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Can better indoor ventilation make schools safer during the COVID-19 pandemic?

Introduction

As children return to school this Fall, parents, teachers, school officials, and others may wonder how safe their school environments are from COVID-19. While, by now, most of us are quite familiar with the enhanced hygiene recommendations provided by health officials to limit the spread of COVID-19 (such as the mask wearing, social distancing, hand washing, and surface cleaning noted in *British Columbia, 2020; British Columbia Ministry of Health, 2020; Vancouver School Board, 2020*), not as much information is available related to preventing indoor airborne transmission over distances greater than two meters. Since this will be the first time in several months that local schools have assembled teachers and children together into classrooms, hallways, and other indoor spaces, it is useful to consider what researchers and industry professionals have documented that might inform how to do this with minimal risk of airborne disease transmission. Some of these considerations follow.

Can children catch and spread COVID-19?

Young children seem to be much less likely than adults to catch COVID-19, and, when they do, they seem to react to it with moderate to no symptoms (*de Souza et al., 2020; Escosa-García et al., 2020; Hagmann, 2020; Isaacs et al., 2020; Kallem & Sharma, 2020; Kevat, 2020; Mallineni et al., 2020; Ranabothu et al., 2020; Ruggiero et al., 2020; Yasuhara et al., 2020; Davies et al., 2020*). It is not well known why this is so (*Yavuz, Kesici, & Bayrakci, 2020*), though research on the topic is growing (*She, Liu, & Liu, 2020*). Children's ability to spread the disease is not well known either (*de Niet, Waanders, & Walraven, 2020; Munro & Faust, 2020; Li et al., 2020*). While they seem to be less likely than adults to spread it, the evidence suggests that they can (*Li et al., 2020*).

Can people without symptoms spread COVID-19?

In one study, He et al. (*2020*) found that 15.6% of adults with COVID-19 and 27.7% of children with COVID-19 were asymptomatic. Researchers generally agree that asymptomatic individuals with COVID-19 can spread the disease (*Abtahi-naeini & Saffaei, 2020; Goyal et al., 2020; Lango, 2020; Lu et al., 2020; Yu & Yang, 2020*), including asympotmatic children (*Ludvigsson, 2020*). In fact, several researchers claim that the viral load for asymptomatic persons is the same as it is for persons presenting symptoms (*Yang & Chen, 2020; Huff & Singh, 2020; Peng, Su, Zhang, & Wang, 2020*), though Luo et al. (*2020*) found the infection rate to be lower from asymptomatic persons.

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Can COVID-19 spread through the air?

While a lack of data (*Anderson et al., 2020*) has engendered some disagreement as to whether the SARS-CoV-2 virus can spread through airborne pathways (*Lewis, 2020; Morawska & Cao, 2020*), concensus seems to be forming that it can (*Allen & Marr, 2020; Christopherson et al., 2020; Correia et al., 2020; Gameiro da Silva, 2020; Goyal et al., 2020; Lu et al., 2020; Lednicky, Lauzardo, et al., 2020; Lednicky, Shankar, et al., 2020; Morawska et al., 2020; Nwanaji-enwerem, Allen, & Beamer, 2020; REHVA, 2020; Shen et al., 2020; Somsen et al., 2020*). The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), a North American professional organization that is a preeminent authority on matters of building ventilation, has taken the position is that

> "*Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning [HVAC] systems, can reduce airborne exposures*." (*ASHRAE, 2020, p2*)

Thus, opinions from both academic and professional sources suggest that aerosolized (airborne) transimission of the SARS-CoV-2 virus is a concern.

What research has been done on indoor airborne disease transmission?

Several studies have discussed the influence of building ventilation systems on airborne disease transmission (*Chung & Hsu, 2001; Du et al., 2020; Hobday & Dancer, 2013; Kembel et al., 2012; Li et al., 2007; Memarzadeh & Xu, 2012; Pantelic & Tham, 2013; Pica & Bouvier, 2012; Qian & Zheng, 2018; Robinson, Stilianakis, & Drossinos, 2012; Seppanen & Fisk, 2004; Stewart et al., 2020; Wan & Chao, 2007; Yu et al., 2004*), with some studies focussing on hospital settings (*Aliabadi, Rogak, Bartlett, & Green, 2011; Beggs, Kerr, Noakes, Hathway, & Sleigh,2008; Bolashikov, Melikov, Kierat, Popiołek, & Brand, 2012; Li, Huang, Yu, Wong, & Qian, 2004; Morawska et al., 2009; Memarzadeh & Jiang, 2004; Mousavi & Grosskopf, 2015; Olmedo, Nielsen, Adana, Jensen, & Grzelecki, 2012; Shajahan, Culp, & Williamson, 2019; Tang, Li, Eames, Chan, & Ridgway, 2006; Wan, Chao, Ng, To, & Yu, 2007*), on office environments (*Bagheriad et al., 2014; Chen et al., 2014; Mendell et al., 2015; Myatt et al., 2004;*), or on school environments (*Kumar, 2019; National Academies of Sciences, Engineering and Medicine, 2020; Ridenhou et al., 2011; Wang et al., 2014; Rubin, 2020; Zhang, 2020*). While most studies of indoor airborne disease transmission have focused on hospital settings, the indication that COVID-19 can spread through aerosolized transmission suggests that further research is needed on airborne disease prevention in other indoor environments, such as retail spaces, offices, and schools.

How can the COVID-19 safety of a school ventilation system be evaluated?

There are two primary ways to evaluate the effectiveness of a building's ventilation system—either by direct visual inspection and physical testing, or by computer

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simulation. When inspecting and testing a ventilation system's potential to transmit infectious disease, several factors should be considered. Of course, air changes per hour is a primary concern, but there are many others. ASHRAE (2020) recommends the following measures to minimize the transmission of COVID-19:

- *verify proper settings for indoor air temperature and relative humidity,*
- *verify proper separation of air intake and exhaust points,*
- *measure and balance building air pressures,*
- *evaluate potential for increased air changes per hour,*
- *verify positive pressure in all indoor spaces (relative to outdoors),*
- *verify airflow rates meet ASHRAE Standard 62.1,*
- *evaluate potential for MERV 13 (minimum) filtration,*
- *evaluate and adjust CO2 sensor levels as required.*

Such evaluations should be carried out by professionals with a background in mechanical systems and an understanding of infectious disease prevention.

Another means of understanding a building's ventilation system is by computer modeling. While building airflow can be modeled in various ways (*Ai, Huang, & Melikov, 2019; Li, Duan, Yu, & Wong, 2004; Pantelic & Tham, 2012; To et al., 2008; Zemouri et al., 2020*), a tool that is particulary well suited to this task is computer simulation software known as Computational Fluid Dynamics (CFD) (*Aliabadi, Faghani, Tjong, & Green, 2014; Aliabadi, Green, Rogak, & Bartlett, 2010; Bandhakavi, 2004; Bustamante et al., 2013; Cunha et al., 2019; Deevy, Sinai, Everitt, Voigt, & Gobeau, 2008; Gao & Niu, 2006; Ivanov & Mijorski, 2017; He et al., 2011; Jiang et al., 2009; King, Noakes, & Sleigh, 2015; Lomax, Pulliam, & Zingg, 2001; Pichurov, Stankov, & Markov, 2006; Shen, Gao, & Wang, 2013; Sekhar & Olesen, 2012; Song & Li, 2010; Tian, Tu, & Yeoh, 2007; Tu, Yeoh, & Liu, 2018; Villafruela, Olmedo, Adana, Méndez, & Nielsen, 2013; Yam, Yuen, Yung, & Choy, 2020*). There are several makers of such software, including PALM, OpenFOAM, ExaFLOW, FDS, Fluent, and SimScale (*Fireman, 2016*). CFD simulations can be validated using experimental data (*Tu, Yeoh, & Liu, 2018*) such as smoke tracing (*Gao & Niu, 2006*) or CO2 tracing (*Chung & Hsu, 2001*). Recently, Vuorinen et al. *(2020)* used CFD simulation to model airborne transmission of the SARS-CoV-2 virus. While potentially able to provide better information about the airflow in a building space, CFD modeling may be time and cost prohibitive relative to a more basic building ventilation evaluation.

Recommendations

While airborne transmission of SARS-CoV-2 is generally less of a hazard than direct transmission (by coughing or touching) or fomite (surface) transmission, it does present some level of risk. Although children are less likely to catch and spread COVID-19, they are able to do both to some degree. And, of course, every school has adults, who may transmit aerosolized SARS-CoV-2 even if they are asymptomatic. Therefore, health and school officials should consider evaluating whether the ventilation systems of schools under their jurisdictions are optimized to resist transmittance of aerosolized viruses such as the one that causes COVID-19.

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