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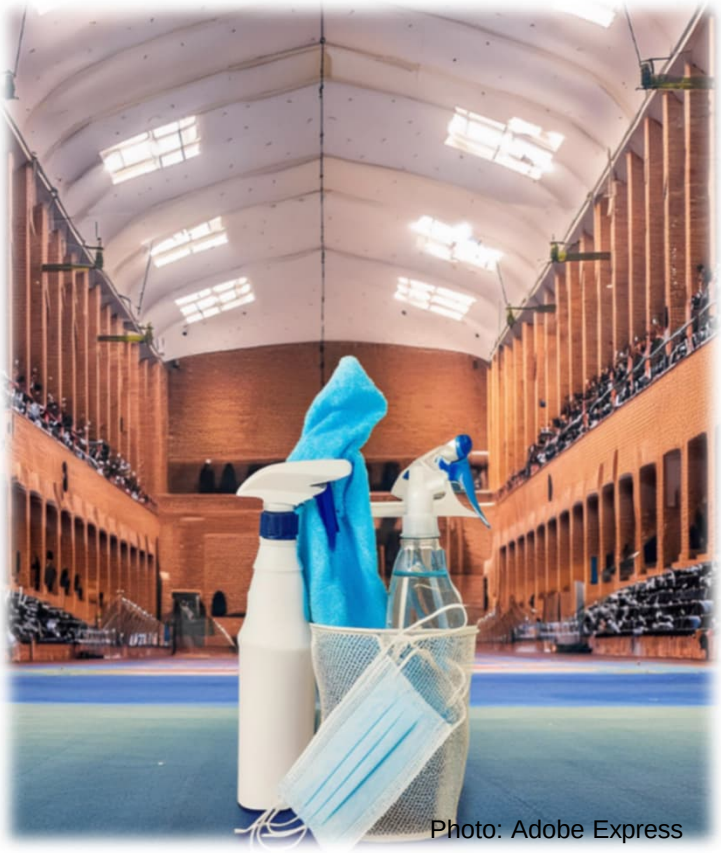
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Occupants' exposure to indoor air contaminants in European sports halls

A review study

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Introduction

- Young people may spend a great deal of time in sports halls.
- Children are more susceptible to the effects of air contaminants than adults because of
  - *their immature immune and respiratory systems,*
  - *lower average body mass index and*
  - *higher breathing patterns.*

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- Although IAQ has been studied extensively in public buildings, little is known about exposure to air contaminants in sports halls.

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Aim of the study

to summarise

- ❖ the occupants' exposure to indoor air contaminants
- ❖ the means to reduce these contaminants in European sports halls.

This review, based on our earlier study (Salonen et al., 2020), includes an updated database of IAQ and occupants' exposure in sports halls.

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Material and methods

- For the literature review, Google Scholar and PubMed were searched.
- 15 search terms and their combinations were used.
- The search was limited to articles published from 2013 to 2023.
- The search included original peer-reviewed scientific journal articles, literature reviews, conference articles and theses.

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→ The search was extended to the reference lists of relevant publications based on their abstracts and/or full texts.

- The decision to examine certain publications in more detail was based on the titles.
- Sports halls with swimming pools were excluded from the study.

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Results and discussion

- We found 17 scientific publications published between 2016 and 2023 that reported the IAQ in European sports halls.

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Table 1. Published studies reporting IAQ in European sports halls

Sport environment	Reported indoor air parameters	Reference
1 sports hall [Barcelona, Spain]	T, RT, Va, RH, CO_2	(Accili, 2016)
1 university sports hall [Eskisehir, Turkey]	SO_2, NO_2, O_3, $PM_{2.5}$, fungi, bacteria	(Bhat et al., 2022)
1 sports hall inside the multifunctional building [Warsaw, Poland]	CO_2, VOCs, NO_2, SO_2	(Bralewska et al., 2022)
1 sports hall [Warsaw, Poland]	PM_1, $PM_{2.5}$, PM_4, PM_{10}	(Bralewska et al., 2019)
3 sports halls [Porto and Lisbon, Portugal]	T, RH, CO_2, CO, PM_{10}, $PM_{2.5}$, O_3, fungi and bacteria	(Filipe et al., 2016)
1 multipurpose sports hall of the university [Oradea, Romania]	RH, T, CO_2, air microflora	(Ilies et al., 2018)
3 university sports halls [Gliwice, Poland]	PM_{10} and $PM_{2.5}$ nitric oxides (NO_2, NO_x, NO), and sulfur dioxide (SO_2)	(Kocot et al., 2020; Kocot et al., 2021)
1 sports hall [Warsaw, Poland]	PAHs, TSP, PM_4	(Kuskowska et al., 2018)

1 sports hall [Bydgoszcz, Poland]	Fungi and bacteria	(Małecka-Adamowicz et al., 2019)
1 university sports hall [Oradea, Romania]	Fungi, bacteria, T, RH, CO_2	(Onet et al., 2018)
1 athletic hall [Lefkovrysi municipal district. Macedonia]	T, RH, CO_2	(Panaras et al., 2019)
1 sports hall [Kaunas, Lithuania]	CO_2, T	(Seduikyte et al., 2019)
1 athletic hall [Kozani, Greece]	VOC, NO_2, O_3, CO_2, T, RH, $PM_{2.5}$, particle mass concentration and chemical analysis	(Tolis et al., 2019)
8 sports halls [Greater Helsinki Area, Finland]	Fungi, bacteria, aldehydes, CO_2, VOC, TVOC, T, RH, PM_{10}, $PM_{2.5}$, $PM_{1.0}$	(Andersson et al., 2023; Koivisto, 2021; Vornanen et al., 2023)

Pollutant/ factor	Mean	Notice
CO_2	420 ppm - 1,287 ppm	Concentrations were highly correlated with occupied hours. Slightly higher concentrations were measured in the heating season. The recommended levels and guidelines were often exceeded.

Pollutant/ factor	Mean	Notice
T	14.7 - 22.6 °C	Often under the recommended range of 20°C to 22°C. If the T is lowered in the winter season to save energy, it is important to ensure that no harmful moisture accumulates in the structures!
RH	19.8 - 49.9%	Mainly in accordance with the recommendations (under 60%).

Pollutant/ factor	Mean	Notice
$PM_{2.5}$	14–114 µg/m^3	> the recommended annual target value ($PM_{2.5}$: 5 µg/m^3) (WHO, 2021).
PM_{10}	40–400 µg/m^3	> the recommended annual target value (PM_{10}: 15 µg/m^3) (WHO, 2021).

Generally PM concentrations were higher in the heating than in the non-heating season.

Pollutant/ factor	Mean	Notice
TVOC	Generally low levels	A higher sum of VOCs was reported outside than inside the hall (heating season ~50%, non-heating season ~20%).
VOCs	Generally low levels	The presence of ethanol, limonene, heptane, methylcyclohexane and 2-phenoxy indicates a significant impact on the part of specific indoor sources on IAQ.

Pollutant/factor	Mean	Notice
O_3	12–36 µg/m^3	< than concentrations in outdoor air (50–64 µg/m^3). < the daily maximum 8-hour mean concentration of 100 µg/m^3 (WHO, 2021).
NO_2	4.4–73 µg/m^3	The annual maximum concentration of 10 µg/m^3 was exceeded in the majority of sports halls.
SO_2	9–43.6 µg/m^3	Mainly in accordance with the given 24 -h maximum concentration of 40 µg/m^3 (WHO, 2021).

The outdoor air is the main determinant of NO_2 and SO_2

Pollutant/factor	Range	Notice
Viable fungi	0 - 1,649 CFUs/m^3	
Bacteria	0 - 6,872 CFUs/m^3	Elevated bacterial concentrations indicated higher number of users (human source) and intense sporting activities were reported in many studies.

The presence and movement of a large number of people had a significant impact on the microbial contamination of IA.

Intense athletic activities influenced microorganisms.

Conclusions

- Target CO_2, NO_2, PM_{10}, and $PM_{2.5}$ concentrations were exceeded in many studied sports halls!

  → possible harmful exposure to occupants.

- In general, the TVOC, VOCs, O_3 and SO_2 concentrations in the halls were within target ranges and lower than the concentrations outside the halls.

- The indoor and outdoor concentrations of TVOC, VOCs, NO_2 and SO_2 were lower in the non-heating season than in the heating season.
- The presence of some individual VOCs (ethanol, limonene, heptane, methylcyclohexane, and 2-phenoxy).

→indicates a significant impact on the part of specific indoor sources on IAQ.

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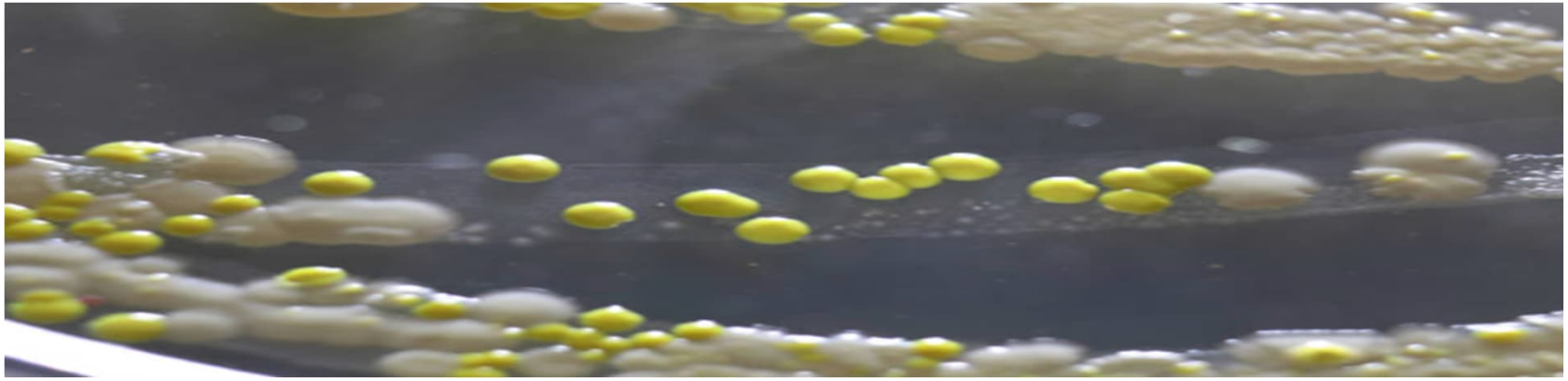
Photos: Adobe Express

- The air T and RH should be in the thermal comfort range and adapted to the activity at hand.
- Elevated bacterial concentrations *(due to the high number of users and intense sporting activities)* could be a potential hazard to the respiratory health of athletes.



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The means of reducing human exposure to harmful indoor contaminants in sports halls include:

- optimal and adequate mechanical ventilation with filters
- suitable cleaning and disinfection practices
- good personal hygiene
- optimal location planning (the location of the hall and its physical openings).

A global means of reducing people's exposure both inside and outside: the improvement in the quality of atmospheric air, including measures aimed at reducing traffic and municipal or industrial emissions!

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Thank you!