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

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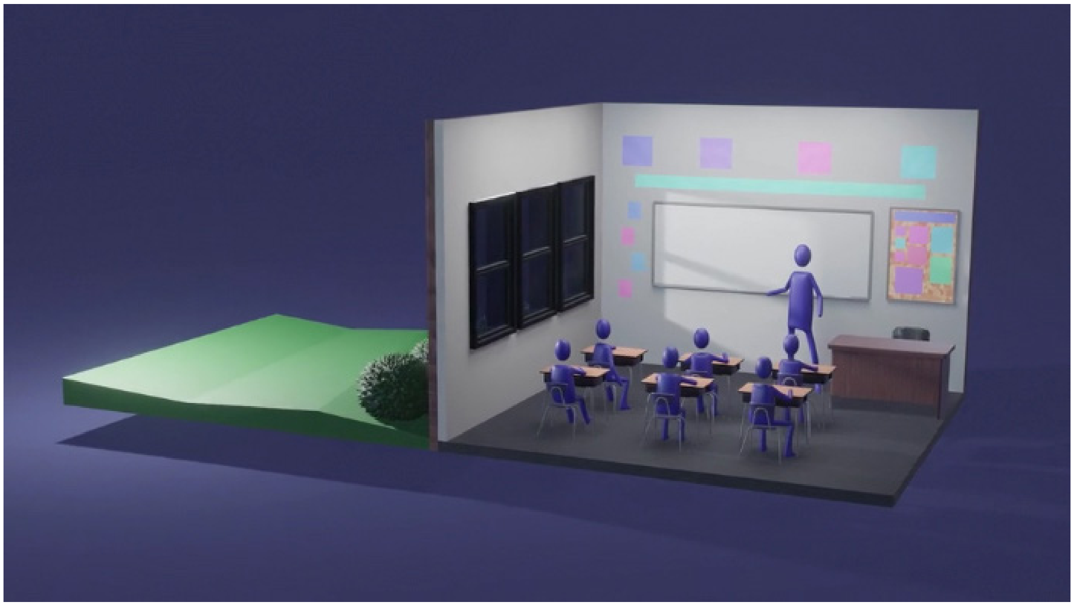
I. Introduction – *Helping to Assure School Room Safety*

Our understanding of a school's safety regarding COVID-19 will benefit 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 the SARS-2 virus exposure and the consequent risk of COVID-19.

II. Background – *Identifying Risk*

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



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

While we know younger adults, and particularly children, seem 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. Recent emergence of SARS-2 variants may be of increased risk to students. The medical and public health concept of universal precautions requires that we treat all individuals, whether or not they have been tested, vaccinated, or belong to a group that is less likely to transmit, with the same concern for safety, exposure and protection. Vacinations will reduce risk, especially if educators are vaccinated, but all hygenic protection should be continued.

There will be vaccination safeguards available for children in the future. The delay is, in part, because there is 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.**

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 style of schools from the 1950s to the late 1990s. There was an unfortunate focus on progressively reducing fresh air intake. As discussed in more depth in other website documents, the school architecture of the post-World War II era was not oriented toward assuring what we would today consider 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 adjusted 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, especially viruses. Findings of a positive relationship were absolutely confirmed. The more air building occupants inhaled containing the exhaled breath of others, as identified by dCO_2, the higher the incidence of viral transmission. The connection was clear and now applies to SARS-2.

When the recent COVID-19 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 as relevant 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 to protect public health in general and school occoupants 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. 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 $dC0_2$ feedback.

The costs associated with implementing this testing protocol are minimal, although there are 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 operational guidance for school administration and reassurance for students, parents, staff and the community.

III. Procedures for Institutionalizing dCO_2 Controls and Safeguards – *Calculating Risks*

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 typically find significant differences within similar 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 seemed to be a reasonably similar dCO_2 range. The readings outside the school sometimes turned out to often be variable and 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 important and will become increasingly reliable as data accumulates from increased numbers of rooms and schools connecting protective actions to reduce exposures.

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–\$300. 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 when helpful. They would display readings and trends over time that could be compiled and provide operational 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 should obtain solid risk-oriented data with which to plan, manage and reassure.

2. Create a Protocol for Outdoor Benchmark Testing

Elevated carbon dioxide thresholds do not inherently represent a risk. We inhale small amounts of carbon dioxide and exhale large amounts 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 the 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. The number and nature of readiness would depend on the situation and level of concern.

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 a virus-based 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 similar patterns.

IV. Conclusion

Since the emergence of the pandemic, institutions, especially schools, have received changing and sometimes confusing guidelines. The seriousness of both COVID-19 and school closures requires administrators to get a handle on reducing exposures and safeguarding all school facility occupants 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 and reassurance of enhanced safety.

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.