Study of CO₂ Concentration in the Livermore Public Library: An Evaluation of Ventilation During the COVID-19 Pandemic

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Abstract

In this study we used a CO₂ monitor to measure the CO₂ 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 CO₂ concentration as a function of time in two open areas: the children and adult sections. From these graphs we found that the change in CO₂ 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 CO₂ concentration below 600 ppm indicating that the ventilation system is doing an excellent job reducing the risk of COVID-19 transmission.
Introduction

Studying CO₂ 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 (CO₂) 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 CO₂, a normal product of human metabolism. With no or poor ventilation both indoor CO₂ 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 CO₂ 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 CO₂ and suspended aerosols to create more healthy spaces in the process. Research shows that keeping indoor CO₂ levels below approximately 800 ppm significantly lowers the risk of airborne disease transmission. In low ventilation conditions, crowded indoor areas can reach CO₂ levels of 3000 ppm or more, becoming dangerous places to be in a pandemic. By comparison, in an outdoor urban setting, background atmospheric CO₂ 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 CO₂ 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 CO₂ emissions, a CO₂ 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 CO₂ reading sensor near tables, doors, or check-out computers where there are more people present and thus CO₂ would be more concentrated throughout the day.
Figure 1: Top An assembled CO₂ monitor. Bottom - The inner components of the CO₂ 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 CO₂ 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 CO₂ concentration was in the morning. The change in CO₂ concentration was up to 70 ppm above background levels.
Figure 3: In general, the CO₂ 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 CO₂ compared to the other days (indicating more people were likely present). The gray vertical lines represent midnight.

The CO₂ sensor was moved from the childrens’ section to the adult section on 7/21/21.
Figure 4: These readings show that the highest level of CO₂ concentration was between 10:00 am to 6:00 pm. The change in CO₂ concentration was about 60 ppm above background.

Figure 5: The CO₂ 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. CO₂ 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 CO₂ sensors (Figures 2-5), we found that the CO₂ 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 CO₂ in the middle of the day. On average, there were about 20 people in this section at a time. The general background value of CO₂ 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 CO₂ 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 CO₂ readings from July 18th, 2021, are a bit lower which was anticipated because there were no children present in the library.

The CO₂ monitor was moved to the adult section of the library in the middle of July 21st, 2021. The observed background CO₂ 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 CO₂ readings in the afternoon, except their high CO₂ 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 CO₂ below 460 ppm, which is only slightly lower than the 500 ppm maximum CO₂ 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 CO₂ readings in the morning but higher readings throughout the afternoon and early evenings. Once again, the CO₂ 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 CO₂ 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 600 ppm level.

**Conclusion**

Through the utilization of a CO₂ sensor, this study shows that under current conditions the ventilation in the Livermore Public Library is excellent. Different sections of the library have similar patterns of increasing and decreasing CO₂ 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 CO₂
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 CO₂ monitors in other locations such as
schools to discover other variables that can affect CO₂ concentrations.

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