Responses to questions from the IfP-CPHA webinar on indoor air and infectious disease transmission

On March 7, 2024, the Institute for Pandemics (IfP) and the Canadian Public Health Association (CPHA) held a webinar for members of CPHA to inform them of the latest research on indoor air transmission of infectious diseases and strategies to reduce exposure. The webinar resulted in many questions that could not all be answered during the webinar. This document provides answers to the questions by the three presenters:

- David Fisman [DF], Professor, Dalla Lana School of Public Health
- Sarah Haines [SH], Assistant Professor, University of Toronto, Dept. of Civil & Mineral Engineering
- Raymond Tellier [RT], Associate Professor, McGill University Health Centre

Personal protections/Interventions

1. **I'm a university student and want to know if it is advisable to wear a respirator during lectures?**
   A: [SH]This comes down to preference and your level of acceptable risk. COVID cases have been declining in recent months however to fully protect yourself a well-fitting mask is advisable if you are concerned about your risk. Well-fitting is crucial here.

   [DF] This is a challenging question to answer: one difficulty with our SARS-CoV-2 response at the moment is that we are putting responsibility for health on individuals and their actions, where we know that for many public health interventions to succeed (safe drinking water, vaccination) they need to occur at the level of the community. We might say the same about indoor air and infection: the tools that we have for managing indoor infection risk (ventilation, filtration, UV decontamination) are available, but often not implemented, and there's a lack of regulation around their use. Similarly, even if we were going to put the onus for safety on individuals, those individuals would need information (on infection prevalence, in-classroom CO_2, and so forth) to make informed decisions and we don't make those data readily available. In that context we do the best we can with what information we have. I can tell you that I [*David Fisman*] continue to use a KN95 respirator when I lecture; I would feel less strongly about using it if I were in a classroom with fewer people, and with windows that open. Infection risk is also likely a probabilistic function of exposure x time, and that may be something to keep in mind around popping your mask off briefly to drink…the incremental change in risk may be acceptable to you (just as, if I briefly closed my umbrella during a rainfall, I might get less wet than if I closed it

for a long time). Ultimately, we have to hope for more action from institutions, universities and workplaces on indoor air, including better information sharing.

2. **How can people stay safe in an apartment building? Living in an apartment, people share air with other residents.**
   A: [SH] There is still more research needed to identify pathways of exposures between apartment units however – increasing your own ventilation, portable air cleaners could be useful. Additionally, shared spaces are commonly of most concern in shared buildings (elevators). If you are concerned, wearing a well-fitting mask in shared spaces has been found to be effective. https://ncceh.ca/resources/evidence-reviews/contextualizing-risks-indirect-covid-19-transmission-multi-unit

   [RT] Depending on the building and how much ventilation is shared between units that can be challenging. Good ventilation by opening windows will help (not always feasible depending on the weather); air purifiers with HEPA filters can help. As far as COVID is concerned, one should definitely take advantage of the vaccine.

3. **Do we have to be worried about cleaning or changing an indoor air filter? Is there potential to get exposed to particles that way?**
   A: [DF] I use a respirator to do this, and do it outside on the porch. My biggest issue is I'm allergic to dust and it's dusty work, but that should protect against infectious particles too. Note that SARS-CoV-2 has a lipid membrane, so it's not a virus that's going to remain infective very long on dry surfaces (see question #14).

4. **When discussing increasing ventilation in shared areas/work spaces, is this simply a matter of increasing the flow, or are most systems already working at maximum capacity?**
   A: [DF] Most systems aren't working at capacity because that costs energy (and hence $$). The recent US CDC recommendation for 5 air changes per hour is an exciting new benchmark in terms of what we should be trying to achieve, but the tradeoffs with costs (and carbon footprint) are real (https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html#:~:text=Added%20discussion%20on%20"How%20much,occupancy%20flushing%20of%20building%20air). Encouragingly the US agency ARPA-H has announced a moonshot on cleaning indoor air, https://arpa-h.gov/news-and-events/arpa-h-launches-breathe-monitor-and-improve-indoor-air-quality

I would also note that new standards for indoor air, informed by the pandemic, are being formulated. ASHRAE-241 (https://www.youtube.com/watch?v=7F_F0cbmjzw) is to my knowledge the first indoor air standard that explicitly talks about improving indoor air in response to local respiratory infection epidemiology, which is a big jump forward. ASHRAE-241 also talks about clean air equivalents because ventilation can't always be improved directly but can be de facto supplemented with filtration or disinfection (e.g., with high room UV and maybe soon with Far-UV).

5. **Are the far UV or UV-C products, that are being marketed as a skin and eye safe alternative to upper room UV devices, effective?**
   A: [DF] This is very much work in progress. The current major hurdle for Far-UV is generation of ozone…it's not clear whether that's enough of an issue to outweigh the benefits of Far-UV but it's an active area of study. The spectrum for Far-UV is attractive precisely because it is different from the spectrum of mercury UV light sources (which are erythrogenic and can only be used high in rooms or in ducts).
   (https://pubmed.ncbi.nlm.nih.gov/38037431/#:~:text=Far%2DUVC%20light%20produces%20very,international%20far%2DUVC%20dose%20standards.)

Aerosols

6. **Does settling time for particles depend on what the particle is made of as well?**
   A: [SH] In aerosol research we often assume an aerodynamic diameter of an irregular shaped particle in which the diameter of a sphere with a unit density (1g/cm3) that has same terminal settling velocity as a non-spherical particle The settling time will change based on the aerodynamic diameter.

   [RT] Yes; but the table I've shown used aerodynamic diameter, which is not the same thing that the physical diameter. A particle with 1.0 µm aerodynamic diameter is a particle that behaves like a sphere of pure water of 1.0 µm diameter. To convert from physical to aerodynamic diameter, you have to correct for the density (usually straightforward) and the shape (which can be very difficult to do mathematically, think about snowflakes…). To an excellent approximation, particles exhaled by the respiratory tract are spherical and have a density close to that of water.

7. **If some viruses only come in "droplets", how do they get inhaled into the alveolar region where they have the most severe effect that we worried about early in this pandemic?**
   A: [RT] The term "droplets" is imprecise, as it has been used to mean different things by different authors; sometimes it's taken to mean only "large droplets",

sometimes it encompasses both "large" droplets and small aerosols. Particles with a (aerodynamic) diameter of 5 µm or less will penetrate all the way to the alveolar space when inhaled.

8. **Can you explain controlling indoor humidity as a means of decreasing infected aerosols spread?**
   A: [RT] This has to do with biological decay, i.e., how long do viruses remain infectious while in aerosol particles. For enveloped viruses such as influenza or SARS-CoV-2, low humidity (RH < 40%) is associated with a slower decay; but for non-enveloped viruses, such as adenoviruses or enteroviruses, it's the other way around.

9. **Where did the two- or one-meter droplet "rule" come from? Relates to the short distance issues for ventilation, amongst other things.**
   A: [SH] Linsey Marr tracked the short distance stuff down to Chapin's textbook on hospital infections…it's from about 1909. It's just been carried forward over time. Chapin was reacting to "miasmas" which had been discredited, but as usual the pendulum swung too far.

   [DF] I have no idea. Many of us have asked several supporters of this advice where it came from, or what were the studies/data supporting it, we have never received a clear answer.

10. **The RNA-to-TCID50 ratio in aerosols is difficult with state-of-the-art techniques. Do you have any ideas to alternatives, changing the detection techniques, looking at physical properties/signatures instead of isolation in cell culture?**
    A: [RT] Not really; the problem is how do you ascertain if viruses are still infectious; successful isolation in cell culture demonstrates that the virus is infectious, but it is not a very sensitive method (in contrast to bacterial culture which can be done on cell free media & is very sensitive, at least for many species of bacteria). So, if the isolation in cell culture is unsuccessful it does not guarantee that there is no infectious virus in the sample; in fact, for some viruses e.g., noroviruses we don't even know how to culture them in cell culture. One of the ways to infer infectivity is by careful analysis of outbreaks.

Infections

11. **Can you clarify why the dosage of aerosol (TLD50) required to infect differs by route of inhalation even though the exposed person is within the same distance of the pathogen laden aerosol particle?**

A: [RT] In real life settings, in close proximity of an infected person one will be exposed to the whole size spectrum of particles, from small aerosols to large droplets.
The measurement of the infectious doses in TCID50 (Tissue culture infectious dose 50%) was done in laboratory experiments, using a stock of virus that has been grown in the lab and which has been quantified in TCID50. In the lab, one can prepare an aerosol inoculum that is free of large droplets, only small aerosols; and so one can do experimental infections with this preparation and measure the dose required to infect the subject. One can do similar experiments in the laboratory by inoculating the subject through nasal instillations, which mimics large droplets which can go only on the mucosa of the upper airways, and cannot penetrate deeper in the airways.

12. **Can you explain why the more recent COVID-19 variants generate more aerosols?**
    A: [RT] The molecular determinants of that observation remain to be fully understood. In part, it may involve the site of replication in the respiratory tract, whether it triggers more aerosolizing behaviors such as coughing and sneezing; and also, at least for some variants, they just replicate faster and so produce more viruses per unit of time.

13. **Public health has described each variant as more transmissible than the one that came before, but they have never defined what that means. How do you explain 'more transmissible' to people who do not have a background in infectious disease? How long do you need to be exposed to the virus before you become infected?**
    A: [RT] In part, variants are more transmissible because they had a greater R0 value, which is defined as the average number that an infected person will infect during her/his illness (but that is often difficult to measure in practice). One gets an idea through the rapidity of spread in a population. Another aspect of variant succession was whether they were escaping (at least in part) immunity acquired by exposure to previous variants.

14. **How important do you consider studies that check how much SARS-CoV-2 has been deposited on surfaces (the "dust studies" which collect samples from level surfaces, so other than door knobs and other high-touch objects, etc.)? Can that information be relevant when considering portable room filtration devices?**
    A: [SH] The CDC did a very good risk analysis on surface/fomite trans of SARS-CoV-2 early in the pandemic. It suggested risk from a contaminated surface is around 1/10000 for a touch.:

https://archive.cdc.gov/www_cdc_gov/coronavirus/2019-ncov/more/science-and-research/surface-transmission.html.

[DF] Our best estimates suggest that the risk of acquisition of SARS-CoV-2 from surfaces is negligible (~ 1:10,000) (https://archive.cdc.gov/www_cdc_gov/coronavirus/2019-ncov/more/science-and-research/surface-transmission.html.) Dust studies are interesting, but they probably mostly tell us that SARS-CoV-2 is in the air! (For example, they may show us that SARS-CoV-2 collects on high no-touch surfaces, like the top of a wall-mounted TV in this study: https://www.sciencedirect.com/science/article/pii/S0048969721012687.

15. **Could you use the surveillance of viruses in filters in hospital settings to check whether a room is clean after an infectious patient? How long does it take to find virus particles in the filter, could you check for viruses twice a day?**
    A: [RT] This is the subject of active research by many groups.

16. **Is there data on how other respiratory viruses transmit?**
    A: [RT] Yes, a lot; see reviews in Wang et al Science 2021; 373: 6558 doi: 10.1126/science.abd9149; Tang et al Indoor Air 2022 32(1) e12937; Tellier et al BMC Infectious Diseases 2019 19: 1-9.

17. **What are your thoughts about using far-UVC and upper room UVGI for controlling aerosol transmissions?**
    A: [RT] I have discussed upper room UV irradiation experiments as one of the lines of evidence for aerosol transmission of influenza, and they have been found to work for other airborne agents e.g., tuberculosis; BUT in practice they are difficult to design and install properly and safely and they must be maintained carefully, so have not found very widespread use.

18. **Is there a cite for CO_2 acidification preserving SARS-CoV-2 infectivity?**
    A: [RT] This is a fairly new finding and will require more research, but the papers I know about this are from the group of JP Reid in Bristol; see Oswin HP et al Proc Natl Aca Sci 2022; 119 (27) e2200109119; and Haddrell A et al J R Soc Interface 2023; 20 20230062.

19. **What level of humidity promotes COVID-19 transmission?**
    A: [DF] The relationship between humidity and infectivity of aerosols is a complicated one but suffice it to say there seems to be a sweet spot around 50% relative humidity where aerosol infectivity seems reduced.

Miscellaneous

20. **Vancouver's Orpheum Theatre has in-seat personal clean air. This was built in the 1920s as a means to stop future pandemic transmissions following the 1918 pandemic. Engineered to clean the air over 100 years ago. Why have we lost this knowledge and engineering capabilities in building codes?**
    A: [DF] In fact, we had a historian (Dr. Sarah Jensen Carr) participate in our IfP symposium ("Something in the Air") last year. This is indeed knowledge that has been lost as awareness of indoor air as an important health issue has faded. The video is here: https://www.youtube.com/watch?v=VAZ9Fqpee8g. There's more from Prof. Carr here: https://www.cbc.ca/radio/spark/how-the-pandemic-put-building-design-and-ventilation-back-into-the-public-health-conversation-1.5783970.

21. **Any indication if the findings and recommendations from the researchers will become part of the building codes, e.g., ASHRAE 62.2 for residential units?**
    A: [DF] Here's hoping, but right now we seem to have political reluctance even to enforce the regulations around indoor air that are already on the books! For example, here in Ontario the opposition NDP introduced a bill that would require CO_2 monitoring in classrooms with remediation for classrooms >1000 ppm which is the existing standard for classroom air! The bill is not considered likely to pass. So not only are we not tightening standards, we don't seem to want to know whether we're meeting existing standards. Notably, Quebec did pass an almost identical bill and found that 1/3 of all their classrooms failed to meet standards and needed remediation.

22. **Are standards like ASHRAE-241 the gold standard for indoor ventilation? Are other standards considered generally acceptable?**
    A: [DF] Yes, ASHRAE-241 is really the state of the science right now, but of course lacks the force of regulation/enforcement. It's best practice.