Indoor Air Quality and Ventilation Resources

Prepared by Catherine Connolly, PhD Student at Boston University School of Public Health for the Distribution to the Town of Andover and the School of Andover officials in conjunction with a partnership with Energize Andover and BU URBAN Program
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Resources for Schools and Ventilation from Universities, Government Agencies, and Engineering Societies

University researchers, government agencies, and engineering societies have compiled resources and recommendations in many documents for schools. These strategies include statements related to COVID-19 and infectious disease transmission risk reduction as well as the importance of ventilation in schools, which has been well documented for decades. Schools in the United States have been well-documented for decades to be chronically under-ventilated. The buildup of carbon dioxide, among other indoor pollutants, has been linked to cognition, academic performance, and attention reduction. The following review article and ASHRAE and Massachusetts Department of Public Health resources provide the background context and importance of ventilating schools properly. They also indicate levels at which carbon dioxide should be kept below to indicate enough ventilation and fresh air is reaching occupants, including students, staff, and teachers.

Harvard University Healthy Buildings Group
SPECIAL COVID-19 REPORT: RISK REDUCTION STRATEGIES FOR REOPENING SCHOOLS
https://schools.forhealth.org

20 QUESTIONS TO ASK BEFORE SENDING YOUR KIDS BACK TO SCHOOL
https://schools.forhealth.org/risk-reduction-strategies-for-reopening-schools/faqs/

United States Government Accountability Office
Report to Congressional Addressees
K-12 EDUCATION
School Districts Frequently Identified Multiple Building Systems Needing Updates or Replacement
June 2020
https://www.gao.gov/assets/710/707374.pdf

Massachusetts Commonwealth Government Site: **"Indoor air quality in schools: a primer for teachers"**
https://www.mass.gov/service-details/indoor-air-quality-in-schools-a-primer-for-teachers

American Society for Heating, Refrigeration, and Air Conditioning Engineers: REPORT
ASHRAE Position Document on Infectious Aerosols
Approved by ASHRAE Board of Directors April 14, 2020
https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf

(See Section 4.1, Pages 9 and 10)

ASHRAE Checklist, Reopening of Schools and Universities
https://www.ashrae.org/technical-resources/reopening-of-schools-and-universities

EPA: Heating, Ventilation and Air-Conditioning Systems, Part of Indoor Air Quality Design Tools for Schools
https://www.epa.gov/iaq-schools/heating-ventilation-and-air-conditioning-systems-part-indoor-air-quality-design-tools

Massachusetts Department of Health Ventilation Requirements for Buildings
https://matracking.ehs.state.ma.us/Environmental-Data/indoor-air-quality/ventilation.html#MyPopup
https://www.mass.gov/doc/carbon-dioxide-and-its-use-in-evaluating-adequacy-of-ventilation-in-buildings-0/download

"Heating, ventilation and air-conditioning systems in the context of COVID-19" Report by European Center for Disease Prevention and Control Report, 22 June 2020
https://www.ecdc.europa.eu/sites/default/files/documents/Ventilation-in-the-context-of-COVID-19.pdf

"Building Evidence for Health: Green Buildings, Current Science, and Future Challenges"
J.G. Cedeño-Laurent, A. Williams, P. MacNaughton, X. Cao, E. Eitland, J. Spengler, and J. Allen
https://www.annualreviews.org/doi/abs/10.1146/annurev-publhealth-031816-044420

"The Ventilation Problem in Schools: literature review" W. J. Fisk, 2017, *Indoor Air*
https://onlinelibrary.wiley.com/doi/abs/10.1111/ina.12403

"DHS Science and Technology, Master Question List for COVID-19 (caused by SARS-COV-2) Weekly Report July 21, 2020"
https://www.dhs.gov/sites/default/files/publications/mql_sars-cov-2_-_cleared_for_public_release_20200721.pdf

Case Studies of Indoor Transmission of COVID-19

These three case studies provide information about transmission spread of COVID-19 in a documented case in China in January 2020 due to a ventilation system with recirculation and little outdoor air on one side of the restaurant. A super-spreading event of COVID-19 in Washington, USA at a choir practice led to transmission of the virus, despite physical distance and attendees remaining the recommended six feet apart and use of hand sanitizer. Finally, the hair salon in Missouri showed an example of the importance of mask wearing as the hair dressers themselves contracted COVID-19 due to time spent together unmasked, while their patrons did not have traceable contraction of the virus.

Restaurant in Guangzhou, China
"To study coronavirus in the air, all eyes on a Chinese restaurant"

https://abcnews.go.com/Health/study-coronavirus-air-eyes-chinese-restaurant/story?id=70443864
"COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020"
https://wwwnc.cdc.gov/eid/article/26/7/20-0764_article

Skagit Valley Chorale Superspreading Event, Washington, USA

"Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event"
Preprint, 2020 to *Indoor Air* Journal. Shelly L. Miller, William W Nazaroff, Jose L. Jimenez, Atze Boerstra, Giorgio Buonanno, Stephanie J. Dancer, Jarek Kurnitski, Linsey C. Marr, Lidia Morawska, Catherine Noakes
https://www.medrxiv.org/content/10.1101/2020.06.15.20132027v2.full.pdf

Hair Salon in Springfield, Missouri
"Absence of Apparent Transmission of SARS-CoV-2 from Two Stylists After Exposure at a Hair Salon with a Universal Face Covering Policy — Springfield, Missouri, May 2020"
Weekly / July 17, 2020 / 69(28);930-932
On July 14, 2020, this report was posted online as an MMWR Early Release.
M. Joshua Hendrix, Charles Walde, Kendra Findley, Robin Trotman
https://www.cdc.gov/mmwr/volumes/69/wr/mm6928e2.htm

Ventilation, Indoor Air Quality, and Tuberculosis

For comparable disease models, the increase in ventilation rate at a university in China led to reduced tuberculosis transmission.
"Effect of ventilation improvement during a tuberculosis outbreak in under ventilated university buildings" Du et al. 2019
https://onlinelibrary.wiley.com/doi/full/10.1111/ina.12639

COVID-19 Transmission and Infection Risk Modeling Tools

Aerosol science researchers have provided technical ways to estimate risk of the spread of COVID-19 based on occupancy, ventilation, room size, number of infected individuals in a room or in another scenario and other important parameters that could affect transmission. These are technical documents that take time to understand, but they can be useful if used properly and in understanding the model assumptions of aerosol (small droplet) transmission.

COVID-19 Airborne Transmission Estimator Excel Spreadsheet, developed by Professor Jose L. Jimenez, UC Boulder
https://tinyurl.com/covid-estimator
https://cires.colorado.edu/news/covid-19-airborne-transmission-tool-available

"Modeling personal risk of contracting COVID19 while attending university classes" and "Notes on estimating personal risk of contracting COVID19 while attending class (updated)" by Andrew Maynard
https://medium.com/edge-of-innovation/modeling-personal-risk-of-contracting-covid19-while-attending-university-classes-7d46ce8faef2

https://therealandrewmaynard.com/2020/06/28/estimating-personal-risk-of-contracting-covid19-while-attending-class/

COVID-19 Airborne Transmission

With increasing evidence of airborne spread of the virus, hundreds of scientists united to call for the clear recognition of the airborne transmission of COVID-19 by WHO and other agencies. The distinction of droplets and aerosols is debated about the size of the actual droplets and the semantics can lead to misinformation and misinterpretation of risk and studies. Ultimately, there are many different sized droplets that humans produce from nose and mouth through breathing, talking, singing, shouting, and laughing. Without proper controls such as mask wearing, distancing, and ventilating, this increases risk of transmission. Scientists and agencies have recommendations (see later in this document) for resources.

New York Times Article "239 Experts with 1 Big Claim: the Coronavirus is Airborne"
https://www.nytimes.com/2020/07/04/health/239-experts-with-1-big-claim-the-coronavirus-is-airborne.html

End of July 2020 Op-Eds by engineers, physicians, and epidemiologists

There was a recent **Op-Ed** by Dr. Linsey Marr (civil & environmental engineering professor who studies how viruses and bacteria travel through the air) on July 30, 2020.
https://www.nytimes.com/2020/07/30/opinion/coronavirus-aerosols.html

"Opening Schools Won't Be Easy, but Here's How to Do It Safely"
By Ezekiel Emanuel, Saskia Popescu, and James Philips
https://www.nytimes.com/2020/07/29/opinion/coronavirus-schools-reopen.html

Academic papers about COVID-19 and Other Infectious Diseases Airborne Spread

"It is Time to Address Airborne Transmission of COVID-19"
Lidia Morawska and Donald K. Milton
https://academic.oup.com/cid/article/doi/10.1093/cid/ciaa939/5867798

Comprehensive review by indoor air researchers with many resources cited:
"How can airborne transmission of COVID-19 indoors be minimised?"
Lidia Morawska, Julian W. Tang, William Bahnfleth, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie Dancer, Andres Floto, Francesco Frachimon, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Jark Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Maosheng Yao
https://www.sciencedirect.com/science/article/pii/S0160412020317876

Identification of SARS-CoV-2 RNA in Healthcare Heating, Ventilation, and Air Conditioning Units. Preprint, 2020.
Patrick F Horve, Leslie Dietz, Mark Fretz, David A Constant, Andrew Wilkes, John M Townes, _ Robert G Martindale, William B Messer, Kevin Van Den Wymelenberg
https://www.medrxiv.org/content/10.1101/2020.06.26.20141085v1

“Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings”
Hua Qian and Xiaochong Zheng
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6072925/

Op-Eds about School Reopening during June-July 2020

Researchers and public health officials have written different Op-Eds about reopening schools at different times during this discourse. Several are provided here as of mid-July 2020, and these can evolve and be supplemented over time leading up to September 2020.

Schools were an Afterthought, Juliette Kayyem
https://www.theatlantic.com/ideas/archive/2020/07/reopening-bars-easy-schools-are-difficult/613861/
Washington Post, Joe Allen “Yes, Kids Should Be Going Back to School in the Fall”
https://www.washingtonpost.com/opinions/2020/06/24/yes-kids-should-be-going-back-school-fall/
VOX “I’m an epidemiologist and a dad. Here’s why I think schools should reopen.”
https://www.vox.com/2020/7/9/21318560/covid-19-coronavirus-us-testing-children-schools-reopening-questions

“Schools: what’s it going to take?” by Emily Oster
https://emilyoster.substack.com/p/schools-whats-it-going-to-take

EPA Webinar Links

Let’s Clear the Air: Using Ventilation Practices to Promote Healthy IAQ in Schools
IAQ, Ventilation, and Schools
July 30, 2020

https://schools.forhealth.org

https://www.epa.gov/iaq-schools/indoor-air-quality-tools-schools-action-kit

https://www.epa.gov/iaq-schools/framework-healthy-indoor-environments-schools

https://www.epa.gov/iaq-schools/forms/webinar-healthy-schools-healthy-students-taking-action-improve-iaq-your-school

https://www.ashrae.org/technical-resources/resources

https://www.nist.gov/services-resources/software/fatima

https://aiha-assets.sfo2.digitaloceanspaces.com/AIHA/resources/Guidance-Documents/Reopening-Guidance-for-General-Office-Settings_GuidanceDocument.pdf

https://www.achrnews.com/articles/142890-comprehensive-guide-hvac-service-calls-during-covid-19

https://www.centerforhealthsecurity.org/our-work/publications/2020/filling-in-the-blanks-national-research-needs-to-guide-decisions-about-reopening-schools-in-the-united-states

https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf

https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf

Lessons about School and Reopening from Other Countries

The United States has not contained the spread of COVID-19 by summer 2020 and leading up to the anticipated reopening of schools for the academic year 2020-2021. Other countries have reopened schools during the pandemic through a series of controls and logistics. Many of these countries also had reduced community transmission, leading to reduced risk of transmission in school settings. There have been mixed results depending on the country and the case studies within them, but there are lessons to be learned from other countries.

NYT Article:
How to Reopen Schools: What Science and Other Countries Teach Us
The pressure to bring American students back to classrooms is intense, but the calculus is tricky with infections still out of control in many communities.

https://www.nytimes.com/2020/07/11/health/coronavirus-schools-reopen.html

“How Schools in Other Countries Have Reopened” By Madeline Will
https://www.edweek.org/ew/articles/2020/06/11/how-schools-in-other-countries-have-reopened.html

“How to Safely Reopen Colleges and Universities During COVID-19: Experiences From Taiwan”
Shao-Yi Cheng, C. Jason wang, April Chiung-Tao Shen, Shan-Chwen Chang, 2 July 2020
https://www.acpjournals.org/doi/full/10.7326/M20-2927

COVID-19 in schools–the experience in NSW
Prepared by the National Centre for Immunisation Research and Surveillance (NCIRS)26 April 2020
http://ncirs.org.au/sites/default/files/2020-04/NCIRS%20NSW%20Schools%20COVID_Summary_FINAL%20public_26%20April%202020.pdf

News Reports and Articles about School Reopening and Indoor HVAC/Filtration Requirements

With the increasing public knowledge of the airborne transmission of COVID-19, researchers, engineers, and government officials have stressed the importance of engineering controls in HVAC systems to combat the infectious disease spread. The following articles highlight the potential strategies that different groups are using to carry this out, including in hospital lobbies and in malls, as well as filter and air cleaner recommendations from several professors. To be clear, this is not a required recommendation for the Town or the School, rather this is to provide resources based on actions taken by other actors.

Effectiveness of Air Cleaners for Removal of Virus-Containing Respiratory Droplets: Recommendations for Air Cleaner Selection for Campus Spaces
Sophie Kirkman, John Zhai, Shelly L. Miller, May 31, 2020
https://shellym80304.files.wordpress.com/2020/06/air-cleaner-report.pdf

"Could a New Ultraviolet Technology Fight the Spread of Coronavirus?"
Columbia researcher David Brenner believes far - UVC light—safe for humans, but lethal for viruses—could be a 'game changer.'
Article updated June 30, 2020, By Carla Cantor
https://news.columbia.edu/ultraviolet-technology-virus-covid-19-UV-light

"Maintaining School HVAC Systems to Address COVID-19"
By Timothy Lehman and Mark Hopf
https://fhai.com/insights/maintaining-school-hvac-systems-to-address-covid-19/

Sophie Tatum "School infrastructure report raises questions about returning to classrooms"
https://abcnews.go.com/Politics/school-infrastructure-report-raises-questions-returning-classrooms/story?id=71072180

LA Times: "Scientists say WHO ignores the risk that coronavirus floats in air as aerosol"
https://www.newsbreak.com/news/1594826905763/scientists-say-who-ignores-the-risk-that-coronavirus-floats-in-air-as-aerosol

"Indoor spread of COVID-19 can be lessened, experts say" By Mary Van Beusekom
https://www.cidrap.umn.edu/news-perspective/2020/05/indoor-spread-covid-19-can-be-lessened-experts-say

New York State Malls Requirement
"Most malls can't use HEPA filters, but there's an easier way to protect shoppers from COVID-19 particles"
https://www.businessinsider.com/cuomos-hepa-filter-mall-suggestion-may-not-be-possible-2020-6

Malls: New HVAC requirement puts 'the nail in the coffin' by Samantha Christmann and Jonathan D. Epstein
https://buffalonews.com/business/malls-new-hvac-requirement-puts-the-nail-in-the-coffin/article_57102df0-bb4b-11ea-9c21-93943cee2aa4.html