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Benchmarking School COVID-19 Risk through Differential Carbon Dioxide (dCO_2)

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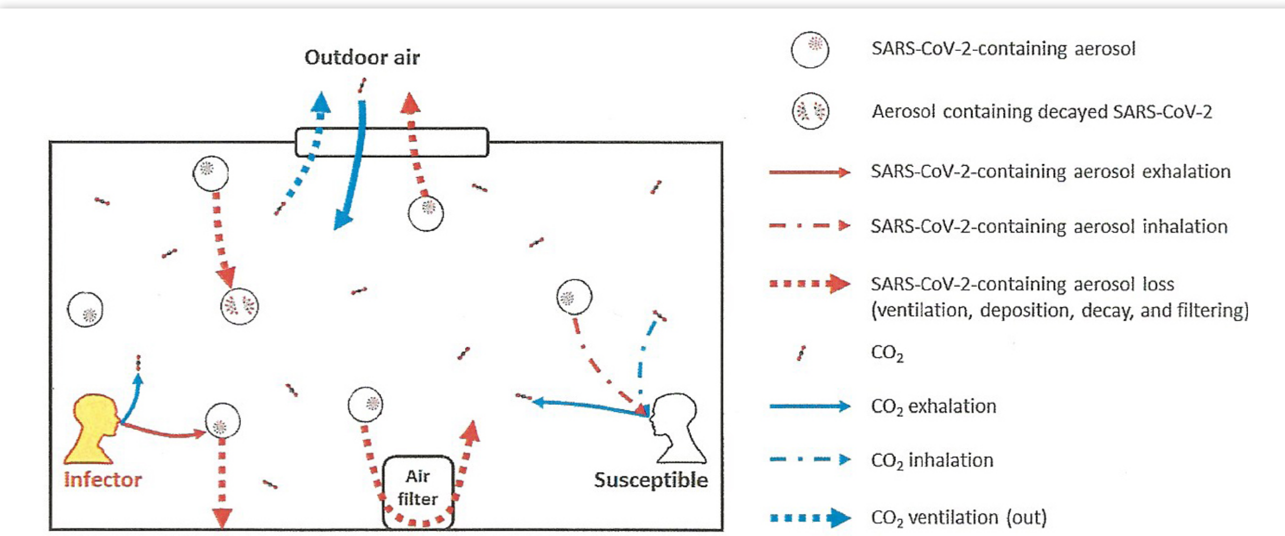
Introduction

Our understanding of a school's safety and COVID-19 will benefit greatly from institutionalizing a program identifying the difference between the levels of carbon dioxide or $C0_2$ outside the school and CO2 inside the classroom and other school areas. This relationship is identified as "differential carbon dioxide" or dCO_2 and can roughly calibrate the potential for transmission of COVID-19 within a school. The burdens of CO_2 outside and inside the school serve as a proxy for SARS-2 exposure and the consequent risk of COVID-19.

Background

When COVID-19 struck, we initially were directed to focus on hygiene and fomite cleansing, i.e., wiping down smooth surfaces with soap or disinfectant. We were to frequently wash hands and cleanse smooth non-porous surfaces that may have been contaminated through airborne exhalations or a contaminated hand touching a face and then a surface. Today we understand that path of contamination may occur, but by far, the primary source of one person contaminating another is airborne aerosols exhaled through coughing, sneezing, or simply breathing shared air. This is a



We wish to thank Drs. Z. Ping and J.L. Jimenex, University of Colorado, Boulder for their work and the above dCO_2 classroom schematic.

particular concern in schools with traditionally dense occupancy and often limited or compromised air exchange.

While we know younger adults, and particularly children, are less likely to be impacted by COVID-19 and somewhat less likely to transmit the disease we also know that, at some level, they can both contract and transmit COVID-2. The medical and public health concept of universal precautions requires that we treat all individuals, whether or not they have been tested or belong to a group that is less likely to transmit, with the same concern for safety, exposure, and protection.

It is also important to understand that it is unlikely that there will be vaccination safeguards available for children in the near future. This delay is, in part, because there is serious concern regarding an immune overreaction or “cytokine storm” response in children. The same vaccine dosage that may be protective for an adult may trigger an immune response overreaction in a child. The protocol for vaccine authorization for children is understandably more protracted. **WHEN A VACCINE IS FORMALLY RELEASED THERE SHOULD BE CONFIDENCE THAT IT IS SAFE**, but release of a safe childhood vaccination will take longer than for adults.

We need to protect the breathing zones of children and adults in the school setting. This task is made somewhat more complicated by the construction of schools from the 1950s to the late 1990s. There was an unfortunate focus on progressively reducing fresh air intake quality. As discussed in more depth in other documents, the school architecture of the post-World War II era was not oriented toward assuring adequate ambient air. Many schools have improved their air exchange, some have not.

In 1996 the EPA tested 41 buildings and detected a direct correlation between virus-based disease and $dC0_2$, or the difference between outside air and inside air in terms of $C0_2$ burdens. Using this base, in 2002 Lawrence Berkeley National Labs conducted a meta study, one involving 100 buildings, calibrating the $dC0_2$ and disease incidence, including viruses. Findings of a positive relationship were absolutely confirmed. The more air building occupants inhaled containing the breath of others, as identified by dCO_2, the higher the incidence of viral transmission. The connection was clear.

When the recent COVID-2 pandemic occurred researchers from the departments of Environmental Science and Chemistry at the University of Colorado completed a detailed analysis of the relationship in schools between $dC0_2$ and potential SARS-2 exposure. Although their publication has not gone through traditional peer review, the concepts being addressed were positively commented upon by the medical journal *Lancet—Infectious Disease*. The authors allowed the results to be distributed pre-formal publication. They understood the importance of quickly sharing their findings in protecting public health in general and schools in particular. They state:

> *$C0_2$ is co-exhaled with aerosols containing SARS-CoV-2 by COVID-19 infected people and can be used as a proxy of SARS-Cov-2 contaminations indoors. Indoor CO_2 measurements by low-cost sensors hold promise for mass monitoring of indoor aerosol transmission risk for COVID-19 and other respiratory diseases. (See citations.)*

Although peer review and expanded research would be helpful and will certainly be forthcoming, it is clear that schools can presently benefit from obtaining low cost $dC0_2$ data in their schools. With real-time feedback on the presumed threat, schools can make knowledgeable adjustments regarding distancing, personal protections, class size, class activity and especially air exchange. The safety of school employees, especially teachers and students, and ultimately the community, should be significantly enhanced through real-time feedback on the safety of breathing zones.

The costs associated with implementing this testing protocol are minimal, although there will be time and coordination demands. The execution of the program requires focus and professional understanding of the concept and technical aspects of $dC0_2$ collection and interpretation of findings. At some level safety and risk of COVID-19 in schools may be numerically calibrated, providing guidance for school administration and reassurance for students, parents, staff and the community.

Procedures for Institutionalizing dCO_2 Controls and Safeguards

It is important to standardize outdoor benchmark testing of the carbon dioxide thresholds near, but outside of, each school property. The research at the University of Colorado compared thresholds of different buildings in different geographic areas and found profound differences in outdoor thresholds of CO_2. Interestingly they did not always find significant differences within the different school indoor areas. They reviewed classrooms, lecture halls, laboratories, wood/metal shops, computer labs, media centers, etc. With some exceptions, including music assembly rooms and some lecture halls there seem to be a reasonably similar dCO_2 range. It was the reading outside the school that turned out to often be variable and is especially significant in computing accurate dCO_2.

There would be two goals to this testing procedure, the first would be to quantify the relative safety of an individual classroom or area. The second would be to develop feedback on the quality of the existing air handling system and the effectiveness of different personal protection and distancing procedures. Since, if this is executed correctly, there will be real-time feedback, it will be a straightforward process to review the findings and make determinations regarding optimal safety procedures, policies, and mechanical engineering options. The capacity to offer a guarded, but numeric assurance of probable safety is extremely valuable and will become increasingly reliable as data accumulates from increased numbers of rooms and schools connecting protective actions to risks.

The following are the basic activities that would likely be part of instituting the $dC0_2$ programs within each building:

1. Obtain CO_2 Detectors

There are a number of brands and products that would be adequate with price ranges from around $100–$250. Some equipment add-ons that we think might be helpful involve graphing printouts and the capacity to interface with software compiling, comparing, and displaying area sensitive read-outs on a weekly or daily basis. They would display daily readings and trends over time that could be compiled and provide safety guidelines. Differences in readouts between classrooms, for instance, could be tied to characteristics of the air handling system especially diffusers or patterns for distancing and class-size. Educators and administrators would have solid risk-oriented data with which to plan, manage and reassure.

It would be important to identify the characteristics most helpful for purchasing detectors and in our view, it makes sense to use a single brand and supplier enhancing comparison of results. We will not recommend any specific product but will comment quite specifically on product characteristics.

2. Create a Protocol for Outdoor Benchmark Testing

Elevated carbon dioxide thresholds do not inherently represent a risk. We inhale carbon dioxide as part of normal breathing. **It is the level of differentiation between indoor and outdoor readings that will indicate the nature of shared breathing zones that serve as a proxy for transmission of disease.**

For each building, when readings are taken inside the building, there should be a somewhat contemporaneous reading of the outside ambient air. Inside the building, decisions need to be made focusing on detector placements involving similar distancing and elevation for students and/or the teacher. This means that the detector would be the same relative distance shared by sitting students and at the same elevation as that of the teacher. The teacher would typically place a detector at the opposite end of the class area, equidistant from his or her positioning relative to students and at the teacher's typical standing or sitting elevation.

The data, comparing outdoor areas and any number of indoor areas including classrooms, fine arts, assembly areas, etc. would be compiled and potentially transposed to a floor plan compatible with the plans used for heating, ventilation and air exchange considerations. It would be helpful to also indicate any uniqueness or basic characteristics of room arrangement, distancing guidelines, activities, diffuser systems, fans, physical barriers, windows, room specific internal or external air treatment equipment, relative humidity, and exterior heating or cooling units.

3. Interpreting Data Results

Although there needs to be appropriate qualifying statements, a low or lower $dC0_2$ reading should provide shareable reassurance to students, faculty, parents and the community that breathing zones have been effectively diluted and transmission of disease, especially COVID-19 is unlikely.

It would be important to connect $dC0_2$ readings to the characteristics of both building-wide mechanical air exchange and other protective measures such as distancing, class size, or activity guidelines. It would be especially helpful if different school districts in different geographic areas compiled and shared information, especially if they conducted their protocols for gathering information in identical patterns.

Conclusion

Since the emergence of the pandemic, institutions, especially schools, have received changing and sometimes confusing guidelines. The seriousness of the issue requires administrators to get a handle on reducing exposures and safeguarding students, employees, and, consequently the community. Although enhanced research is still forthcoming, it is clear that carbon dioxide differential $C0_2$ monitoring will provide warnings, insights, and guidelines to better safeguard those in the building.

CA Erdmann, KC Steiner, and MG Apte (2002)
Indoor Carbon Dioxide Concentrations and Sick Building Syndrome Symptoms
Analysis of the 100 Building Data Set
Proceedings: Indoor Air 2002
Indoor Environment Department, Lawrence Berkeley National Laboratories

Goldman E. (2020)
Exaggerated Risk of Transmission of COVID-19 by Fomites
LANCET – INFECTIOUS DISEASES 2020
(Published online) https://doi.org/10.1016/S1473-3099(20)30561-2

Z. Ping, J.L. Jimenez (2020)
CO_2 as COVID-19 Infection Risk Proxy for Different Indoor Environments and Activities
Cooperative Institute for Research in Environmental Sciences
Department of Chemistry
University of Colorado, Boulder Colorado
(Made available under a CC-BY-NC-ND-4.0 international license)
Recently released and not peer-reviewed at this time
COVID-19 Aerosol Transmission Estimator https://tinyurl.com/covid-estimator

Nicholas G. Davies, DPhil, Rosanna C Barnard, PhD, Christopher I. Jarvis, PhD, Timothy W. Russell, PhD, Prof Malcolm G. Semple, Phd, Prof Mark Jit, Phd, et. Al. (2020)
Association of tiered restrictions and a second lockdown with COVID-19 deaths and hospital admissions in England: a modelling study
LANCET – INFECTIOUS DISEASES 2020 (December 23)
https://doi.org./10.1016/SI473-3099 (20) 30984-1)

ERC Note: The above Lancet publication comprehensively describes and details the dynamics of approach to lock downs and preventative options, but does not specifically address $dC0_2$ baselines as indicators.