Public Schools of Brookline - Expert Advisory Panel #4 (Public Health, Safety, and Operations)

Panel Statement on Indoor Environment

Final - Adopted by Unanimous Vote August 21, 2020

Our panel is composed of Brookline parents with expertise in public health, medicine, and occupational health who are assisting the Brookline School Committee with the difficult process of re-opening the Public Schools of Brookline (PSB). Below is a summary of the discussions the panel has had since June 12, 2020 on the subject of providing clean air to dilute concentrations of any airborne virus particles inside school buildings, through the use of increased outdoor air ventilation and increased filtration of recirculated air. For more technical information, minutes, and recordings of the meetings, please refer to the school website.

Advisory Panel 4 Members
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Panel 4 recommends that PSB enhance clean air ventilation of shared-occupancy indoor spaces to target levels well above pre-pandemic building code requirements or industry standards for school construction, to provide a further layer of defense against the transmission of the virus causing COVID-19. The Healthy Buildings Team (HBT) based at the Harvard T.H. Chan School of Public Health, has characterized ≥4 air changes per hour (ACH) as "good" and ≥5 ACH as "excellent" in the pandemic context (assuming universal mask wearing inside buildings). The HBT has recommended that schools target 5 ACH, but we emphasize that this recommended 5 ACH target does not reflect a bright line standard for occupant health and safety because there are additional safety precautions that are relevant to this target (e.g., mask wearing, lower occupant densities), as well nuance in measuring and interpreting "snapshot" measurements of ACH. The Massachusetts Teachers Association and Brookline Educators Union have recommended a minimum ventilation standard of 20 cubic feet per minute per occupant which, at least for occupancy levels derived from 6-foot

distancing requirements, is roughly equivalent to 3 ACH. Based upon consideration of these sources, Panel 4 recommends that PSB:

- **Initially target 4 ACH of clean air (the HBT's "good" level) for use of indoor spaces, as long as universal masking requirements and occupancy based on minimum 6-foot distancing remain in place.**
- **Longer-term, target 5 ACH of clean air (the HBT's recommended "excellent" level) as an ultimate goal for ongoing operations during the pandemic, to allow for the possibility of increased flexibility on occupancy/distancing and other measures in months to come, as more evidence of the efficacy of specific measures becomes available.**

1. The recommendations below focus on enhanced clean air ventilation as an additional defensive measure against airborne transmission of the virus causing COVID-19. Other risk reduction strategies, such as masking and distancing and hand hygiene, address droplet and fomite transmission. Based on expert guidance from the Harvard T.H. Chan School of Public Health Healthy Buildings Team (HBT), led by Dr. Joseph Allen, we define "clean air" for purposes of hitting the ACH targets described here to consist of **a combination of: (a) fresh outdoor air, (b) recirculated air - filtered at MERV 13 level or higher (for rooms with mechanical ventilation), and/or (c) air passed through a portable air cleaner with a HEPA filter**. Each component (a,b,c) can be used to complement the other two with the goal of achieving the recommended enhanced targets. (E.g. outdoor air volume equal to 2 ACH plus portable HEPA filtration at a clean air delivery rate--CADR--equal to 3 ACH would together meet the ultimate 5 ACH goal.)

- **Pre-COVID Ventilation Standards:** Various pre-COVID standards exist for school building ventilation.
  - Clean air ventilation is measured in air volume per unit of time, such as liters per second (L/s) or cubic feet per minute (cfm).[1]
  - The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) sets minimum outdoor air ventilation rates that often become adopted as building code. Ventilation standards for indoor air quality are defined as minimum ventilation rates that are calculated as the sum of a per-person ventilation rate and a per-area rate. With reference to per-person rates, the total volume of clean air delivery is divided by the number of occupants to derive a per-occupant rate (e.g., 200 cfm of clean air delivery / 20 occupants = 10 cfm per occupant, or 10 cfm/p), or vice-versa.
  - For schools, the ASHRAE standard calls for providing classrooms with outdoor air ventilation at a rate of at least 10 cfm/p plus another 0.12 cfm per square foot of space, with an assumed occupancy of 25-35 people depending on student age range. Using default occupant densities for schools of 25 per 1,000 square feet (sqft) for 5-8 year old students, and 35 per 1,000 sqft for 9+ year old students, as defined by the standard, this equates to 14.8 cfm per person (cfm/p) and 13.4 cfm/p, respectively, as the minimum outdoor air ventilation rate for schools. In a

[1] 1 L/s = 2.11888 CFM; 1 CFM = 0.47194745 L/s

typical 900-sqft PSB 1st grade classroom with 9-foot ceilings (presumed occupancy up to 25), for example, that standard would call for at least 358 cfm of outdoor air ventilation.

- ➢ For simplification, the HBT uses 15 cfm/p as a "rule of thumb" to approximate the 13.4 - 14.8 cfm/p levels just described. In that 900-sqft 1st grade classroom with up to 25 occupants, that rule of thumb would call for approximately 375 cfm of outdoor air ventilation.
- ➢ The International Mechanical Code/2015, which forms the basis of the current Massachusetts State Building Code, is based on this ASHRAE standard. Note that this standard has increased over time and pre-existing buildings are typically exempt from such updates until they undergo major renovations. Accordingly, school buildings built or significantly renovated more recently typically provide higher levels of outdoor air ventilation than older school buildings do.

- ❖ **Understanding ventilation rates and ACH:**
  - ➢ Air changes per hour (ACH) is derived from this ventilation rate, but is calculated based on the volume of the space in a room without regard to the number of occupants. One air change per hour (1 ACH) means that the volume of air introduced into the room each hour is equal to the total volume of the room (length x width x height).[2] 2 ACH means that the volume of air introduced each hour is twice the total volume of the room. Assuming eight foot or nine foot ceilings, the minimum outdoor air ventilation rates for newly constructed schools in cfm/p, described above, equate to approximately 3 ACH. For comparison, an average home in the U.S. has approximately 0.5 ACH, and studies across the U.S. have found that the average school classroom gets approximately 1.5 ACH (half the current ASHRAE standard for new school construction). We understand from Town of Brookline and PSB staff that ACH across PSB school buildings varies, but all are thought to presently deliver at least roughly 2 ACH, with the newly-built Florida Ruffin Ridley School designed for 4 ACH.

2. There is widespread scientific consensus favoring increased clean air ventilation as a protective measure against COVID-19 to reduce airborne transmission, alongside mask wearing, distancing, frequent hand hygiene, and other preventive measures.

- ❖ For instance, ASHRAE generally recommends reducing airborne transmission of particles of infectious aerosols through measures that include increased outdoor air ventilation, improving HVAC filtration to MERV 13 or the highest level achievable, keeping HVAC systems running for longer hours, and adding portable room air cleaners with HEPA or high-MERV filters when needed.
- ❖ Drawing upon (but also adding specificity to) this ASHRAE guidance, the Massachusetts Teachers Association (MTA) -- in its August 11th position statement on safe return to school -- recommended several measures including the following, which the Brookline Educators Union (BEU) endorsed on August 12th: operable windows, 20 cfm/p of fresh

[2] E.g., a 30 ft. by 30 ft. (900 sq. ft.) classroom with 9-ft. ceilings contains a volume of 8,100 cubic ft. 8,100 cubic ft. per hour (equal to 135 cfm) of clean air supply would yield 1.0 ACH; 16,200 cubic ft. per hour (equal to 270 cfm) would yield 2.0 ACH; etc.

air through continuously-running HVAC systems, and MERV 13 or higher filtering when recirculation of air is required.

3. Our panel has complemented these sources of information and standards with recommendations received from the HBT, based primarily on a presentation from Dr. Allen to our panel on July 17, 2020 (available here), information derived from the HBT's online tool, and follow-up clarifications and updates.

4. The MTA/BEU recommended minimum level of 20 cfm/p is generally similar to the baseline ASHRAE/code standard, when applied to reduced occupancy levels driven by 6-foot distancing. The HBT, on the other hand, has expressed higher COVID-driven clean air volume recommendations, derived from the ventilation standards, and presented here primarily in terms of ACH:

ACH	**Harvard HBT's Characterization**
<3	Low
3 - 4	Bare minimum
4 - 5	Good
5 - 6	Excellent
≥6	Ideal

Based on the scale above, the HBT recommends that school systems target ≥5 ACH of clean air as a goal for spaces occupied by multiple persons, but they simultaneously caution that these are not bright-line rules and reduced occupancy is also relevant (as reflected in the ASHRAE, building code, and MTA ventilation standards discussed above, which are entirely or primarily based on occupancy, not in terms of ACH or another room volume-based measure).

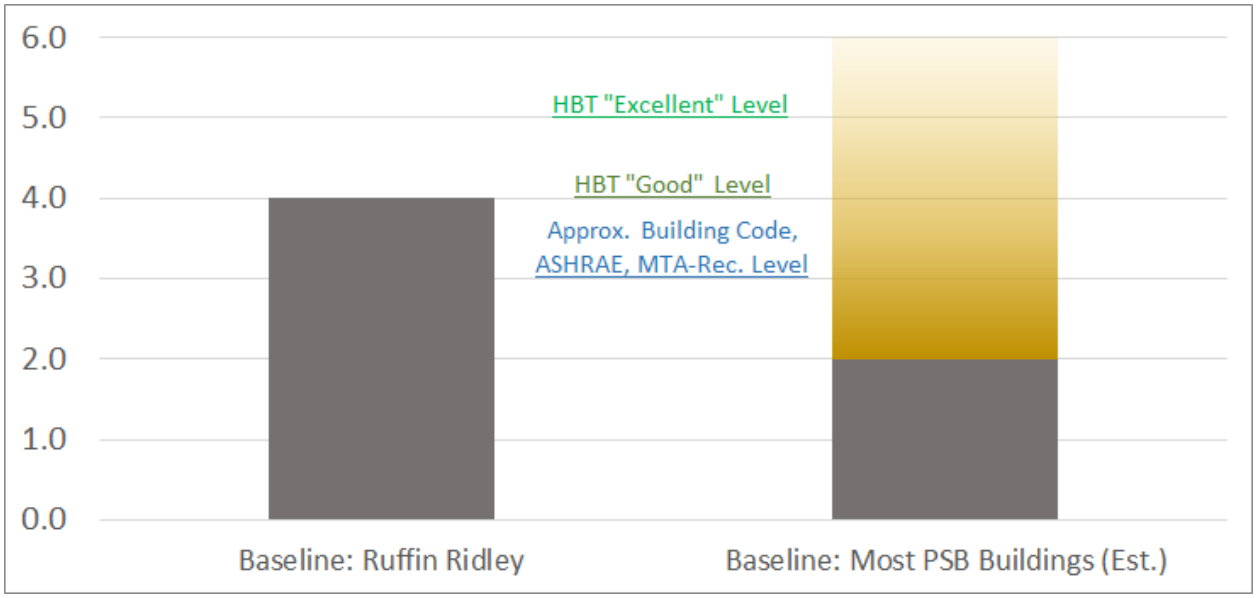
Here are two representative examples of how the standards compare:

Room Size (assuming 9 ft. ceilings throughout)	**Approximate Maximum Occupancy at 6-ft. Distancing**[3]	**ACH Per Current Mass. State Building Code for Classrooms (new or reno.)**	**ACH at MTA's 20 CFM/Occ. with Approx. Max. Occupancy at 6-ft. Dist.**	**Enhanced ACH Target at Harvard HBT's "Good" Level**	**Enhanced ACH Target at Harvard HBT's "Excellent" Level**
750 sq. ft.	15	2.5 - 3.1	2.7	4.0	5.0
1,000 sq. ft.	20	2.5 - 3.1	2.7	4.0	5.0

[3] Approximate maximum room occupancies at 6-foot distancing sourced from: https://www.cannondesign.com/massachusetts-capacity-dashboard/

5. Based on these sources, Panel 4 recommends that PSB use enhanced clean air ventilation as an additional layer of defense against airborne transmission of the virus causing COVID-19. More specifically, Panel 4 recommends that PSB use 4 ACH of clean air (the HBT's "good" level) as an initial target for use of indoor spaces this fall, as long as universal masking requirements, occupancy based on minimum 6-foot distancing, and other anti-transmission measures in place. We further recommend that PSB target 5 ACH of clean air (the HBT's recommended "excellent" level) as an ultimate goal for ongoing operations, to allow for the possibility of increased flexibility on occupancy and other measures in months to come.

- We recommend that HVAC system improvements and HEPA-filtered portable air cleaners be deployed broadly across PSB spaces wherever needed to meet such enhanced targets, the latter matched to room size by minimum CADR[4] for each unit and centrally located in rooms as much as possible (to maximize consistent mixing of air throughout the space, which an air cleaner placed in a corner will not achieve as consistently). Note that the HBT recommends that PSB avoid add-on technologies in such cleaners (e.g., plasma, ultraviolet, ion generators) and rely instead on good filtration.
- As weather and climate conditions allow, opening windows and doors can be helpful to increase clean air ventilation rates toward the targets above, with placement of fans in windows to facilitate movement of outdoor air to indoors, where necessary. (Such measures obviously are only helpful as long as room occupants are willing to keep windows/doors open and fans running, so may be less reliable as fall turns to winter.) To the extent possible, window fans, unit ventilators, and portable air cleaners should be placed/configured such that their air flows do not blow directly across any individual onto adjacent ones.
- Here is an illustration of how these various pieces come together to meet the enhanced targets our panel recommends:



[4] CADR for smoke should be used, if multiple CADRs are listed for a given unit.

(Gold shading represents impacts of various combinations of HVAC upgrades, opened windows, and portable, HEPA-filtered air cleaners across PSB indoor spaces. Approx. Building Code/ASHRAE level applies to new construction and major renovations--not pre-existing buildings.)

6. The enhanced ventilation targets we recommend here apply to classrooms and other spaces occupied simultaneously or serially by multiple people for extended periods of time. They are not meant to apply to storage rooms, hallways, single-occupant offices/work spaces, or bathrooms. Additionally, the ACH targets are set for classrooms, and are not directly applicable to large volume spaces, such as an auditorium or gymnasium.

7. With respect to bathrooms, drawing again on the HBT's advice, we recommend that all exhaust fans be checked to ensure they provide exhaust ventilation in keeping with specifications and applicable code/industry requirements, and then be operated continuously (with any bathroom windows closed) while schools are occupied--in order to negatively pressurize the bathrooms versus adjacent indoor spaces and rapidly exhaust any bathroom air contaminants to the outdoors.

8. In keeping with further advice we have received from the HBT, we recommend that PSB prioritize these ventilation and filtration improvements, along with mask wearing, distancing, and other such measures, over costly air quality mechanisms such as ultraviolet germicidal irradiation (UVGI) or significant HVAC overhauls to more tightly control temperature and relative humidity. Some of these other air quality mechanisms may ultimately be worthwhile to consider, but they are not prerequisites to a low-risk re-opening of in-person teaching and learning and are considered to be less cost-effective compared to other resources that should be prioritized such as outdoor air ventilation (mechanical and/or natural ventilation), portable air cleaners with HEPA filters, PPE, tents, and other outdoor space facilitators.

9. Our panel recommends routine monitoring of all spaces once occupied to ensure that target rates of clean air ventilation are being provided on a consistent basis, understanding that ACH levels naturally fluctuate.

- Direct measurement at outdoor air intakes through the use of a balometer can be used to help determine outdoor air ventilation rates.
- Carbon dioxide concentrations may also be a useful proxy for outdoor air ventilation rates, but the HBT reminds us that using carbon dioxide as an indicator will not capture the air cleaning of HEPA-filtered portable air cleaners and/or higher-efficiency filters in the recirculated air stream (e.g., MERV 13), because these particle removal mechanisms do not impact carbon dioxide. As such, the impact of air cleaning through filtration should be accounted for separately. For portable air cleaners, this is done by using the manufacturer-reported CADRs). For mechanical systems with MERV 13 or higher filters, a balometer can be used to measure the ventilation rate at the supply side of the system (ie, in the room) to measure the total volume of clean air being delivered, which, in this instance, will be a mix of outdoor air and air through the higher-efficiency filter.

10. Consistent with the HBT's most current advice to us, we want to emphasize again that the recommended enhancements described above are additional protective measures against airborne transmission. The ACH targets are just that - targets - and should not be viewed as "bright-line" cutoffs for opening/closing classrooms. The HBT's target ACH values include several factors that are important to consider when used:

- ❖ They are based on maximum occupancy from pre-pandemic design standards, while efforts are now being made to de-densify classrooms and encourage physical distancing.
- ❖ They assume universal mask wearing will be in place, which significantly reduces risk.
- ❖ They are approximations, recognizing that estimating or measuring ACH is dependent on many factors (e.g., daily weather conditions, whether windows and doors open/closed, location of portable air cleaners, etc.). As such, an ACH measurement that does not hit a particular target does not automatically render an indoor space unsafe for occupancy during the pandemic--especially if other strong safeguards, such as universal masking and physical distancing, are in place.

11. We note two things in closing.

- ❖ First, scientific understanding of airborne exposure and risk from SARS-CoV-2 continues to evolve. Accordingly, our panel intends to revisit this guidance and the associated evidence on airborne transmission and dose-response (i.e., infectivity) periodically and to incorporate new scientific evidence and updated recommendations, as warranted.
- ❖ Second, PSB's investment in increased clean air (and especially fresh outdoor air) ventilation in classrooms is likely to yield long-term benefits in terms of student and teacher well-being and performance long after the COVID-19 pandemic is behind us. We commend the HBT team's Schools For Health: Foundations for Student Success report as an evidence-based analysis of such long-term benefits.

Panel 4 is deeply grateful for the expert advice and ongoing support we have received from Dr. Allen and the Healthy Buildings Team at the Harvard T.H. Chan School of Public Health in developing these recommendations.