Study of CO_2 Concentration in the Livermore Public Library : An Evaluation of Ventilation During the COVID-19 Pandemic

Nikhila Juluri and Eileen Seetho

August 29, 2021

Abstract

In this study we used a CO_2 monitor to measure the CO_2 concentration in different sections of the Livermore Public Library to determine the effectiveness of the HVAC system in removing human exhalation products. The data generated was analyzed using Grafana which we used to create graphs of the CO_2 concentration as a function of time in two open areas: the children and adult sections. From these graphs we found that the change in CO_2 concentration was about 50-70 ppm (parts per million) throughout the day driven by occupancy levels. Overall, the library is doing well at keeping the CO_2 concentration below 600 ppm indicating that the ventilation system is doing an excellent job reducing the risk of COVID-19 transmission.

Introduction

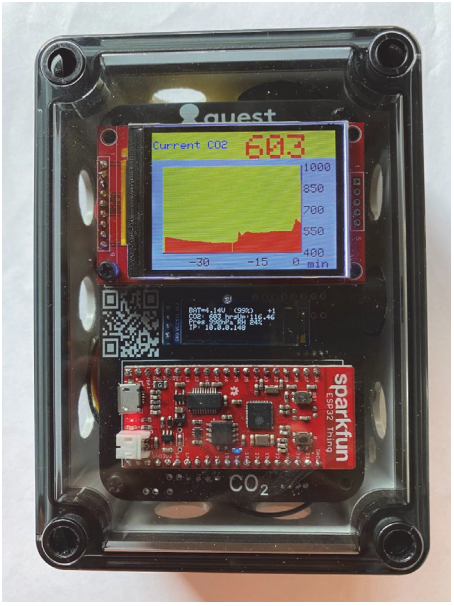
Studying CO_2 levels can not only inform whether or not buildings have good HVAC (ventilation) systems that are functioning properly, but can also further help advance knowledge on how to better protect ourselves from airborne viruses. Various studies have been conducted on how viral outbreaks can be prevented and what are considered to be thresholds for which the chances of infection of COVID-19 begin to rise (Miller, 2020; Allen et al., 2020; Du et al., 2019). These studies share the similar conclusion that better ventilation helps to reduce infection rate for airborne diseases. A sensor, designed and built by Quest Science Center, measures the concentration of carbon dioxide gas (CO_2) in the air around us for students to study and improve indoor ventilation, ultimately reducing the spread of infectious airborne disease such as COVID-19. The device shows the current value along with a graph of this data over the previous 30 minutes.

COVID-19 is proven to spread through inhalation of airborne particles, or aerosols, generated by an infected person. These tiny aerosols are produced through normal talking, coughing, or sneezing. They are too small to see with the human eye and due to their small mass, they remain floating in the air where they can be inhaled by others thereby transmitting disease. In addition to aerosols, with each breath humans exhale about 40,000 ppm of CO_2, a normal product of human metabolism. With no or poor ventilation both indoor CO_2 and aerosol concentrations will steadily increase together with time at rates that depend on the number of people present and their activity level. While we can’t measure infected aerosol concentrations directly, we can easily measure the CO_2 which then becomes an indicator for potentially unsafe indoor air conditions (if an infected person has recently been present).

Buildings with good ventilation constantly replace stale indoor air with fresh air from the outside, reducing both CO_2 and suspended aerosols to create more healthy spaces in the process. Research shows that keeping indoor CO_2 levels below approximately 800 ppm significantly lowers the risk of airborne disease transmission. In low ventilation conditions, crowded indoor areas can reach CO_2 levels of 3000 ppm or more, becoming dangerous places to be in a pandemic. By comparison, in an outdoor urban setting, background atmospheric CO_2 is typically between 400-500 ppm. In simpler words, the more we can make the indoors look like outdoors, the safer we will be. This research project measures human generated CO_2 levels to determine whether different sections of the Livermore Public Library -which possesses a relatively new HVAC system fall under safe levels regarding the risks of contracting COVID-19.

Methods

To determine CO_2 emissions, a CO_2 reading sensor (Figure 1) was placed in two different locations to be left undisturbed in the Livermore Public Library: the children and adult sections. The data that was collected by the sensor, in ppm, was sent directly to a Quest Science Center database hosted by Amazon Web Services and then to Grafana -an observatory platform- where the data could be displayed, analyzed, and eventually discussed. The sensor remained in full operation both in the childrens' section from June 21, 2021, to July 20, 2021, and in the adult's section from July 21, 2021, to August 6, 2021. Both of these locations were in open areas where other factors could not influence the data such as placing the CO_2 reading sensor near tables, doors, or check-out computers where there are more people present and thus CO_2 would be more concentrated throughout the day.



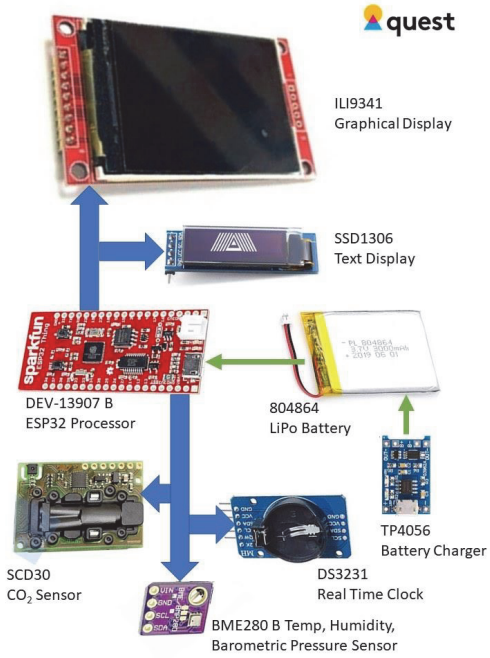


Figure 1: Top An assembled CO_2 monitor. *Bottom* -The inner components of the CO_2 monitor designed and developed by the Quest Science Center in Livermore. Green lines show the battery flow. The blue lines show the interconnectivity of the information flow from and to the information center. The main component is the red processor which is a microcomputer that sends out directions to the other components of the device as well as sends the data to Amazon Web Services through a wifi connection.

Results

This section contains typical readings from the CO_2 sensor placed in the library which is open Monday through Thursday from 10:00 am until 9:00 pm, Friday 10:00 am until 6:00 pm, and Saturday from 10:00 am until 5:00 pm.

Children's Section of Library: 7/15/2021

Figure 2: For this day, the readings show that the highest peak of CO_2 concentration was in the morning. The change in CO_2 concentration was up to 70 ppm above background levels.

Children's Section of Library: 7/14/2021 - 7/19/2021

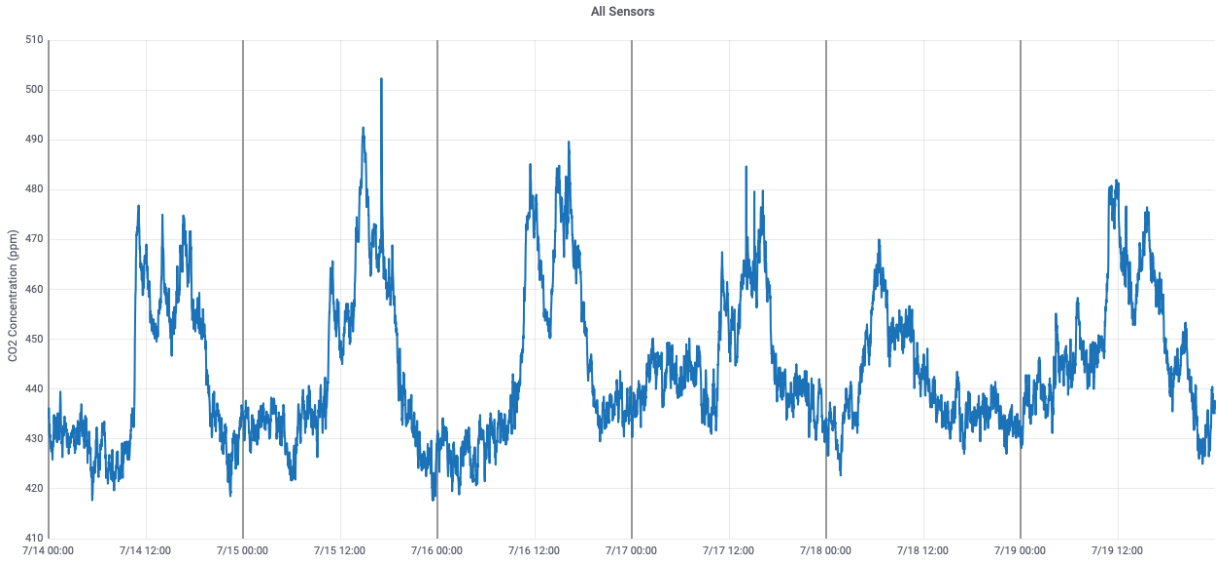


Figure 3: In general, the CO_2 readings seem to follow a pattern where the highest concentrations are in the middle of the day. On certain days, such as 7/15/2021, there are somewhat higher concentrations of CO_2 compared to the other days (indicating more people were likely present). The gray vertical lines represent midnight.

The CO_2 sensor was moved from the childrens' section to the adult section on 7/21/21.

Adult Section of Library: 7/26/2021

Figure 4: These readings show that the highest level of CO_2 concentration was between 10:00 am to 6:00 pm. The change in CO_2 concentration was about 60 ppm above background.

Adult Section of Library: 7/21/2021 - 7/27/2021

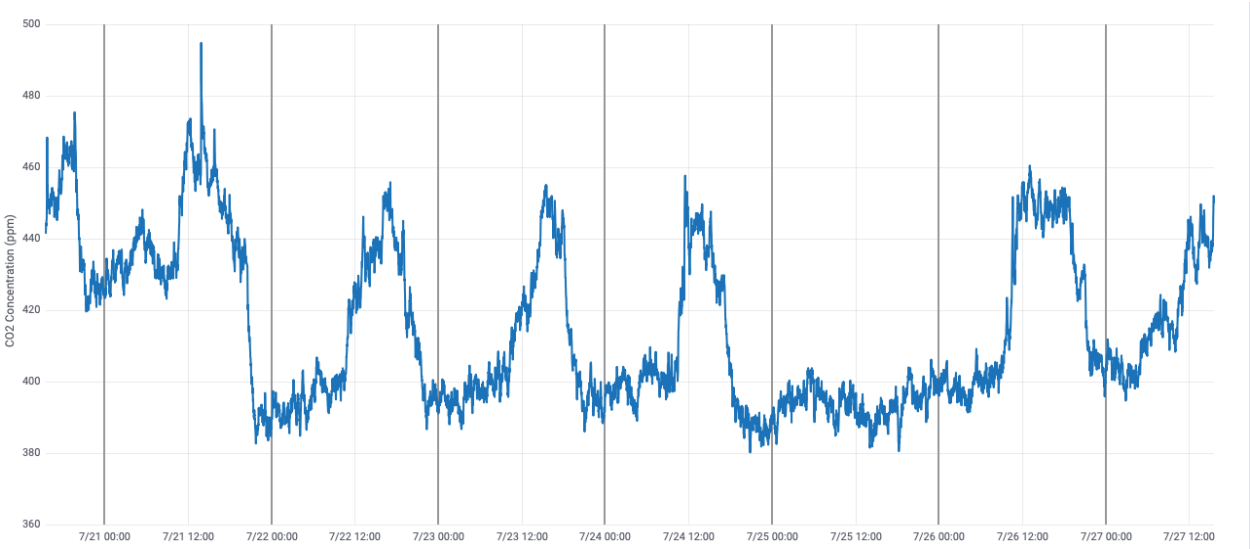


Figure 5: The CO_2 readings in the adult section also follow a daily pattern. Notice that July 25 is a Sunday when the Library is closed.

Discussion

By doing this experiment, we were able to see how the HVAC system was performing in the Livermore Library while people were present during normal operation. CO_2 could be used as a measure to assess the risk of spread because it reflects the HVAC's ability to clear out the indoor air during the day. From the data that was generated using the CO_2 sensors (Figures 2-5), we found that the CO_2 readings were always below 500 ppm in both the children and adult sections of the library. We also noticed that there was a general pattern in each of these sections.

The children's section of the library produced the greatest amount of CO_2 in the middle of the day. On average, there were about 20 people in this section at a time. The general background value of CO_2 concentration was about 430 - 440 ppm in this section. The data from Figure 2 shows that on this particular day the peak in the data of 510 ppm was at about 11 am. The change in CO_2 concentration due to the people present was up to 70 ppm. This pattern was followed throughout the week as can be seen in Figure 3. The results can be used to show the busiest time for each day when there are a larger amount of children/adults present. Since the library is closed on Sundays, the CO_2 readings from July 18th, 2021, are a bit lower which was anticipated because there were no children present in the library.

The CO_2 monitor was moved to the adult section of the library in the middle of July 21st, 2021. The observed background CO_2 concentration appears to be around 390-400 ppm, slightly lower than the values seen in the children's section. The adult's section also had high CO_2 readings in the afternoon, except their high CO_2 readings were more spread out compared to the ones from the children's section. This tells us that there are more occupants in the adults section

evenly throughout the day, whereas there are mostly occupants present in the children's section during the afternoon. The change in delta was about 60 ppm. It can be seen from Figure 5 that the adult's section always had a concentration of CO_2 below 460 ppm, which is only slightly lower than the 500 ppm maximum CO_2 concentration found in the children's section. This could be because there were fewer adults at a given time compared to the number of children present. This data also followed a similar pattern with lower CO_2 readings in the morning but higher readings throughout the afternoon and early evenings. Once again, the CO_2 readings are very low on July 25th, 2021, because the library is closed on Sundays and there are no people present.

So far, a Quest sensor has been used in a hospital, an elementary school, a dentist office, a hearing aid office, a hair salon, and a physical therapist's office. Of these locations, the library appears to be among the best.

While this experiment was done to measure the CO_2 concentration in the library, the sensor was only placed in the two major areas. The results might have been different if it was located in smaller rooms. In addition, the library was not at full capacity during the tests due to COVID-19 safety protocols. Our results are also not indicative for the rest of the year as these tests were run during the summer. However, the results that were generated show that the ventilation system is working very well. It would be interesting to repeat this survey when the occupancy of the library increases to see if it stays below the 600ppm level.

Conclusion

Through the utilization of a CO_2 sensor, this study shows that under current conditions the ventilation in the Livermore PublicLibrary is excellent. Different sections of the library have similar patterns of increasing and decreasing CO_2 emissions during the day driven by the number

of people present in each area. It does appear that the children's area may be slightly higher than the adult's area (because of higher occupancy) but both fall well within the healthy range of CO_2 below 800 ppm. The data was collected within a limited timespan of a little less than two months. It would be useful to monitor the space year round to ensure that the ventilation can handle increased occupancy in the different seasons and in areas that we did not sample (offices, conference rooms, cafe. etc).

In our future work we hope to begin using CO_2 monitors in other locations such as schools to discover other variables that can affect CO_2 concentrations.

Authors

Eileen Seetho

Eileen Seetho is a 12th grader who attends Granada High School in Livermore, California. She is taking a variety of advanced science classes and hopes to continue to deepen her knowledge on the subject in college.

Nikhila Juluri

Nikhila Juluri is a 12th grade student at Dublin High School in Dublin, California. She is a passionate student interested in the sciences and explores these interests through her science courses. Nikhila hopes to continue studying medicine in her future studies.

Acknowledgements

We would like to acknowledge the Livermore Public Library, Nathan Brumley, Rick Stulen, Dennis O'Brien, and Donald Sweeney for helping us succeed in creating this report. This would have not been possible without Nathan Brumley's interest and consent for allowing these measurements to be made and Quest Science Center's guidance and making the CO_2 monitors available.

Bibliography

Allen, J., Spengler, J., Jones, E., & Cedeno-Laurent, J. (2020, August). 5-step guide to checking ventilation rates in classrooms. http://schools.forhealth.org/wp-content/uploads/sites/19/2020/08/Harvard-Healthy-Buildings-program-How-to-assess-classroom-ventilation-08-28-2020.pdf.

Bowers, E. (2021, May 11). *CO2 concentration AND COVID-19*. YouTube. https://www.youtube.com/watch?v=i-dHCRbu0Ow.

Du, C.-R., Wang, S.-C., Yu, M.-C., Chiu, T.-F., Wang, J.-Y., Chuang, P.-C., Jou, R., Chan, P.-C., & Fang, C.-T. (2020, May). *Effect of ventilation improvement during a tuberculosis outbreak in underventilated university buildings*. Indoor air. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7217216/.

"How Coronavirus Spreads." *Centers for Disease Control and Prevention,* Centers for Disease Control and Prevention, 28 Oct.2020, www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html.

Issarow, Chacha M., et.al. "Modelling the Risk of Airborne Infectious Diseases Using Exhaled Air." *Journal of Theoretical Biology*, vol. 372, 2015, pp. 100-116., https://royalsocietypublishing.org/doi/pdf/10.1098/rsos.170726

Kenarkoohi, Azra, et al. "Hospital Indoor Air Quality Monitoring for the Detection of SARS-CoV-2 (COVID-19) Virus." *Science of the Total Environment*, vol. 748, 2020, p.141324., https://pubmed.ncbi.nlm.nih.gov/32805566/

Miller, Shelly. "How to Use Ventilation and Air Filtration to Prevent the Spread of Coronavirus Indoors." *The Conversation,* 22 Feb. 2021, https://theconversation.com/how-to-use-ventilation-and-air-filtration-to-prevent-the-spread-of-coronavirus-indoors-143732

Mooney, Chris. "The Coronavirus Is Airborne. Here's How to Know If You're Breathing Other People's Breath." *The Washington Post,* WP Company, 11 Feb. 2021, www.washingtonpost.com/health/2021/02/10/carbon-dioxide-device-coronavirus/.

Peng, Zhe, and Jose L. Jimenez. "Exhaled CO2 as COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities." *MedRxiv,* 10 Sept. 2020, doi:10.1101/2020.09.09.20191676.

Rudnick, S. N., and D. K. Milton. "Risk of Indoor Airborne Infection Transmission Estimated from Carbon Dioxide Concentration." *Indoor Air,* vol. 13, no. 3, 2003, pp. 237-245., https://pubs.acs.org/doi/10.1021/acs.estlett.1c00183.

Seppänen, O. A., Fisk, W. J., & Mendell, M. J. (1999). Association of ventilation rates and CO2 concentrations with health and other responses in commercial and institutional buildings. *Indoor air*, *9*(4), 226–252. https://doi.org/10.1111/j.1600-0668.1999.00003.x

US Department of Commerce, NOAA. "Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases." NOAA GML CO2 *Trends RSS*, 1 Oct. 2005, www.esrl.noaa.gov/gmd/ccgg/trends/monthly.html.