Spatial and temporal analysis of air speeds in equine indoor arenas

S. McGill[1], M. Hayes[1,*], J. Jackson[1] and R. Coleman[2]
[1]*Biosystems and Agricultural Engineering Department, University of Kentucky, 128 C.E. Barnhart Building, Lexington, KY 40546, USA*
[2]*Department of Animal and Food Systems, University of Kentucky, 613 W.P. Garrigus Building, Lexington, KY 40546, USA*
[*]Corresponding author: Morgan Hayes, hayesmorgan@uky.edu

Abstract

Indoor arenas are semi-indoor structures located on equine farms and facilities for exercising horses, exhibiting skills during competitive events, and other equine related activities. These spaces do not always include mechanical ventilation or stirring fans and occupancy by horses and humans can be sporadic and inconsistent, which creates a challenging space for understanding and predicting airflow. Typically, indoor arenas have a sand-based footing over which the horse travels. The impact of the hooves can cause dust to become a concern within the facilities. Spatial variability analysis in previous research indicates the variability of air speeds in these facilities is not impacted by design characteristics of the indoor arena. In addition, air speeds were low enough to be considered still air conditions. To further understand the interior environment within indoor arenas, monitoring was conducted at 15 facilities within 200 kilometers of Lexington, KY. Environmental monitoring of air speeds took place over 7 days in the winter and summer to examine temporal variability. Air speed data was collected every 5 minutes using the HOBO RX3000 Remote Monitoring Station with the HOBOnet Ultrasonic Wind Speed and Direction Sensor. Similar results to the spatial variability indoor arena characterizations were observed during the environmental monitoring with air speeds being below the threshold for still air in livestock facilities (0.51 m/s). Sensor technology and implementation provides a better understanding of airflow and how indoor arena design can impact and improve it.

Keywords: equine, indoor arenas, spatial variability, temporal variability

Introduction

Equine indoor areas are a semi-indoor structure typically used for exercising horses and equine related competitions. Occupancy can be both sporadic or consistent depending on factors such as the type of facility (boarding, training, competition venue, etc), riding or competition schedule, or weather. Mechanical ventilation, mixing fans, or exhaust fans, are used in some indoor arenas, but are not a common design aspect for the majority of facilities making it difficult to understand or predict airflow. Users of indoor arenas have expressed concern about airflow in addition to other environmental conditions such as dust and moisture (McGill et al., 2021). Respirable dust and crystalline silica dust are both present in indoor arenas, but little work has been completed examining the interior environment within the indoor arenas (Bulfin et al., 2019; Wheeler, Zajaczkowski, and Diehl 2003). Over the course of 3 years, one-time facility characterizations were conducted at 37 equine facilities within 200 km of Lexington, KY (McGill et al., 2022). In this research air speed variability across the facilities was not impacted by various design aspects (windows, climate control mechanisms, ridge ventilation, etc), but, the average air speeds for 86% of the indoor arenas, was below minimum air speed recommendations (0.51 m/s) in livestock facilities (Figure 1) (McGill et al., 2022; Albright 1990; Norton et al., 2010). The recommended minimum air speed is such that air can carry containments out of the facility and potentially create a cooling effect for the animals.

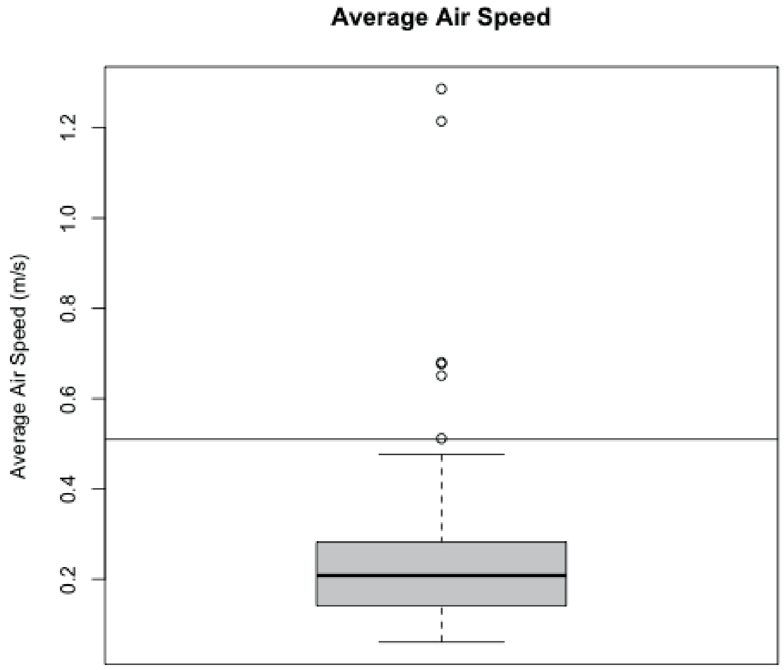

Figure 1: Average air speed of indoor arenas from spatial analysis involving the one-time characterizations of 37 equine indoor arena facilities (McGill et al., 2021).

Temporal variability of environmental conditions has not been examined in equine indoor arenas as it has for other livestock species. Swine, dairy, and beef confinement systems have been monitored for seasonal differences for temperature, dust, air speeds, and other environmental aspects (Cortus, Darrington, and Rusche 2018; Cortus et al., 2021; Kumari and Choi 2014). Dust and biotic containments in various types of swine facilities demonstrated seasonal differences with concentrations of both being higher in the winter than in the summer (Guingand 1999; Kumari and Choi 2014). Air speeds in cattle facilities were impacted by the weather conditions and wind speed and how well outside air infiltrated through openings in the barns (Cortus et al., 2021; Cortus, Darrington, and Rusche 2018).

Air speeds observed in most of the equine indoor arenas were below minimum air speed recommendations (Albright 1990; Norton et al., 2010).The objective of this paper is to characterize the seasonal air speed data from 15 equine indoor arenas that are within 200 kilometres of Lexington, KY. Similar to the one-time site characterization measurements at equine indoor arenas, we hypothesize that air speeds will be below recommendation for both the summer (June – September) and winter (October – March) seasons.

Materials and methods

Enrollment

For this study, environmental monitoring was conducted at 15 equine facilities in and around central Kentucky from October 2020 to February 2022. The 15 indoor arenas used for environmental monitoring were selected from the 37 equine facilities where the one-time site characterization visits were conducted. All facilities were identified with the aid of Cooperative Extension contacts. The 15 facilities were chosen with an intentionality towards including a balanced and diverse set of equestrian disciplines and indoor arena design characteristics. In accordance with IRB protocol (#43857), the facilities were assigned random identifying numbers which only IRB approved members of the research team had the ability to access. Each facility was required to sign an informed consent form which detailed all the information of the study and that participating in the study presented a minimal risk to the facility as analysis was performed on the aggregate data and not the individual facilities.

Data Collection

Each indoor arena was monitored for 7 days during the winter (October – March) and the summer (June – September) between October 2020 and February 2022. The HOBO RX3000 Remote Monitoring Station with the HOBOnet Ultrasonic Wind Speed and Direction Sensor (Range: 0 to 41.16 m/s; Accuracy: greater of ±0.8 m/s or ±4% of reading) was used to collect measurements every 5 minutes. Two ultrasonic wind speed and direction sensors were placed in each indoor arena in locations to optimize measurement capabilities and minimize impact on the functioning of the facilities. In addition, the sensors were placed in the same locations for both monitoring sessions.

Data Analysis

Initial analysis was conducted using HOBOware Pro software (version 3.7.25, Bourne, MA). The HOBOware Pro software was used to calculate hourly averages for the entire week of data collection. From the hourly averages for the entire week, each of the hour averages were combined into one complete days' worth of hourly averages for each indoor arena for the summer and winter monitoring sessions. This created a representative day of air speeds in the indoor arenas for the summer and winter seasons. The ultrasonic wind speed sensor recorded gust air speeds and sustained wind speeds and both were processed to determine a diurnal air speed profile.

Results and discussion

Overall, air speeds observed in most of the indoor arenas were below minimum air speed recommendations. Two of the equine indoor arena facilities had open or nearly open sides so the 24-hour period averages were calculated with and without those 2 indoor arenas. Examining the data with and without these 2 indoor arenas, provides insight into air speeds in facilities with 4 solid walls. Figures 2 and 3 represent the measurements without the indoor arenas that were considered to have an open design. The average outdoor wind speed for the winter monitoring sessions was 1.8 m/s with the predominate wind direction being from the south and the west northwest and the average air speed for the summer monitoring sessions was 1.1 m/s from the south ("Custom Wind Rose Plots"). None of the average air speeds observed in the gusts or sustained air movement were as high as the average for winter or summer. The gust speeds in the summer were higher than the winter gust speeds during the day, but that trend reversed overnight, while the sustained air speeds were consistently slightly higher during the summer than winter. However, none of the observed air speeds in either season were near the recommended air speeds for livestock spaces (Albright 1990). In fact, the air speeds were almost 0 m/s for sustained wind speeds in both seasons.

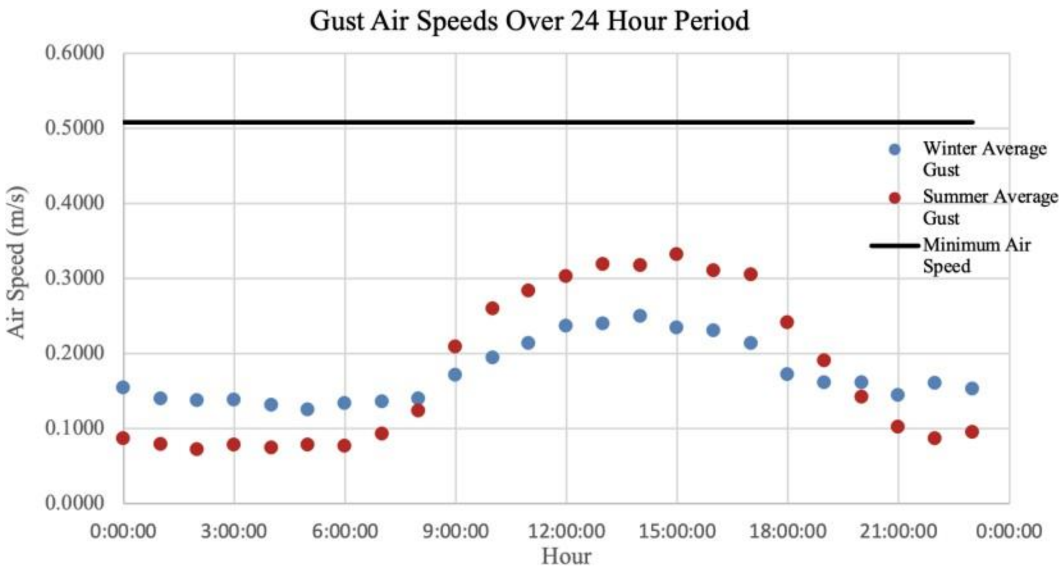

Figure 2: Gust air speeds of the 13 enclosed indoor arenas over a 24-hour period. The winter average gusts are represented in blue, and the summer average gusts are represented in red. The minimum recommended air speed is also provided. Air speeds were consistently below recommended air speed levels.

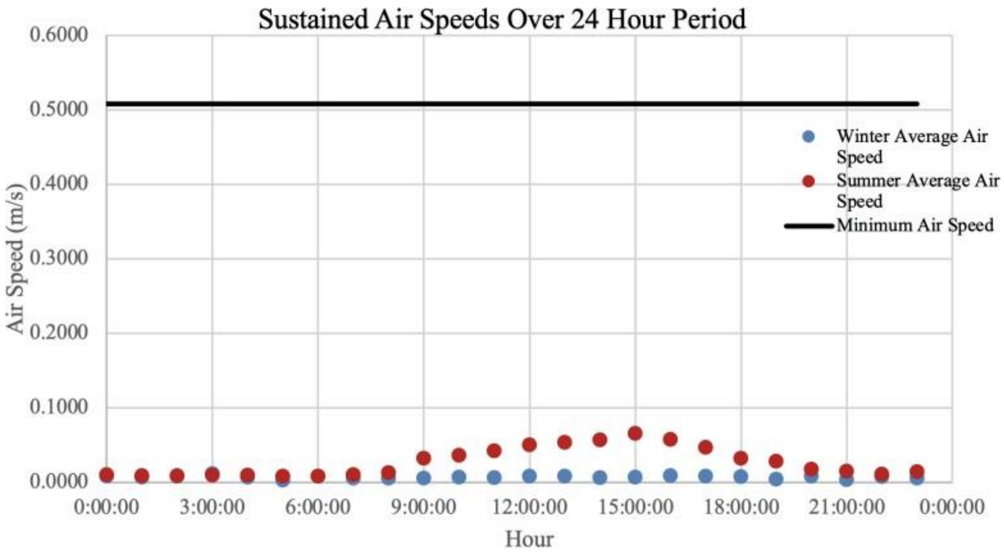

Figure 3: Sustained air speeds of the 13 enclosed indoor arenas over a 24 hour period. The winter average air speeds are represented in blue, and the summer average air speeds are represented in red. The minimum recommended air speed is also provided. Air speeds were consistently below recommended air speed levels and were very close to 0 m/s.

Including all the indoor arenas in the 24-hour air speed data changes which season had the higher average air speeds. The winter season for both the gust average air speed and the sustained average air speed observed higher air speeds, though overall the air speeds were still below the minimum recommended air speed of 0.51 m/s (Albright 1990). This shift was likely due to the indoor arenas with the larger openings in the walls experiencing more of the outdoor weather rather than the wind being prevented from entering the facilities.

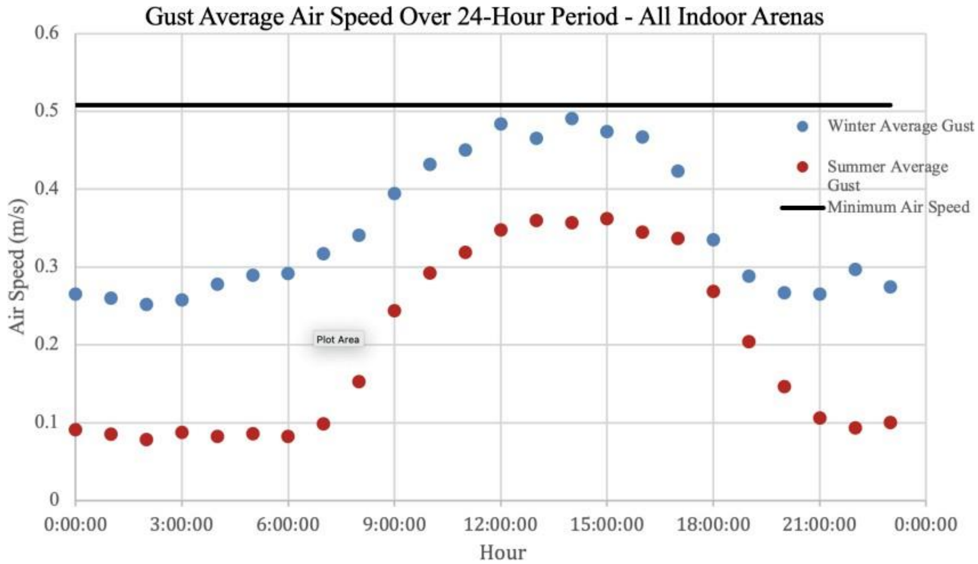

Figure 4: Gust air speeds of all the indoor arenas over a 24-hour period. The winter average gusts are represented in blue, and the summer average gusts are represented in red. The minimum recommended air speed is also provided. Air speeds were consistently below recommended air speed levels.

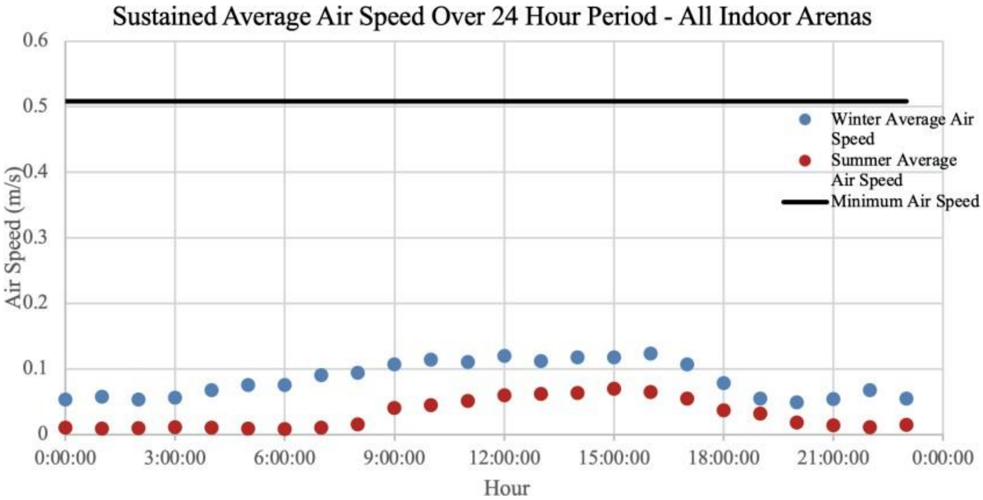

Figure 5: Sustained air speeds of all the indoor arenas over a 24-hour period. The winter average air speeds are represented in blue, and the summer average air speeds are represented in red. The minimum recommended air speed is also provided.

A trend that carried across the gust and sustained air speeds for the subset of 13 indoor arenas and all the indoor arenas was an increase in air speeds during the day compared to overnight. These facilities typically encounter most of their usage during the day when horses are being exercised. For the facilities with a more enclosed space, this suggests that during the day is when doors would be opened and closed to bring horses in and out of the facilities as needed. In addition, the higher air speeds were observed more in the afternoon than in the morning. As some of the equine facilities were horse boarding operations, it is likely riders would be coming after school or work to ride or participate in lessons during the afternoon and evening. Overall, trends were observed within the variation of the air speeds during the day as well as between seasons. Nonetheless, the air speeds were consistently at very low levels in both seasons and throughout the day. The low air speeds in indoor arenas are unlikely to aid in the removal of dust, moisture, or other environmental concerns within the facilities.

Conclusions

Equine indoor arenas are unique semi-indoor spaces used for exercising or exhibiting horses. Environmental issues within these facilities have recently been characterised, the actual interior environment has not been adequately examined. This research determined air speeds within these facilities during the winter and summer seasons in 15 indoor arenas within 200 km of Lexington, KY. A seasonal difference in the gust and sustained air speeds was observed as well as a diurnal pattern to when higher air speeds were observed. While these patterns were identifiable, none of the air speeds observed were at the minimum recommended levels for livestock facilities. More research is necessary to determine if better ventilation could help with environmental concerns like dust and moisture, but understanding the interior environment within indoor arenas is vital to this process.

Acknowledgments

This project was funded by the AFRI Predoctoral Fellowship grant 2020-67034-31729 from the USDA National Institute of Food and Agriculture.

This research would not have been possible without all of the equine facilities that graciously allowed us to conduct research in their indoor arenas.

References

Albright, L.D. (1990) *Environment Control For Animals And Plants*. American Society of Agricultural Engineers.

Bulfin, K., Cowie, H., Galea, K.S., Connolly, A., and Coggins, M.A. (2019) Occupational exposures in an equestrian centre to respirable dust and respirable crystalline silica. *International Journal of Environmental Research and Public Health* 16(17), 3226.

Cortus, E.L., Darrington, J., and Rusche, W. (2018) Measured airflow through gable-roofed naturally-ventilated beef cattle barns. In: *2018 ASABE Annual International Meeting,* Detroit, Michigan, USA

Cortus, E.L., Hetchler, B.P., Spiehs, M.J., and Rusche, W.C. (2021) Environmental conditions and gas concentrations in deep-pit finishing cattle facilities: A descriptive study. *Transactions of the ASABE* 64(1), 31-48.

Guingand, N. (1999) Dust concentrations in piggeries: Influence of season, age of pigs, type of floor and feed presentation in farrowing, post-weaning and finishing rooms. In: *Dust Control in Animal Production Facilities, Aarhus (Denmark), 30 May-2 Jun 1999*

Kumari, P., and Choi, H.L. (2014) Seasonal variability in airborne biotic contaminants in swine confinement buildings. *PLoS One* 9(11), e112897.

McGill, S., Hayes, M., and Jackson, J. (2021) Spatial mapping within indoor arenas. In: *2021 ASABE Annual International Virtual Meeting* 1.
McGill, S., Hayes, M., Tumlin, K., and Coleman, R. (2021) Characterization of indoor arenas through an anonymous survey. *Translational Animal Science* 5(4), txab198.
Mesonet, I.E. (2023) *Custom Wind Rose Plots*. *https://mesonet.agron.iastate.edu/sites/dyn_windrose.phtml?station=OMDW&network=AE__ASOS*
Norton, T., Grant, J., Fallon, R., and Sun, D.-W. (2010) Assessing the ventilation performance of a naturally ventilated livestock building with different eave opening conditions. *Computers and Electronics in Agriculture* 71(1), 7-21.
Wheeler, E.F., Zajaczkowski, J.L., and Diehl, N.K. (2003) Temperature and humidity in indoor riding arenas during cold weather. In: *2003 ASAE Annual Meeting*, Las Vegas, Nevada, USA.