Room-level Ventilation in Schools and Universities

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Supporting Information

Mountain West University

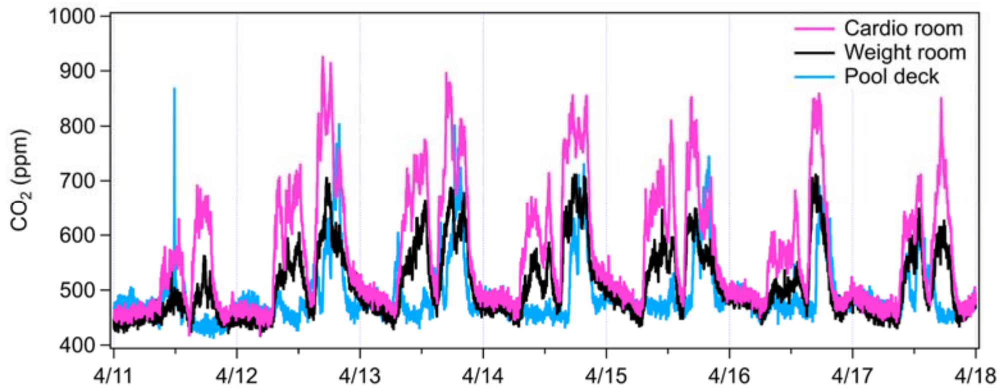

Figure S1: CO_2 concentrations for a one-week period in three areas of the Mountain West University campus gym.

Figure S1 shows the time series of CO_2 concentration in three areas of the campus gym. The average concentrations match observations shown in Figure 12a. Having access to CO_2 information at high resolution, especially if in real-time, however, shows trends in usage that are not observable from broader averages. Figure S1 shows a very repeatable daily cycle matching differences in room usage. The cardio and weight rooms are used more heavily, with daily peaks in the late morning and early evening. A drop in CO_2 concentrations can be seen at 1:00 PM when the gym closes for an hour. Having access to passive CO_2 data like this can be an efficient, non-invasive way not only to record gym usage, but to verify that occupancy is well-matched to HVAC strategies. In this example, the data shows that concentrations rarely exceed 800 ppm in the cardio room, and never significantly above 700 ppm in either the weight room or on the pool deck. These results suggest a ventilation strategy generally well-matched to the usage of rooms.

Simultaneous passive CO_2 and PM_1 monitoring results from one private music practice room are shown in Figure S2. As described in the main text, the correlation between PM and CO_2 in this space was poor.

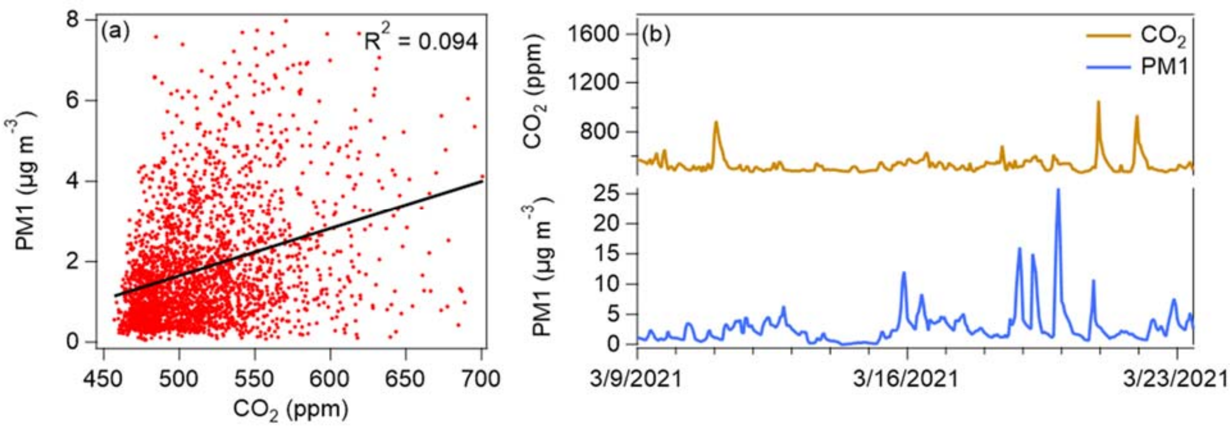

Figure S2: Comparison of PM1 and CO_2 concentrations in a private music practice room of the Mountain West University. Data shown as 1-hour averages from November 1 - April 23. Time series (b) shown for a 2-week period as an example of lack of correlation.

North East University B

The testing space was ~600 ft^2 with an 11-foot ceiling (6,600 ft^3). The room had single pane glass windows on both long walls of the room and furnishings included wood tables, lamps, and chairs. The room had no mechanical ventilation but had a passive air transfer grille and wall radiators with recirculating blowers below the window bays. Significant efforts were taken to create as clean, enclosed, and air-tight a space as possible to minimize influences from air infiltration/exfiltration and resuspension of dust from books, furnishings, and flooring.

The AFVU unit consisted of flexible supply and exhaust ductwork, an energy recovery element, main blower fan, MERV 14-rated filter, and a ducted supply air register (Figure S3). The device was operated as an air handling unit, delivering air to the space and exhausting a portion of room air back outdoors. As configured for testing, the AFVU provided 125 CFM of outdoor air and 645 to 670 CFM of total supply air, comparable to or higher than applicable ASHRAE ventilation standards (ASHRAE 2019) and typical of mechanical ventilation systems on campus. This unit was placed in the corner of the test space with an elevated discharge (8 ft above the floor) through an upward angled grille – this configuration was demonstrated to be optimal for PM removal efficiency based on testing in the library space (data not shown). The AFVU was purposefully designed to operate on standard 120 V power for widespread deployment, with a fan motor rheostat to provide a range of total delivered airflows. Since the AFVU operates at equal volumetric airflows of outdoor supply and exhaust air, its deployment was not expected to impact room pressurization.

To simulate continuous PM generation as would occur in an occupied classroom, two new candles were placed on a table in the center of the room and were burned for 15 minutes. PM number concentration was measured at the four sampling locations (S1-S4, Figure S4). This test was performed twice; once while operating only the AFVU and again with only the HEPA recirculating air cleaner operated at 320 CFM. The variation in PM levels across the test space are shown in Figure S4. The AFVU and commercial cleaners produced noticeably different results with continuously burning candles. With the AFVU running, PM concentrations reached a maximum of ~30,000 particles/cm^3, then decreased by about 33% in 15 minutes. When the AFVU was turned off, PM concentrations increased at all sampling locations while the candles were burned. In contrast, when the commercial air cleaner was running, PM levels remained high at two of the four sampling locations (S1 and S3).

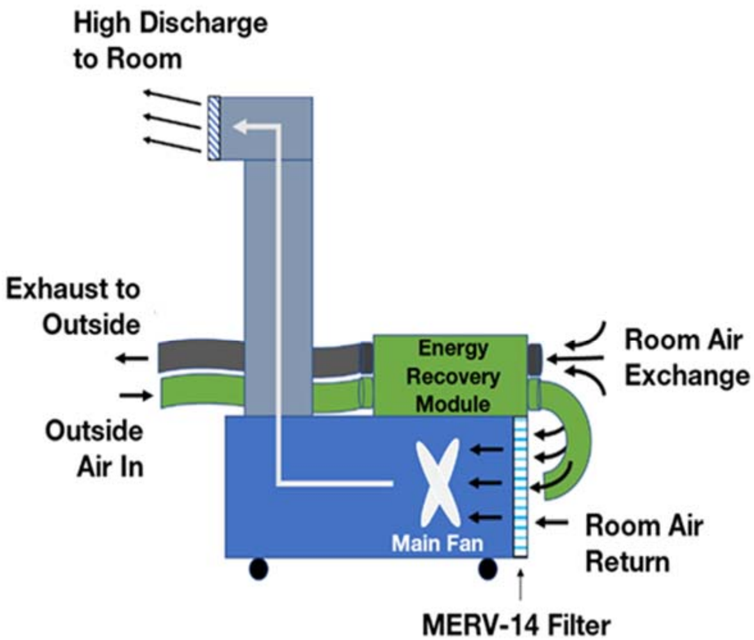

Figure S3. Schematic diagram of the air filtration ventilation unit designed for use in naturally ventilated spaces for North East University B.

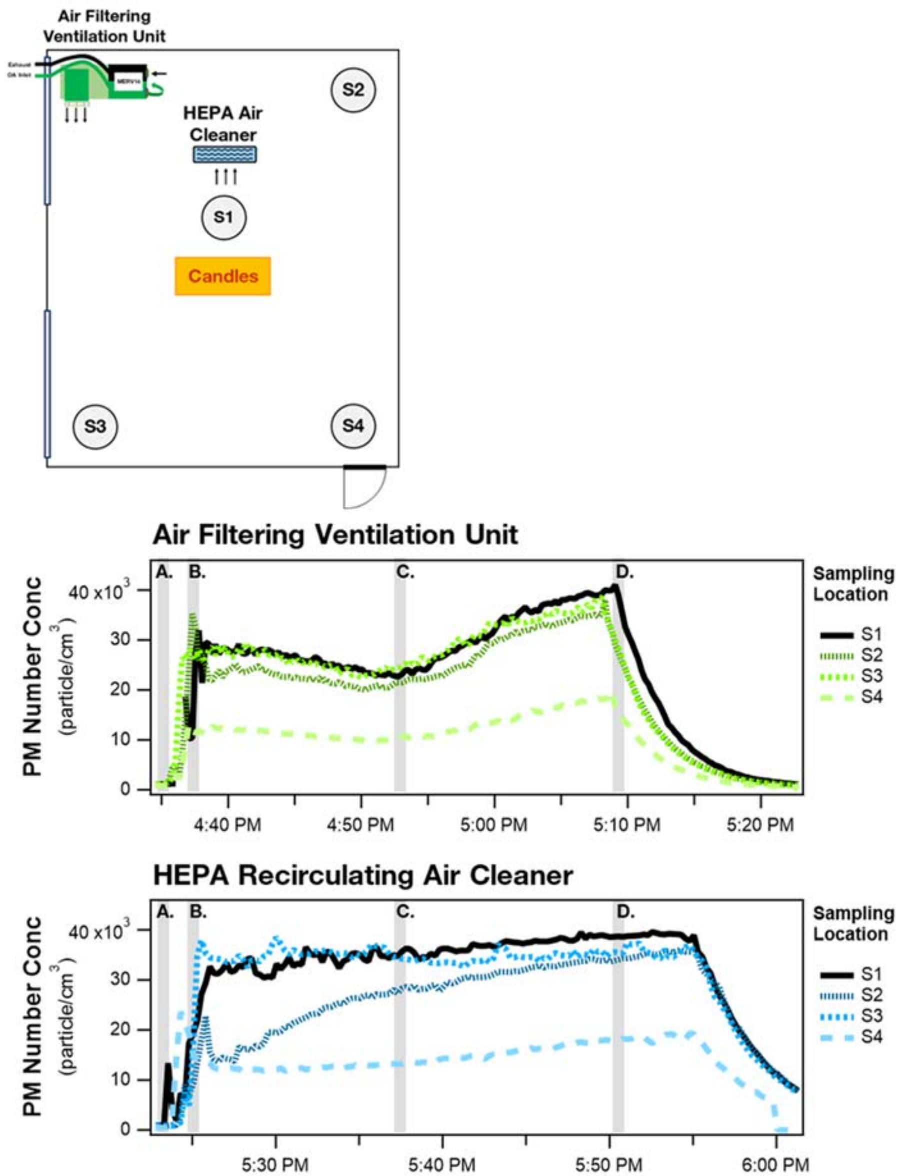

Figure S4. Evaluation of the spatial distribution of PM in a naturally ventilated library test space in North East University B using different filtration/ventilation approaches. *Top*: The plan view indicates the location of candles used for continuous PM generation, the PM sampling locations (S1-S4), and the two supplemental filtration/ventilation devices that were individually evaluated: an air filtering ventilation unit and a commercially available air cleaner. *Bottom*: PM number concentration measured at the four sampling locations across the test space for each filtration/ventilation approach. Time point A indicates when candle burning was started, time point B shows when the AFVU or HEPA-recirculating air cleaner was turned on, time C notes the time when these devices were turned off, and time D indicates the time candles were extinguished and the recirculating HEPA-filtered blowers started operation.

References

ASHRAE Standing Standard Project Committee 62.1, ANSI/ASHRAE Standard 62.1-2019, Ventilation for Acceptable Indoor Air Quality (2019)