

**A study of the location of CO₂ generated sources and their effect on ambient CO₂
levels around and in schools in South Florida**

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Abstract

In a quantitative study of CO₂ levels in Broward County, it was determined that the effects of CO₂ generation from vehicle exhaust from major roadways did not significantly affect the ambient CO₂ levels around various schools.

Introduction

The objective of this study was to determine the influence of major roadways (i.e. interstates) as sources of CO₂ and their effects on outside CO₂ levels; and the effect on indoor air via the ventilation system. This study is part of a larger study. The larger study is a mechanical assessment and indoor environmental quality study to evaluate the fresh air ventilation and determine if outside air flow quantities specified at original design are satisfactory to meet ASHRAE Standard 62-2004. CO₂ is colorless,

odorless, incombustible gas, formed during respiration, combustion, and organic decomposition and used in food refrigeration, carbonated beverages, inert atmospheres, fire extinguishers, and aerosols.(Dictionary,2007). CO₂ has been an important constituent (0.035%) of the global atmosphere since the formation of the atmosphere. CO₂ is not harmful to breathe; has been recognized has an indicator of air quality. CO₂ has been studied by the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) to determine the effects on people in class room settings. CO₂ is not harmful to people in this setting, but is used as a surrogate or indicator for odors and acceptable ventilation. Excessive CO₂ levels have been documented to create tiredness, and lack of attention in people. OSHA defines CO₂ permissible limits at 5000 ppm in an

occupied space. CO_2 has been recorded at atmospheric levels in the 300 ppm around 50 years ago on the Hawaiian chain in the Pacific Ocean and recently at 350 ppm at ambient levels in Barbados in the Atlantic Ocean. These locations are both places in the center of an ocean well away from very large metropolitan areas. The average level of ambient CO_2 is 400 ppm globally. Broward County's average level of ambient CO_2 was estimated at 435 ppm during this study.

Site

Figure 1 . A map of Broward County showing major road ways and the 8 schools in the study.



The pool of schools started with all of Broward County. Based on the age of the Air handler, 72 schools were chosen for re-design and repair/ replacement of their systems. Part of this evaluation used Telaire monitor and a HOBO data logger paired together (logger). The Telaire monitor recorded CO_2 measurements, while the HOBO data logger recorded temperature and relative humidity. Of these 72 schools 20 schools to date had outside air loggers placed on site while other loggers were placed in classrooms. Two of the loggers had data that was skewed by some direct source, such as someone breathing right on it or a car park running right next to it leaving 18 loggers. Eight loggers were chosen out of this pool of 18 because of proximity to I-95 or for their distance away from I-95(Figure 1). The two loggers away from I-95 are the control schools for this study.

Method

All loggers were calibrated by a bump test method prior to going out into the field, using a two point test (400ppm and 2000ppm). In the two point test we warmed up Telaire and filled a Tedlar bag with

gas of a known CO₂ level. Gas is applied to Telaire for 1 minute then 3 readings are record at 15 second increments. Telaire is rejected as out of calibration if reading on average is 5% out from the target concentration.

Figure 2. Logger used for this study



Data Collection

The CO₂ monitor used for the study was a Telaire 7001 attached to a HOBO, a data logger. The Telaire has a high range sensor drift of approximately 100 ppm and a low range of 50 ppm (Figure 2). Loggers placed in the classrooms were placed in locations that followed the ASHRAE standard of breathing zone (ASHRAE, 2004) (Figure 3). Outside loggers were placed in a location protected from the weather (rain) and in close proximity to a power source. Because of these two requirements

for the outside loggers an outside electrical room with louvered doors and an exhaust fan to allow air in was an ideal location for this experiment..

Loggers were set to sample every 6 minutes. CO₂, light, relative humidity, and temperatures were recorded. Telaire CO₂ monitors were plugged into an auxiliary power source (Figure 4), and the HOBO ran on battery power alone. The logger was set to record to catch five full school day of class and usually ran for seven days total. After pick up the HOBO and Telaire unit was brought back to the office where the data was downloaded and the results were exported into an excel spread sheet. The voltage measurements recorded by the HOBO logger were then converted to ppm. All Telaire meters were posts processed to record any sensor drift that had occurred in the field.

Figure 3. Logger is placed on the bookcase away from influences such as door, windows and AC supply.



Weather Data is archived for many years at multiple sites all over the country by NOAA and stored online and is available to the public via a subscription. This study utilized the directional wind records for Broward County against the exact time period that CO_2 was measured, and then compared them to an aerial map to identify the locations of major roadways in relation to the locations of the school where CO_2 was measured. For the purposes of this study, all logged data is compared to the weather data observed at Ft. Lauderdale International Airport. Data was obtained from the NOAA web site through a subscription purchased online via credit card. After logging in and selecting a station, the corresponding month and year could be chosen, downloaded, and viewed as a text document. This text document was then imported through excel. All wind direction was converted to wind heading using a “less than if then” formula, grouping numbers into categories of N, NE, E, SE, S, SW, W, NW. Groups were

constituted by 45 degree angles with 0 on center to start.

Discussion

The loggers recorded measurements every six minutes over the course of a week. Once data was post processed for the 8 schools in this study, a max range seen was 708 at 8ES and 493 at 2MS.

Minimum range seen was 337 7ES, 6MS and 425 at 4ES, 5ES, 8ES, 1ES. What this all comes down to is that the average CO_2 level at schools across Broward county is 435 ppm.

Most schools today are closed systems and are designed to have the windows and doors closed at all times. This is to have less infiltration of outside CO_2 because of tighter construction practices that reduce energy costs and limit hot humid air from entering the building humidity control. People generate CO_2 when they exhale, which allows CO_2 to accumulate within closed spaces. CO_2 can be reduced within an indoor setting through dilution ventilation. A classroom’s air is like a glass of salt water; if we add fresh water to the glass water spills out, and the water that is left has a lower

concentration of salt. The same is true with the classroom if we add fresh air to a room with high concentration of CO₂; the air will spill out and a lower concentration of CO₂ will be left in the room by means of dilution. The spilling out effect in this example is called positive pressure and prevents air from entering the room (infiltration) through other sources other than the air supply.

In this study classrooms come to or close to background levels when unoccupied and reach a peak ppm at or around the time of lunch dismissal or final dismissal. Then, a steady decay curve can be seen as the outdoor air supply dilutes the classroom air after the population has left the space.

Figure 4. Typical installation process of logger.



Abnormalities are seen in this curve when the people re-enter the room. In some schools a fluctuation could be seen after- hours, if the system shut down and wind gusts were sufficient enough to over power the building envelope. Most air handlers in this study cleared the CO₂ in the room within an 8 to 10 hour period. The rates at which an air handler can clear the CO₂ from a room heavily depend on the air it is using to dilute the room. If CO₂ levels are high in the outdoor air the unit may never clear the room and in some case add more CO₂ back at point.

Conclusion

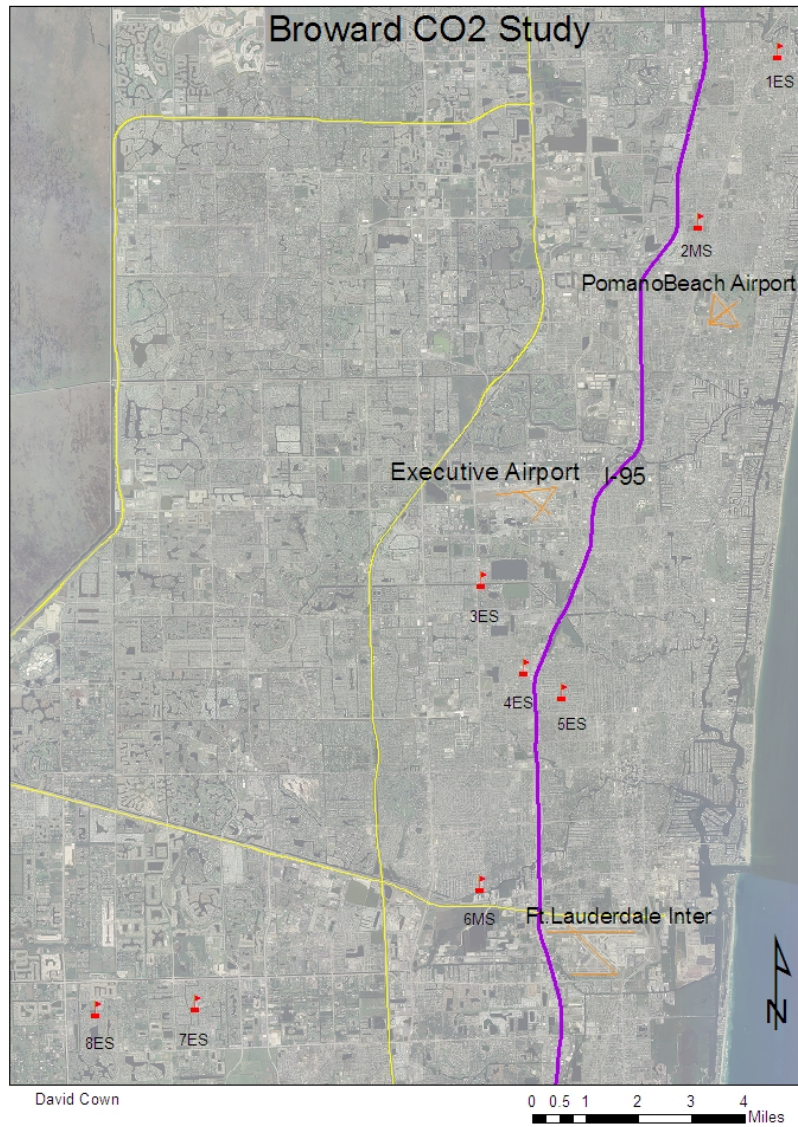
6 out of 8 schools in this study were all chosen for the relative proximity to I-95. The location to I-95 does not seem to affect the CO₂ level in these schools. School 8ES, located the farthest from all roads and the interstate, has a higher level than all the schools along I-95. The other control school named 7ES had the lowest CO₂ levels out of all the schools, which was not that much lower than school 6MS, which is located right near the apex of a major road and I-95. There is some data that shows

that in certain times of the day (drop off and pick up) numerous combustion engines in the bus loop for example can elevate the CO₂ levels within the school. None of the schools showed a trend that could be explained by wind blowing from the direction of a major roadway (I-95) to the schools where there was an elevated level of CO₂. If the road was a cause of elevated CO₂ levels in the schools, you would expect it to compound with wind velocity added. Though I-95 does not seem to be a cause of elevated CO₂ levels in schools, there is an interesting fact that

was found during research. There are four airports in Broward County, including one that is not visible on the map provided (Figure 5).

Spikes of CO₂ that were identified do seem to coincide with wind direction that is traveling from the direction of the airports to the school. Though this is an interesting idea, the effects of airports on outdoor air quality in schools, the resources are not available to me to pursue this. I do think this a notable finding and invite others to follow up on this lead.

Figure 5. Map showing relative location of airport to school.



Acknowledgement

I would like to thank
Dean Zehnter, Matt Divine, Paul Haas, and Mike Snyder; Morse Zehnter Associates.
Prof. Brett Strong, Prof. Donatto Surratt, and Prof. Jessica Miles; Palm Beach
Community College, Dan Cowan and Leo Capoferri

References:

Carbon dioxide. (n.d.). *The American Heritage® Dictionary of the English Language, Fourth Edition*. Retrieved April 25, 2007, from Answers.com Web site:
<http://www.answers.com/topic/carbon-dioxide>

ASHRAE. (2004) *Ventilation for Acceptable Indoor Air Quality 62.1-2004*, Atlanta, GA.