Research on NV Transformation of Univ. Billiards Rm. in TS Based on CO_2 Conc. Control

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Abstract. Sports pursue health and a strong body. A good exercise environment is crucial for good results. Thus, air quality in sports venues is essential for students' exercise and health. This article takes a university billiards room in Shenyang as an example. In the transitional season, through questionnaires, we understand teachers and students' overall feelings. Using FLUENT software, air quality is numerically simulated. It is found that during peak hours, the CO2 concentration in the staff area and student area exceeds three times the standard. Considering energy consumption and feasibility, transformation suggestions are proposed for the transitional season: add a window on the south wall of the student area and cowls on the roofs. After simulation, the CO2 concentration meets the standard.

Keywords: Billiards room; CO_2 concentration; Natural ventilation; Transformation suggestions

1 Introduction

Currently, many domestic studies on the relationship between indoor environment and pollutants mainly center on citizens' residences and large public places, with relatively few on sports venues. In Wang Tiantong [1]'s research on large ball game venues, aspects of fitness venues in severe cold areas are studied and summarized. Fluent software is used to simulate ventilation parts. By comparing indoor wind environments under different ventilation methods, a natural ventilation design strategy for large ball game venues in national fitness centers in this area is proposed. Scholars T. Van Hoof and B. Bloclccn [2] from the Netherlands compared their model with the original in the research on large-scale sports spaces with retractable structures and studied the complex physical processes. Professor Mei Hongyuan[3] proposed that setting windows on roof and sides accelerates air convection and cools indoor air. A height difference between windows on both sides of sports training hall speeds up indoor air flow. Swedish scholar F Flouseftzou [4] compared ventilation system energy performance in stadiums. Natural ventilation has the best heat recovery. Professor Li Jin [5] analyzed symmetrical and

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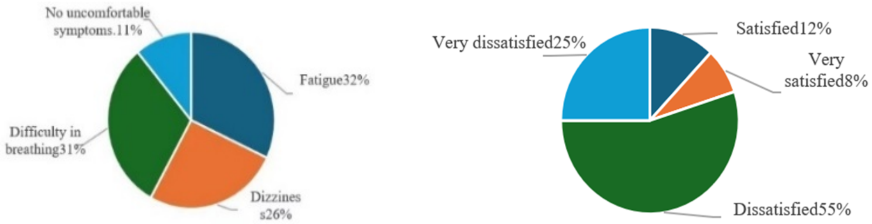
asymmetrical gymnasium forms with Fluent. Asymmetry increases wind pressure difference on both sides. Deeper cornice makes it greater, strengthening natural ventilation and solving indoor air quality issue.

This study aims to examine the air quality status of the billiards hall of a university in Shenyang from the perspective of carbon dioxide concentration and propose a reasonable natural ventilation renovation plan in the transitional season to promote students' healthy and green sports.

2 Questionnaire Survey

The questionnaire survey aims to understand teachers and students' feelings about billiards room air quality. Conducted from March to April. Random surveys during 13:30-15:15 and 18:00-20:00 for 20 days. Collected 300 questionnaires, retrieved 282 valid ones. 68% student samples, 32% staff samples. Made pie chart for key questions as in Figure 1.



(a) (b)

Fig. 1. (a) Billiards personnel symptoms, (b) Indoor air quality satisfaction

In a comprehensive study conducted in the billiards room, it was found that a significant number of 251 respondents experienced various adverse symptoms during their exercise sessions. Among these symptoms, fatigue emerged as the most prevalent one. This was a cause for concern as it indicated that something within the environment of the billiards room was affecting the well-being of the individuals using it.

Regarding the indoor air quality of the billiards room, a large proportion of 226 people expressed dissatisfaction. This dissatisfaction was a clear indication that the air within the room was not up to the expected standards. It strongly suggested that indoor air pollution was a real issue in this particular setting. The presence of such pollution was not only unpleasant but also had the potential to cause a more serious condition known as sick building syndrome. This syndrome is associated with a range of health problems that can occur when people are exposed to poor indoor air quality over an extended period.

To ensure the validity and reliability of the results, great care was taken in the methodology design of this study. The questionnaire used in the research was carefully crafted, taking into account the unique characteristics of the billiards room. It was designed to gather relevant and accurate information about the experiences and perceptions of the respondents. The sample size of 251 was determined based on a thorough analysis of the people flow in and out of the billiards room as well as its usage frequency. This approach ensured that the selected sample was representative of the overall population of users. Through the application of appropriate statistical analysis methods, the study was able to effectively reveal the relationship between the indoor air pollution and the physical symptoms reported by the respondents.

Given the significant impact that indoor air pollution in the billiards room has on people's health, it becomes crucial to consider renovating the billiards room. Renovation could involve measures such as improving the ventilation system to enhance air circulation and reduce the concentration of pollutants. It might also include the use of air purifiers to filter out harmful substances. Additionally, the choice of building materials and furnishings could be reevaluated to ensure that they do not contribute to air pollution. By taking these steps, the overall indoor air quality of the billiards room could be improved, thereby safeguarding the health and well-being of the users and creating a more comfortable and healthy environment for everyone who frequents the billiards room.

3 Simulation Analysis

3.1 Case Simulation

For this simulation, spring in Shenyang is selected, and 42 people on the court during the peak period from 18:30 to 20:00 are taken as the research object. For modeling convenience, the human body is set as a 1.75m×0.5m×0.3m cube, and a 5cm×5cm rectangle is set at 1.5m height of the human body as the mouth position. The billiards room is modeled via Space Claim.

The CO_2 in the billiards room mainly comes from the gas exhaled by people during exercise. To grasp the release amount of CO_2, this paper needs to calculate the amount generated when athletes breathe. The oxygen consumption and CO_2 emission during breathing mainly depend on the metabolic rate. Studies show that the relationship between an individual's CO_2 emission and metabolic rate is as follows.

$$V_{CO_2} = 0.04M \times A_D \tag{1}$$

In the formula: V_{CO_2}—CO_2 volume produced by human body per unit time in mL/s at 0°C and 101.325 kPa.

M—metabolic rate, W/m^2;

A_D—body surface area of human body, m^2

The experimental regression formula for personnel's metabolic rate is:

$$\mathrm{M} = \frac{21(0.23\mathrm{RQ}+0.77)\mathrm{V}_{\mathrm{O}_2}}{\mathrm{A}_\mathrm{D}} \tag{2}$$

In the formula: RQ—Respiratory quotient, the molar ratio of exhaled CO_2 to inhaled O_2 per unit time;

V_{O_2}—O2 volume consumed by human body per unit time in mL/s. Oxygen consumption at different activity levels.

Calculation of naked body surface area by D. DuBois in 1916. Formula as follows:

$$A_D = 0.202 m_b^{0.425} H^{0.725} \tag{3}$$

In the formula:H—The height of the person in question, m;

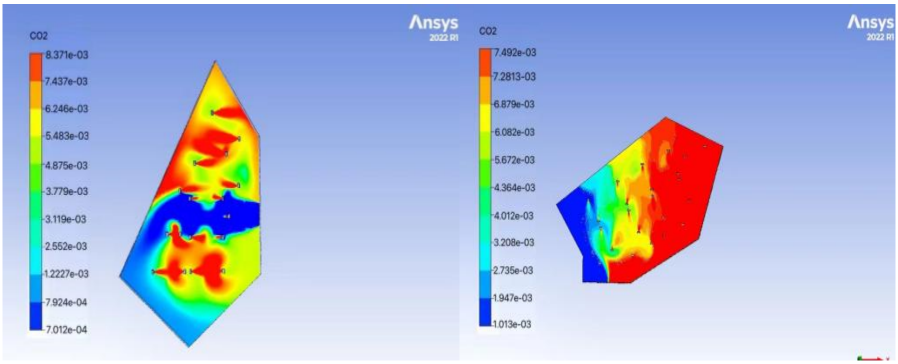
m_b—The weight of the person in question, kg.

According to the billiards room situation, set indoor personnel height as 1.75m and weight as 75kg. Formula (3) gives a body surface area of 1.88m². As they are in high-intensity exercise and analyzed by activity intensity and heart rate, they are in moderate labor. Take oxygen consumption as 16ml/s and respiratory quotient as 1.0. Formula (2) shows a metabolic rate of 201.06W/m². Formula (1) gives a CO_2 release rate of 15.12mL/s.

At 25°C and 1.01×105Pa, with a molar volume of 24.5L/mol and a molar mass of CO_2 of 44g/mol, the rate of CO_2 release per person is 0.3×10^{-4}kg/s.

Finally, using CFD-POST, establish a Z = 1.5m plane as breathing height and obtain the CO_2 concentration distribution nephogram as in Figure 2.

The simulation results show natural ventilation at the entrance door dilutes indoor CO_2 concentration. But no window ventilation leads to CO_2 accumulation and poor release, showing a trend of increasing CO_2 concentration from the doorway to the interior. On the Z = 1.5m plane from 18:30 to 20:00, the average mass fraction of indoor CO_2 in the staff area is 6.78×10^{-3} (4101ppm), and in the student area is 7.09×10^{-3} (4289ppm), almost three times the specified range, indicating extremely serious pollution in the billiards hall.

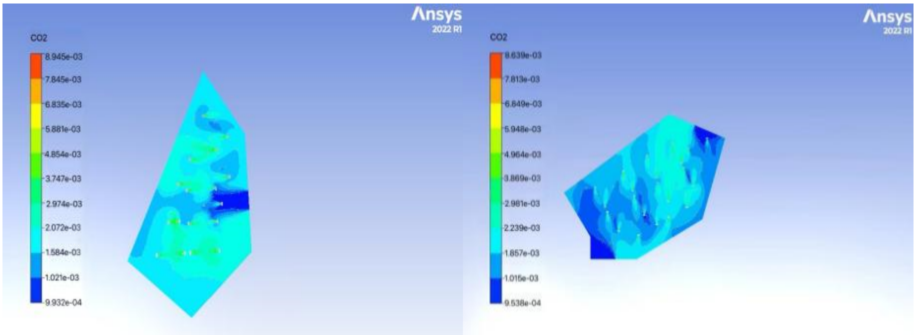


(a) (b)

Fig. 2. (a) Staff area CO_2 concentration nephogram. (b) Student area CO_2 concentration nephogram.

3.2 Transformation Simulation

The billiards hall simulation shows lower CO2 concentration at well-ventilated entrance. A renovation plan is proposed. Shenyang's spring average wind speed allows natural ventilation. Adding a fresh air system in transition season increases energy consumption. So, a 2.1m×1.8m window is added as air inlet on south wall of student area, and 3 (0.5m diameter) wind caps are added to student area roof and 2 to staff area roof. FLUENT software is used to simulate CO2 concentration distribution nephogram from 18:30 to 20:00 as in Figure 3.



(a) (b)

Fig. 3. (a) Staff area CO_2 concentration nephogram. (b) Student area CO_2 concentration nephogram.

The simulation results show that from 18:30 to 20:00 on the Z = 1.5m plane, the average mass fraction of CO_2 in the staff area is 2.41×10^{-3} (1458ppm), and in the student area is 2.46×10^{-3} (1488ppm), significantly lower than before renovation. It shows that good indoor air circulation can dilute indoor CO_2 concentration and meet the specification standards.

4 Conclusion

The comprehensive questionnaire survey, which encompassed various aspects such as comfort, ventilation perception, and overall user experience, clearly demonstrates a multitude of problems plaguing the billiards room. It reveals not only issues related to the physical environment but also potential concerns regarding the well-being of those who frequent the space.

FLUENT software simulation, a highly accurate and reliable tool in analyzing indoor air quality, has unearthed a significant issue of high CO2 concentrations in both the staff and student areas during peak hours. These concentrations have been found to soar far above the established safety and quality standards, posing a serious threat to the health and productivity of the occupants.

Following the implementation of a meticulously designed renovation plan, which incorporated advanced ventilation technologies, optimized space utilization, and enhanced air filtration systems, a subsequent FLUENT simulation was conducted. The results were highly encouraging, as the CO2 concentrations had dropped substantially and now meet the stringent air quality requirements during the transitional season. This achievement not only ensures a healthier environment but also serves as a practical guide for school gymnasium managers in their renovation endeavors.

This particular study, while valuable in highlighting the CO2 concentration issue and its resolution, has admittedly focused mainly on this single aspect. Other crucial factors like volatile organic compounds, which can emanate from furniture, paints, and cleaning agents, and particulate matter, which may be introduced from outdoor sources or internal activities, have not been deeply analyzed. These elements can have a profound and complex impact on the overall air quality and the well-being of individuals.

Looking ahead, future research and improvement efforts will involve considering multiple air quality indicators simultaneously. This will entail conducting comprehensive multi-parameter monitoring and evaluation, which will provide a more accurate and holistic understanding of the indoor air quality dynamics. By doing so, a solid basis can be established for formulating more comprehensive and effective air quality improvement strategies that address all aspects of a healthy indoor environment.

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