Contribution ID: **32** Type: **Oral presentation**

Carbon Dioxide Measurements at Multiple Points in an Elementary School Classroom And Risk Estimation of Airborne Transmission: A Two-Month Field Campaign

Wednesday, May 7, 2025 11:15 AM (15 minutes)

Introduction:
The concentration of carbon dioxide (CO2) is commonly used as a proxy for indoor air quality, particularly for assessing ventilation in indoor environments and estimating the risk of airborne transmission. Ventilation rates are commonly estimated using the mass balance equation under the assumption of a well-mixed environment. To estimate transmission risk, the Wells-Riley models are frequently employed as a balance between accuracy and computational efficiency. These models account for the estimated ventilation rate or utilize the rebreathing fraction of air, which is derived from CO2 concentration (Rudnick & Milton, 2003). However, in most cases, a single CO2 measurement point is used for both purposes.

Motivated by the COVID-19 pandemic, recent studies have explored the use of multiple measurement points in school classrooms, although these efforts have typically been limited to periods shorter than a week.

Aim:
The objective of this study is to evaluate, over a relatively long measurement campaign, the spatial variability of CO2 concentration within a naturally ventilated elementary school classroom and assess their impact on estimating the risk of airborne transmission.

Methodology:
The study was conducted in a naturally ventilated classroom in Montevideo, Uruguay, measuring 8 m × 6 m × 3.5 m (length × width × height). The classroom features four windows on one wall, a door, and an upper window on the opposite wall. It operates in two shifts: a morning session (8:00 a.m. –12:00 p.m. with a 30-minute break at 10:00 a.m.) and an afternoon session (1:00 p.m. –5:00 p.m. with a 30-minute break at 3:00 p.m.), hosting fifth-grade students aged 10–11 years (25 students in the morning, 30 in the afternoon).
Over two months, 13 monitoring devices were deployed in the classroom. Four devices were installed on each of the side walls at two different heights (1 m and 2.2 m), one on the front wall at a height of 2 m, one on the back wall at a height of 2.2 m, and three along the classroom axis at a height of 2.4 m. Each device recorded data every 30 seconds, measuring CO2 concentration using an NDIR sensor (Senseair Sunrise 006-0-0008), air temperature, and relative humidity (Sensirion SHT40-AD1B-R2).
The differences in CO2 concentration, based on daily averages for each occupancy period, were analyzed. Additionally, the daily risk of airborne transmission, estimated from the rebreathed fraction of air measured by each device, was evaluated for different quanta emission rates, ranging from 1 quanta/h to 100 quanta/h.

Results:
When comparing the daily averages of each device, there is greater variability in the morning shift than in the afternoon shift. In contrast, the minimum and maximum daily CO2 concentrations are similar for both shifts. The ratio between the maximum and minimum daily averages across the different devices ranges from 1.05 to 1.47. The minimum daily average is most frequently measured by one of the devices installed on the side wall with windows (100% and 89% of the days for the morning and afternoon shifts, respectively), as expected. Meanwhile, the maximum daily average is typically recorded by the devices installed at higher positions, particularly those along the classroom axis (60% of the days).
Regarding the risk of airborne transmission, the variation in estimated risk across devices for each day is

greater than the variation in daily average CO2 concentration. The ratio of the minimum to maximum estimated risk can reach as high as 2.7. Interestingly, this difference in estimated risk is not observed on the day with the largest variation in daily average CO2 concentration across devices; instead, it occurs on the day with the lowest average CO2 concentration. This is consistent with the model equation, which shows that for the same ratio of mean CO2 concentrations measured by two sensors, the corresponding ratio of estimated risks is larger at lower CO2 concentrations.

Conclusions:
A two-month measurement campaign was conducted in an elementary school classroom, recording CO2 concentration, air temperature, and relative humidity at 13 points. The daily average CO2 concentration during occupied hours was analyzed, and its spatial and temporal distribution was evaluated. The estimated risk of airborne transmission and its variability across devices were assessed. The results show that daily CO2 averages can differ by up to 47%, while the estimated risk can vary by as much as 170%. The variation in risk across devices depends on the CO2 concentration, decreasing as the concentration increases. Consequently the influence of the measurement point on the estimated risk decreases with higher CO2 concentrations. Additionally, the observed variability is relatively low compared to the uncertainty associated with other factors, like quanta emission rate.

Primary author: Dr MENDINA, Mariana (Instituto de Mecánica de los Fluidos e Ingeniería Ambiental, Facultad de Ingeniería, Universidad de la República, Uruguay.)

Co-authors: Dr OLIVER, Juan Pablo (Instituto de Ingeniería Eléctrica, Facultad de Ingeniería, Universidad de la República, Uruguay.); AZZIZ, Julia (Instituto de Ingeniería Eléctrica, Facultad de Ingeniería, Universidad de la República, Uruguay.); DÍAZ, Leandro (Instituto de Ingeniería Eléctrica, Facultad de Ingeniería, Universidad de la República, Uruguay.); Dr PARDO, Lorena (Instituto de Higiene, Universidad de la República, Uruguay.); Dr DRAPER, Martin (Instituto de Mecánica de los Fluidos e Ingeniería Ambiental, Facultad de Ingeniería, Universidad de la República, Uruguay.)

Presenter: Dr MENDINA, Mariana (Instituto de Mecánica de los Fluidos e Ingeniería Ambiental, Facultad de Ingeniería, Universidad de la República, Uruguay.)

Session Classification: SESSION 3b - Mitigation Measures and Strategies: Exploring environmentally sustainable solutions such as indoor ventilation and beyond, Oral Presentations