article as DOI: <https://doi.org/10.35614/ISSN-2341-6408-IK-2022-13-RL>

Järvenpää, the mean training temperature was below 5 °C in November-March, thus increasing risk, whereas the relative humidity was mostly above 60 %, thus decreasing risk. All in all, to know better how to improve the level of safety in the inflatable football arenas as regards COVID-19 infection as well as the overall breathable air risks, we conclude that there is an urgent need to do more measurements and research.

Acknowledgements: Funding from Academy of Finland, Flagship (grant no. 337552) is gratefully acknowledged. Collaboration with the football clubs and their representatives MPS (Malmin Palloseura) Jukka Airaksinen and JäPS (Järvenpään Palloseura) Jari Kurittu and Marika Hagelin are acknowledged for inviting science to meet practice. Tero Auvinen from Finnish Football Association and Mihaly Szerovay (University of Jyväskylä) are acknowledged for boosting collaboration.

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