

HEALTHY LEARNING ENVIRONMENTS



Delos[™]

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EXECUTIVE SUMMARY

Our schools and universities represent a massive and untapped opportunity to promote the health and well-being of our children. Children and adolescents spend a large portion of their time inside school buildings, during a period of their lives when they are especially vulnerable to environmental influences on their development. On average, children in the U.S. spend about six hours per day, or 1,000 hours per year in school. Many school buildings in the U.S. are old and not up to date; the average age of U.S. school buildings since the time of construction is 44 years. This often results in substandard conditions and environments that fail to help students thrive. Leveraging physical environments to support rather than harm student's health can have a profound societal impact both today and for the future.

Delos recognizes this as a tremendous opportunity to implement preventive interventions so that our school buildings can be healthier. This white paper aims to address two questions:

1

What factors can help optimize learning environments?

2

How can healthier spaces—and behaviors inside them—help position students for success?

To answer these questions, we overview key components of healthy learning environments—spanning air, water, lighting, thermal comfort, noise, biophilia, materials, and the neighborhood environment—and share emerging scientific insights on how our physical environments affect the health and academic performance of students and the well-being of teachers and staff. In addition, we discuss a variety of social and psychological factors—attention, stress, and social-emotional development—that can significantly impact students' success as they progress through their formal education and beyond. Finally, we offer evidence-based strategies that can be implemented in pre-kindergarten (pre-K), school, and university buildings to promote health and well-being for all.

INTRODUCTION

Educational environments play a critical role in helping students learn, shaping their everyday experiences and affecting their development, health, and overall well-being. There are around 137,000 educational institutions in the U.S. today. Between pre-K and college, children and adolescents spend around six hours per day, or 1,000 hours per year, in school (out of the ~6,000 hours in a calendar year, students in lower grades spend less and those in higher grades spend more time in school). In fact, time spent in learning environments is second only to time spent at home for this age group. By the time a typical student graduates from high school, they will have spent more than 15,000 hours of their life in school. In the 2020-2021 academic year, approximately 56.6 million students are projected to attend pre-K through high school and 19.7 million are estimated to be enrolled in higher education institutions . How can we optimize the learning environments in which the next generation will spend a quarter of their waking hours?

The current conditions and physical state of many learning facilities are far from optimal, with different factors at play. First of all, school density is higher than that of many other types of buildings; in fact, a typical school has about four times the number of occupants as a typical office building for the same amount of floor space. More occupants per square footage of space means greater levels of carbon dioxide generated through breathing; less physical space as well as more frequent and closer interactions between people, which can contribute to the spread of respiratory infections and illnesses; and more wear-and-tear of the building itself, making it “age” faster. Second, many school

By the time a typical student graduates from high school, they will have spent more than 15,000 hours of their life in school

buildings are old. As of 2012, the average age of U.S. public school buildings since the time of construction was 44 years, and the average age since renovation was 12 years. Buildings that are old are more likely to have issues that can negatively impact student health: they may not adhere to more recent building standards and best practices, and conditions can deteriorate without extensive preventive maintenance. Furthermore, up to a third of public schools lack basic maintenance and are in poor shape: among schools with permanent buildings, 14 to 32% rated their building systems/features as being in fair or poor condition.

Furthermore, many schools use temporary buildings due to funding limitations and fluctuating enrollment levels. Many of these temporary buildings have suboptimal conditions that present challenges with respect to healthy environments. In fact, among public schools with portable (temporary) buildings, the building systems/features were rated as being in fair or poor condition in their portable buildings in 29 to 45 percent of the schools.

Common physical issues in school buildings include:

- mold problems;
- unhealthy building materials;
- outside air seeping indoors;
- lack of windows and inadequate or poor lighting;
- poor drinking water quality;
- absence of or unreliable AC and heating systems;
- inadequate ventilation and filtration systems;
- inadequate insulation to protect from outdoor noise;
- disconnection from nature.

Thus, many students spend the majority of their waking hours in poor-quality environments, over a period of 12 or more years. Unsurprisingly, unhealthy or sub-optimal learning environments have been associated with poorer health and performance outcomes, such as asthma and allergy

NATIONAL CENTER FOR EDUCATION STATISTICS 2012-2013 SURVEY



of public schools needed to spend money on repairs, renovations, and modernizations to put the schools' onsite buildings in good overall condition

total amount needed was approximately **\$ 197 BILLION**

the average dollar amount for schools needing to spend money was about **\$ 4.5 MILLION PER SCHOOL**

symptoms, slower recovery from stress and mental fatigue, headaches and concentration issues, learning problems, lower test scores, among others. In light of these findings, it is important to note that students, especially young children, can be especially vulnerable to unhealthy physical environments.

During early childhood, a rapid and extensive development of organs and systems takes place—which makes this period disproportionately important to a child’s future health. Infants and children have an increased hand-to-mouth activity and spend more time on the floor, which can increase their exposure to harmful chemicals. Younger children also consume more air, food, and water relative to their body weight, which increases the relative dose of potentially toxic exposures. The fragility and plasticity of younger children’s organs and systems leaves them vulnerable to harmful influences and disruptions that may affect their future function.

It is also important to note that children’s natural defenses against potential toxins are less developed than they are in adults, meaning that children are more likely to be harmed when exposed to pollutants. This is because children have highly permeable skin, lower filtration efficiency in their nasal passages, a more permeable blood-brain barrier, and not yet fully-developed organs and processes (e.g., digestive system and kidney clearance) that are involved in defending the body from toxins and pathogens. Developmental processes and sensitivity to sub-optimal environmental conditions carry on beyond early childhood, as children and adolescents continue to grow physically and develop psychologically throughout their years at school.

The bright side is that because the physical environment has a significant influence on children, schools have a unique opportunity to positively impact students by creating safe, healthy, and enjoyable learning environments that enable kids to thrive in their health, well-being, and academic performance.

Young children
can be especially
vulnerable
to unhealthy
physical
environments



Finally, it is important to note that not all students experience poor learning environments to the same extent. Low-income schools and schools serving Black, indigenous, and people of color (BIPOC) students are more likely to have unhealthy conditions due to significantly lower funding compared to schools with a predominantly white student population, and because they are often located in neighborhoods with poorer air quality and greater levels of noise. For example, based on a study of nearly 85,000 public schools (grades K-12) across the United States, students from racial/ethnic minorities disproportionately suffer from exposure to air neurotoxicants in school. In addition to posing health risks, this can also impact school performance and future potential. It is not just students that are negatively affected but also educators and staff—due to factors beyond the physical school environment. For example, teachers in schools that are located in low-income neighborhoods more often report occupational burnout, and take more long-term sick leave. While it may be difficult to meaningfully modify neighborhood environments and social inequality, schools themselves can and should be improved.

The physical environments of schools have the potential to make an enormous impact on the health, performance, and well-being of millions of children, adolescents, teachers and staff in the U.S., and hundreds of millions throughout the world. By working to improve the quality of our learning environments, we can help students achieve not only their full academic potential but also help ensure they are healthy, happy and well throughout their learning years.

We can help students achieve not only their full academic potential but also help ensure they are healthy, happy and well

Education and Covid-19: How Delos Is Helping to Advance Health and Safety in America's Schools

Small aerosolized particles carrying SARS-CoV-2 (the virus that causes Covid-19) can remain suspended in the air and persist in aerosol form for long periods of time indoors. Therefore, air purification systems are considered by many to be a critical supplementary approach to reducing transmission rates by remediating airborne pollutants and contaminants. While schools have taken significant measures to address surface and behavioral viral load through extensive cleaning protocols, social distancing and mask wearing, to name a few, the critical aspect of airborne viral transmission remains largely unaddressed.

Recognizing the need for research-backed solutions across the education sector, Delos is collaborating with schools and universities around the globe to integrate air purification and other solutions in response to Covid-19. In fact, Delos has provided over 100,000 Delos Powered by Healthway Compact air purification units to schools across the country, along with evidence-based recommendations on necessary measures for safer school reopening. Delos Powered by Healthway Compact air purification units capture ultrafine particles and can reduce particles that carry airborne bacteria and viruses. Furthermore, the portable nature of these air purification units provides a scalable, implementable, and highly efficient solution, as they do not require schools to undergo heavy renovations or upgrades to their aging buildings and existing HVAC systems.

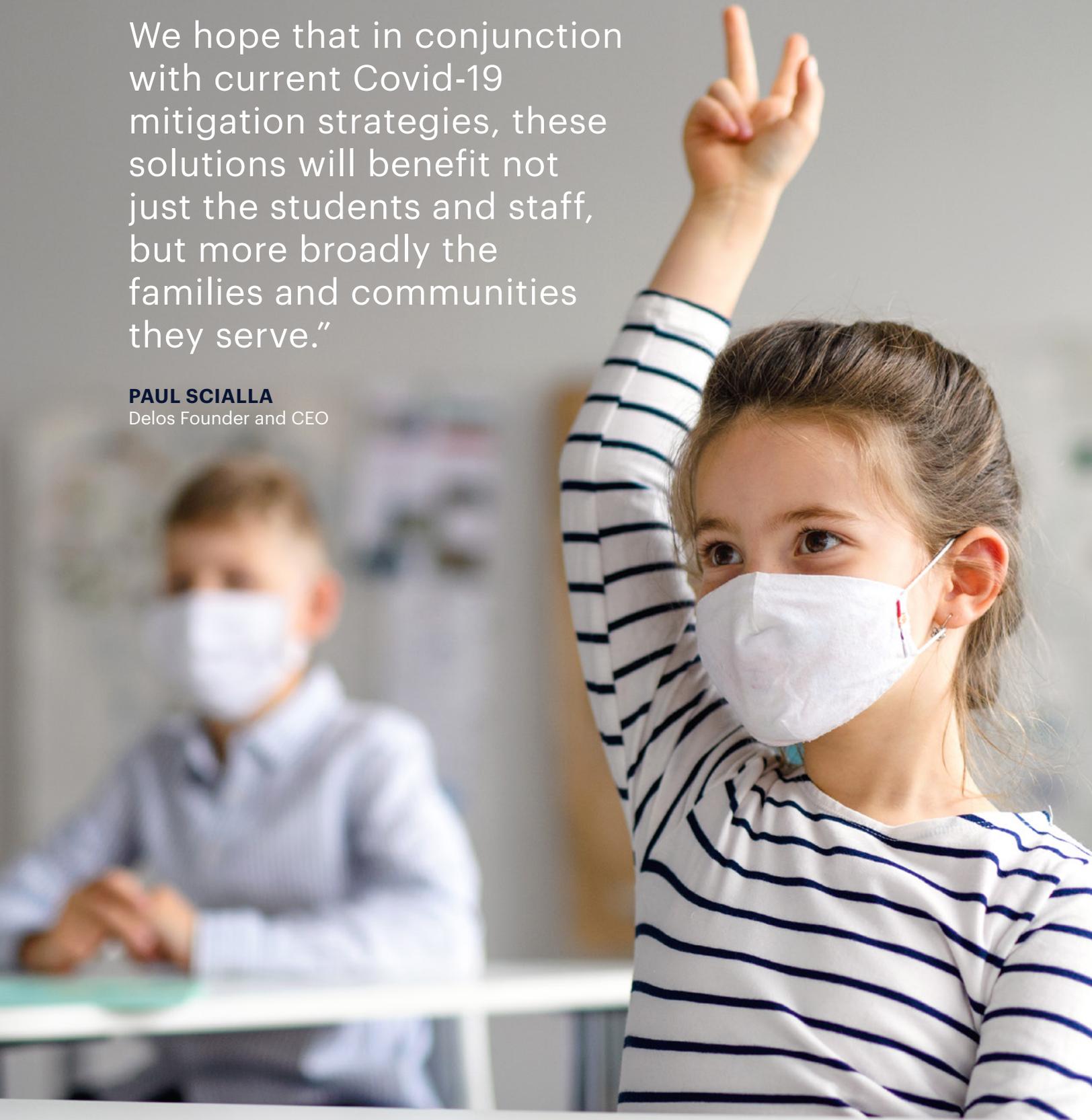
"We hope that in conjunction with current Covid-19 mitigation strategies, these solutions will benefit not just the students and staff, but more broadly the families and communities they serve," said Delos Founder and CEO Paul Scialla. "Ultimately, we hope that school systems around the world will follow the model example set by each of these schools, prioritizing cleaner air and healthier learning environments."

Delos has provided over 100,000 Delos Powered by Healthway Compact air purification units to schools across the country

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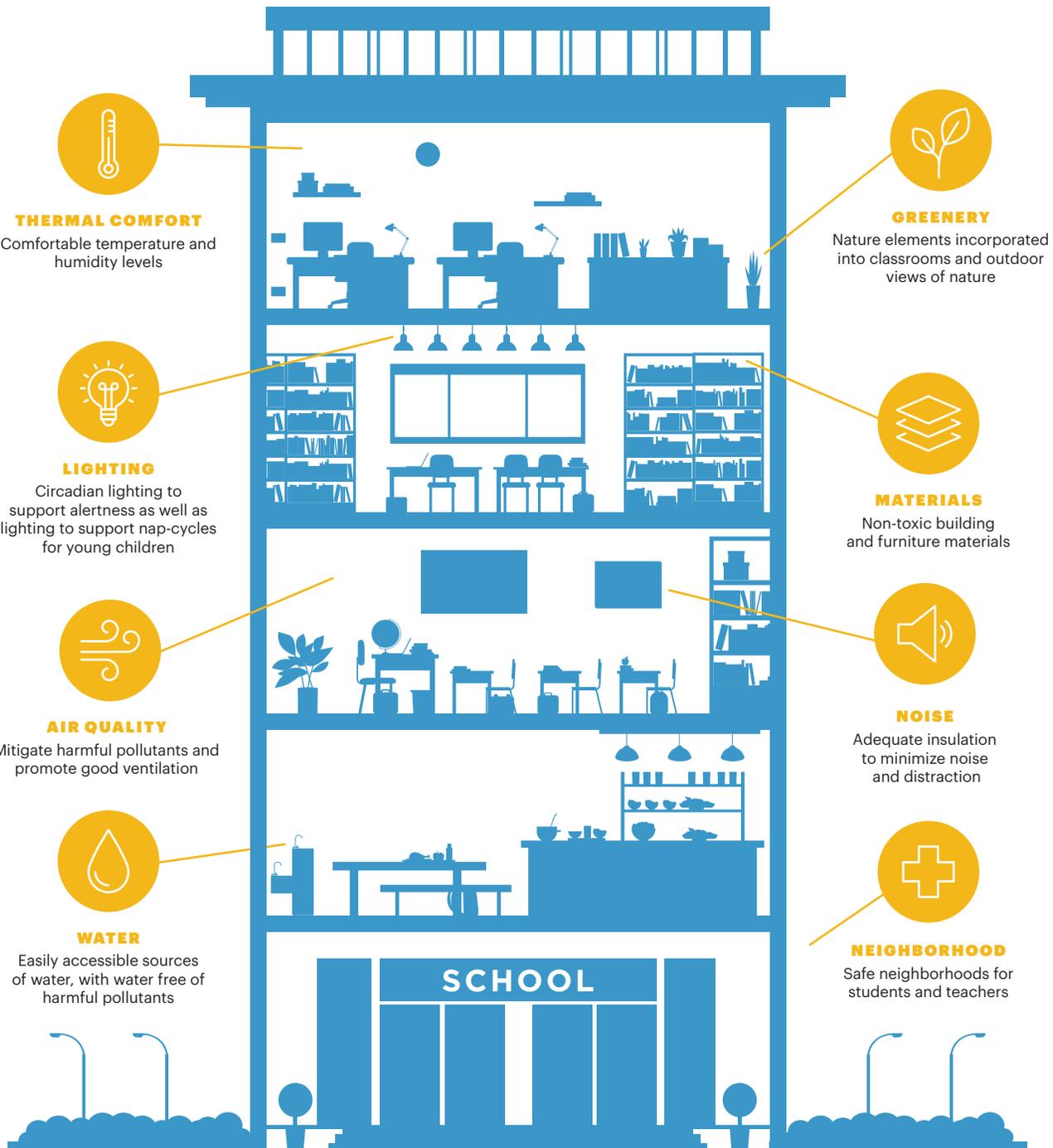
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PAUL SCIALLA
Delos Founder and CEO



OPTIMAL LEARNING ENVIRONMENTS

Key Features of Healthy Learning Environments





ENVIRONMENTAL FACTORS THAT IMPACT STUDENT HEALTH AND PERFORMANCE

We have long been aware of how our physical environments can impact our health and well-being. With millions of students spending a quarter of their lives in learning environments, we now recognize schools as a critical site to improve both individual and population health. Below, we summarize how different factors of the school environment—such as air and water quality, lighting, thermal environment, access to greenery, noise levels, materials within school buildings, and the environment around schools—can impact student health. We also map out some of the ways in which school administrators, teachers, and to some extent parents, can work together to promote learning environments that are healthy for all. We are also dedicating a special ‘Covid-19’ section to discuss environmental and behavioral strategies that can help reduce the risk of the novel coronavirus at school.



Special Section: **Covid-19**

Covid-19 has impacted the school environment in numerous ways. Many schools have transitioned from traditional in-person education to online learning; a necessary prevention tool during certain phases of the pandemic. However, in-person learning is critical to children’s psychosocial and educational development, and remote learning can impact student life and well-being in a variety of ways. In addition to academic instruction, schools also offer a platform for social interaction where children learn to manage their emotions, establish and maintain positive relationships, make responsible decisions, develop crucial communication skills, and improve self-esteem and feelings of self worth and belonging. In-person interactions at school also help students establish and maintain good relationships. These interactions are very difficult to replicate through distance learning, and this can affect general emotional well-being and lead to less externalizing behaviors, depression and anxiety. Recognizing the importance of in-person instruction, many schools returned to either traditional or hybrid learning where possible, and depending on community transmission rates. In this situation, there are various environmental and behavioral strategies that can help to reduce risk.

Many factors can make it difficult for schools to control the potential spread of respiratory viruses such as Covid-19

According to a comprehensive and ongoing survey conducted by the data service burbio.com, as of January 2021, 32.6% of students will be attending schools offering traditional, in-person learning every day, 49.6% of students will be attending schools that only offer virtual learning, and 17.8% of students will be attending schools that offer a hybrid schedule with 2-3 in-person learning days per week.

Below we also share a list of environmental factors that can influence the spread and transmission of SARS-CoV-2 (the virus that causes Covid-19), as well as strategies to help mitigate risk.

STRATEGIES TO MITIGATE THE RISK OF COVID-19

Many factors can make it difficult for schools to control the potential spread of respiratory viruses such as Covid-19. Schools are often crowded; facilities and resources such as bathrooms, books, and desk space are shared by large groups of people; and young children are more likely to engage in behaviors that are associated with the risk of viral transmission, such as lack of (or improper) handwashing and tendency to play in close proximity to others.

Strategies to help ensure healthier schools include:

1. De-densify school buildings
2. Increase ventilation. For example, in preparation for the 2020-2021 school year, NYC Department of Education conducted a survey of 64,000 classrooms and found that more than 95% had ventilation that was in good working order. Repairs or improvements were ordered for classrooms that needed them, ensuring that each classroom had at least one functioning mode of ventilation (e.g., an operable window, a type of mechanical ventilation, or a combination of both).
 - Bring in more fresh outdoor air
 - If possible, considering holding classes and other activities outside

3. Filter indoor air using advanced technologies
 - The virus causing Covid-19 (SARS-CoV-2) ranges in size from 0.06 to 0.14 microns, which is significantly smaller than particles that are captured by conventional filters in most mechanical systems. These particles can, however, be captured by air purifiers with advanced filtration efficiency, such as electrostatic or HEPA filtration.
4. Ensure regular and sufficient maintenance of ventilation and filtration systems
5. Consider advanced strategies for improving air quality
 - Experts recommend maintaining indoor humidity levels between 40% and 60% in order to curb the survival and spread of SARS-CoV-2
6. Install no-contact infrastructure
 - Install touchless technologies for dispensers of hand soap, hand sanitizer, and paper towels
7. Focus on bathroom hygiene
 - Keep bathroom doors and windows closed and run exhaust fans at all times
 - Install lids on all toilet seats and keep the lids closed, particularly during flushing

It is also essential to continue to follow public health recommendations

Of course, while it is important to ensure that the school buildings are healthy, it is also essential to continue to follow public health recommendations, such as:

- Wear face coverings
- Wash hands frequently
- Maximize physical distancing and group distancing
- Disinfect high-touch surfaces and objects
- Prioritize staying home when sick
- Develop plans for when there is a case identified at school
- Promote viral testing and antibody testing



Special Section: **Remote Learning**

While this white paper focuses on school environments, it is important to note that learning environments are not limited to physical school buildings. Many students attend some or all of their classes remotely, especially during the Covid-19 pandemic. While the majority of data and research presented in the sections below was conducted on students in traditional learning spaces, the associations between physical environmental factors and health and performance apply universally. For example, a student studying in a poorly ventilated bedroom at home is likely to experience similar levels of poor concentration and cognitive performance as a student in a poorly ventilated classroom. Thus the solutions that we propose for making learning environments healthier also apply to the many homes across the country that have become micro-learning environments for millions of students.



Indoor Air Quality

Children are especially vulnerable to air pollution's adverse effects

Air Pollution Isn't Just an Outdoor Problem: When we think about air pollution, we usually imagine the outdoor environment. However, the concentration of air pollutants can in fact be several times higher indoors compared to outside. Various factors in school settings—such as students spending extended amounts of time in close proximity, the presence of pollutants from different activities, and limited budgets and resources to address indoor air quality issues, to name a few—create a unique environment for managing indoor air quality.

Clean Air Is Essential to Our Health: Air pollutants can contribute to a range of short-term symptoms, such as eye, nose and throat irritation and headaches, as well as long-term adverse health outcomes, such as diabetes, cardiovascular disease, lung cancer, and respiratory issues. They can even play a role in premature mortality: air pollution is considered one of the greatest killers of our generation. Children are especially vulnerable to air pollution's adverse effects due to their developing bodies and behaviors, as discussed in previous sections.



Healthy Air, Healthy Minds: Air quality isn't just important for physical health. Growing evidence suggests that exposure to air pollution negatively affects children's neurodevelopment. And research has linked better air quality to higher productivity and better performance among students, such as improved concentration and test scores.

An estimated 41% of districts need to update or replace heating, ventilation, and air conditioning (HVAC) systems in at least half of their schools, representing about 36,000 schools nationwide that need HVAC updates

Our Schools Present Air Quality Concerns: An estimated 41% of school districts need to update or replace heating, ventilation, and air conditioning (HVAC) systems in at least half of their schools, representing about 36,000 public schools (grades K-12) nationwide that need HVAC updates. According to the last School Health Policies and Practices Study (SHPPS) conducted by the CDC, only 48.9% schools reported implementation of indoor air quality management programs in 2016. However, in response to the Covid-19 pandemic, many schools are now prioritizing air quality and ventilation. In fact, the District of Columbia school system has spent \$24 million on HVAC updates in preparation for school re-opening.



According to the Centers for Disease Control and Prevention, only 48.9% schools reported implementation of indoor air quality management programs in 2016

AIR EXPOSURES

1

Infiltration of Ambient Air Pollution: Indoor air quality is significantly influenced by outdoor air quality, due to the infiltration of air from outdoors. However, research suggests that the concentration of toxins, allergens and other pollutants can be up to five times higher indoors than it is outside. Studies suggest that outdoor air pollution can negatively influence students' attendance and performance. For example, one study of public schools in Michigan found that schools located in areas with the highest air pollution levels had the lowest attendance rates and the highest proportions of students failing to meet state educational testing standards.

2

Allergens & Asthma Triggers: Indoor environmental exposures to substances such as pollen, dust mites, and pests—which are commonly present in schools—can cause allergic reactions in many people. Common symptoms of allergic reactions are similar to those of a cold, including a runny nose and congestion, sneezing, and watery eyes. Asthma often accompanies allergies, and asthma symptoms in the lungs and airways can be triggered by the same allergens.

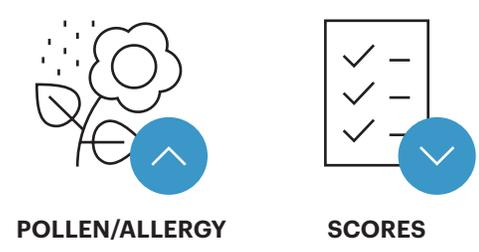
Effects of Poor Indoor Air Quality on Students

SCHOOL DAYS LOST PER YEAR Among children and adolescents



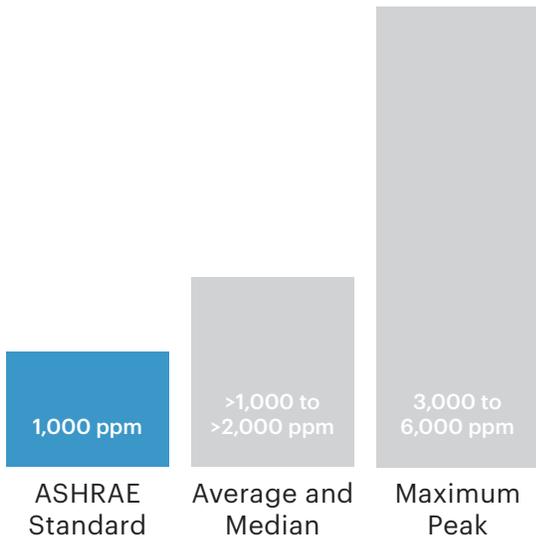
EDUCATIONAL OUTCOMES

Seasonal pollen allergies are linked to poorer cognitive performance



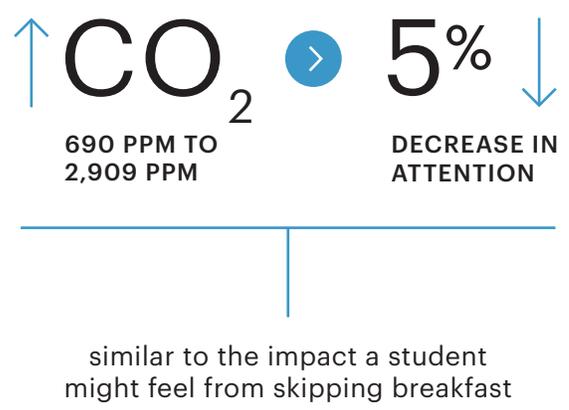
CO₂ LEVELS IN CLASSROOMS

Often exceed recommended maximums



INCREASED LEVELS OF CO₂

Can lead to reduced attention in students*



*Study conducted among students aged 10-11 years

3

Dampness and Mold: Building dampness and mold in schools have been associated with increased respiratory health symptoms such as coughing, wheezing and allergic rhinitis; greater prevalence of asthma; and respiratory-related absenteeism. A study of over 1,000 school children found that the concentration of mold found in floor dust was associated with headache, dizziness, and concentration problems.

4

High Levels of Carbon Dioxide: Carbon dioxide (CO₂) levels are a good indicator of the availability of fresh air in an indoor space; without fresh air, it is harder for indoor pollutants to disperse, and their levels can build up. CO₂ can also have a direct negative impact on cognitive performance; elevated levels of CO₂ have been associated with increased student absence and wheezing among children attending day-care. Higher CO₂ levels in the classroom have also been linked to poorer concentration and cognitive performance, among other indicators of academic performance.

ASHRAE recommends
that indoor CO₂
concentrations be
maintained below 1,000
parts per million

Higher levels of CO₂ are also a proxy for poor ventilation. Lower ventilation rates have been linked to more upper respiratory symptoms and a higher number of missed school days caused by respiratory infections; greater prevalence and incidence of symptoms of sick building syndrome ; greater mean number of school nurse visits caused by respiratory symptoms; as well as increased symptoms of asthma and risk for viral infections.

The EPA estimates that
70,000+ schoolrooms in use
today have high short-term
radon levels

5

Radon: Radon is a colorless, odorless, radioactive gas that is released from the breakdown of radioactive elements in rocks and soil, and can seep into buildings from cracks in floors, construction joints, and/or around service pipes. According to EPA estimates, radon is the number one cause of lung cancer among non-smokers and is the second leading cause of lung cancer in the U.S., after smoking. Radon is estimated to cause around 21,000 deaths a year. Studies have shown that the risk of lung cancer in children resulting from exposure to radon may be up to three-fold higher when compared to similarly exposed adults, due to differences in lung shape and size.

SCHOOL SOLUTIONS

Ventilation: Ventilation systems can play an important role in diluting pollutant concentrations that have built up indoors by bringing in fresh air from the outdoors. Studies of schoolchildren suggest that increasing the outdoor air supply can meaningfully improve their academic performance at relatively low energy and capital costs.

Filtration: Different air purification technologies are necessary to effectively target different types of pollutants. Delos Compact units, for example, have patented technology that utilizes electrostatic precipitation combined with mechanical filtration to capture and deactivate bacteria and viruses, as well as trap particulate matter (PM2.5 and PM10) and ultrafine particles as small as 0.007 microns at 99.99% efficiency*.

Indoor Air Quality Monitoring: An indoor air quality monitor can help track particulate matter pollution and other air quality parameters across the school. Many consumer-grade, easy-to-use monitors are available online.

Outdoor Air Quality Monitoring: It is important to stay informed about local outdoor air quality. If the outdoor air quality is poor, keep all classroom windows closed, and close the fresh-air intake of the AC unit (if applicable).

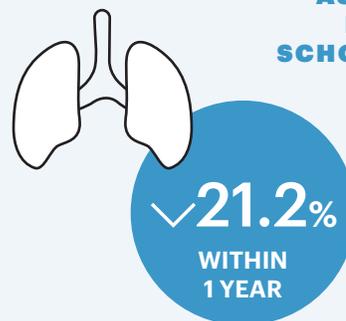
* Individual particle sizes and specific particle ranges may have different filtration efficiency rates. SARS-CoV-2, the virus that causes Covid-19, ranges in size from 0.06-0.14 microns.

One experiment found that doubling the outdoor air supply rate to classrooms improved schoolwork performance in terms of speed by about 8%

Among school districts that implemented the EPA's Indoor Air Quality Tools for Schools Program:

- In the Hamden school district, absenteeism rates fell by more than half within a single year (from 484 days to 203 days).
- In the North Haven school district, school nurse visits were reduced by 11% (4,978) and reported respiratory cases declined by 48%.
- The Chester school district saw a decrease in health office visits related to headaches, dizziness, and sinus difficulties among both students and staff.

REDUCTION IN ASTHMA CASES IN HARTFORD SCHOOL DISTRICT





Water Access and Quality

Water is vulnerable to pollution that can harm our health as well as the environment

Water Is an Essential Building Block of Life: Access to water that is free of inorganic, organic, and biological contaminants is essential for maintaining optimal health. Humans are mostly made of water – in fact, water comprises over 50% of an adult's body weight. However, water is vulnerable to pollution that can harm our health as well as the environment. These contaminants, especially in high doses, can be toxic and impair health and overall quality of life.

Testing drinking water quality is a voluntary decision, and many unregulated schools and child care facilities may not be testing their drinking water. In fact, there are approximately 98,000 public schools (grades K-12) and 500,000 child care facilities not regulated under the Safe Drinking Water Act (SDWA).

Water Contamination Is Possible from Numerous Sources: Even today, with our advanced treatment technologies, it is still challenging to ensure that everyone has access to water that is free of contaminants. For one thing, conventional water treatment systems do not always remove contami-

Despite the fact that water quality in the U.S. is quite good compared to many other countries, there are still many risks for contamination



nants effectively. Furthermore, in addition to pollution from industry and agriculture, the treatment and distribution systems meant to keep drinking water safe can also be potential sources of contamination, as pollutants can be introduced through these water distribution infrastructures. Finally, because scientific knowledge concerning new water contaminants and safe exposure levels is always evolving, it is challenging for regulations to keep pace.

Americans Face Ongoing Water Challenges: Despite the fact that water quality in the U.S. is quite good compared to many other countries, there are still many risks for contamination. The American Society of Civil Engineers gave U.S. drinking water infrastructure a “D” grade in 2017, citing its aging and deteriorating infrastructure, and the EPA estimates that over \$743 billion are needed for nationwide water infrastructure improvements. In fact, each year since 1982, up to 28% of Americans have been affected by water that is in violation of health-based water quality standards.

WATER EXPOSURES

- 1** **Lack of Access to Clean Drinking Water:** While the United States Department of Agriculture (USDA) requires schools participating in the National School Lunch Program and the School Breakfast Program to make free drinking water available to students during meal service, many schools still lack readily available, clean drinking water. Lack of access may be due to an inadequate number or poor placement of drinking fountains, broken or poorly maintained water fountains, and poor water quality.

DEHYDRATION

A study conducted among students aged 9 to 11 years found that:



of students were in a state of mild dehydration at the beginning of the school day.

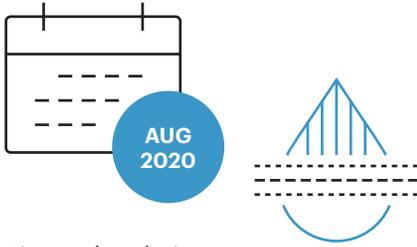


As levels of dehydration increased, students' short-term memory decreased.

- A state of mild dehydration is defined as a 1-2% loss of body water, whereas moderate dehydration is when the loss is in the range of 2-5%. Being dehydrated by just 2% can impair performance in tasks that require attention, psychomotor, and immediate memory skills.
- A study conducted in 59 middle schools and high schools in Massachusetts found that less than half of the schools met the federal Healthy Hunger-Free Kids Act requirement for free water access during lunch. Slightly more than half (59%) met the Massachusetts state plumbing code, which specifies the minimum number of water sources per a given number of students. While schools, on average, provided at least 1 water source per 75 students, within each school almost a third of these water sources were broken or appeared unclean.

- 2** **Lead:** Water pipes are often made from lead, which can leach into water if the pipes are corroded. Young children are particularly vulnerable to lead exposure because the physical and behavioral effects of lead occur at lower exposure levels compared to adults. Low levels of lead exposure have been linked to behavior and learning problems, lower IQ and hyperactivity, slowed growth, and anemia among children; in rare cases, exposure can also cause seizures, coma, and even death. As of February 2018, 24 U.S. states and the District of Columbia have school drinking water lead testing programs.

Based on available data from 12 states, a report conducted by the Harvard T.H. Chan School of Public Health and the Nutrition Policy Institute at the University of California found that **12%** (57,152) of all water samples tested had lead concentrations at or above the states' action level, and **44%** (4,777) of schools tested had one or more water samples at or above the states' action level.



Five schools in Ohio and four schools in Pennsylvania detected *Legionella* in their water supply. **Legionella bacteria** can cause **Legionnaires disease**—a type of **severe pneumonia**—if small water droplets containing the bacteria become aerosolized and are inhaled.

3

Bacterial Contaminants: Regular water use helps prevent water stagnation by bringing in new water, along with disinfectant substances. However, many school buildings are experiencing prolonged periods of low-to-no water use due to various reasons, including the Covid-19 pandemic shutdowns. Furthermore, most schools do not check or flush their water pipes regularly, which helps remove stagnant water from the interior pipes. Stagnant water can increase the risk for growth and spread of harmful bacteria, which may make the water supply unsafe to drink or use.

SCHOOL SOLUTIONS

Improved Access: It is important to ensure that clean, free drinking water is readily available to students throughout the school. Every school has unique water accessibility needs, so administrators must assess the state, district, and school water policies related to water access in addition to their current school water environment. Schools can help improve water access by installing more water fountains, water coolers, water bottle refilling stations, and other clean drinking water sources. Students tend to drink more water when cups are provided, so schools may consider promoting refillable water bottles and offering cups for students who do not have refillable water bottles.

Regular Water Quality Testing: Conducting regular water quality testing is essential to ensuring students' access to safe drinking water. Twenty-four U.S. states and the District of Columbia had lead testing programs for school drinking water as of 2018.

Regular Maintenance: Ensure that drinking water access points (such as water fountains) are well maintained and cleaned regularly. This helps to reduce possible bacterial contamination and also makes drinking water stations more appealing to students.



Water filters should be selected based on the specific water quality concerns in a given school

Filtration: Filtration is one of the most effective treatment methods for mitigating water quality concerns. Different types of filters are designed for different types of contaminants. For example, activated carbon filters target chemicals, while kinetic degradation fluxion (KDF) filters help reduce dissolved metals. In addition, water filters differ in terms of their placement and can be installed either at point-of-entry (POE; meant to treat all the water that comes into the building) or point-of-use (POU; meant to treat water that comes out from a specific location). Water filters should be selected based on the specific water quality concerns in a given school.

Water Softening: “Hard water,” or water that contains excessive minerals such as calcium, can sometimes taste “off”. This can discourage children from drinking enough water. Water softeners that filter out these minerals can help improve the taste and appearance of water.

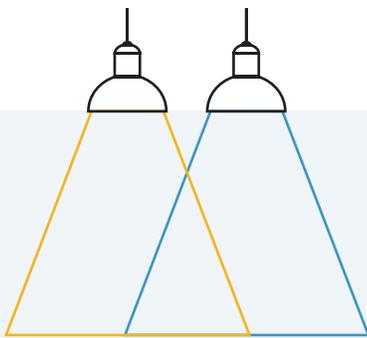


Lighting

Light Helps Regulate Critical Body Functions: Our bodies are naturally programmed to function on a cycle that matches the solar day. This cycle, known as the circadian rhythm, governs many aspects of our physiology, metabolism, and behavior. Daily, regularly-timed exposure to light helps us maintain a healthy and robust circadian rhythm; this process is called “entrainment.” It is important that adequate natural lighting be available to students, or that the indoor lighting match the properties of natural light, which is bright and in the blue-white spectrum during daytime hours.

Lighting Can Impact Children’s Health: Light affects many functions of our body, including the sleep-wake cycle, alertness, mood, cognition, and metabolism, which, in turn, impact our health, well-being, and performance. The lighting that students are exposed to during the school day can thus affect their sleep at night. In fact, around $\frac{1}{3}$ of school-aged children (36.4% of 6- to 12-year-olds, and 31.9% of 13- to 17-year-olds) don’t get enough sleep. According to the American Academy of Pediatrics, regularly getting the recommended hours of sleep is associated with better

It is estimated that about 30,000 schools need to update or replace their interior lighting



One study of third- and tenth-graders compared students whose classrooms had bright, cold light (1,060 lux, 5,800 K) vs. students whose classrooms had conventional classroom lighting (300 lux, 4,000 K). Compared to conventional lighting, students in the bright, cold light group made **20.8% fewer errors of omission** in a test measuring attention and demonstrated a **9.7% increase in reading speed**.

In a similar study of third-graders, students showed a **19% increase in oral reading fluency performance** after exposure to brighter, cooler “focus” lighting (1,000 lux, 6,500 K) compared to students exposed to normal lighting (500 lux, 3,500 K).

health outcomes in children—including improved behavior, learning, quality of life, and mental and physical health, among others. Furthermore, inappropriate lighting can impede napping, a regular school day practice for younger children that benefits their learning, attention and emotion regulation development.

Lighting Plays a Role in Academic Performance: Good quality lighting is important so that schoolchildren can properly read and see the materials presented and taught to them. But lighting may also affect children’s academic outcomes through circadian pathways that support alertness and cognitive performance.

LIGHTING EXPOSURES

1

Illuminance: “Illuminance,” measured in lux, represents the amount of light reaching an area from a light source. Brighter light during the daytime helps to support alertness.

2

Correlated Color Temperature (CCT): The “temperature” of lighting indicates its color appearance. A higher CCT, i.e., a cooler color which contains more blue-white light, has been linked to improved alertness and cognitive performance, including in students. For example, studies have found that pre-school-aged children show greater improvement in executive function abilities (e.g., improved task switching accuracy), and that in classrooms with higher-CCT lighting, high schoolers show greater improvement in cognitive processing speed and concentration.

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SCHOOL SOLUTIONS

Tunable Lighting: Specialized lighting fixtures and controls can make indoor electric lighting adjustable, so that it resembles natural daylight. This can better support students’ visual needs and alertness, and also keep their circadian rhythms healthy and aligned with the solar day. For younger students, lighting should be adjustable to allow for darkness during naptime. Settings should also account for the fact that younger people have higher light sensitivity.

Open Window Shades: If there are window shades in the room, keeping them up during the daytime when possible can help to maximize daylight exposure. However, window shades should be closed leading up to and during naptime for younger students.

Dark Environments for Napping: Dark rooms help to facilitate daytime napping, which in turn can help improve academic performance and psychological wellness as well as reduce emotional/behavioral problems among school children. Consider installing blackout shades to darken classrooms and be sure to dim or turn off the lights during nap time.

Illuminance for Safety and Reduced Violence: Finally, good lighting helps students feel safer at school. Research has shown that there is an indirect association between illumination and violence in educational settings, where illuminated non-classroom areas may serve as a deterrent to bad behavior through an increased awareness of consequences due to bad behaviors being more visible.



Thermal Environment

Our bodies have a basic need to maintain a constant internal temperature within a specific range

Temperature Is Key to Our Comfort and Health: Our thermal environment is important not only for our comfort, but also for our health. Our bodies have a basic need to thermoregulate, or maintain a constant internal temperature within a specific range. If the indoor environment is too hot or too cold, this can be a challenge.

Hot/Cold Temperatures and High/Low Humidity Can Be Detrimental to Health: Cold indoor temperatures have been linked to respiratory and cardiovascular problems, including increased blood pressure and asthma symptoms, as well as poorer mental well-being. Hot temperatures can be similarly detrimental. Furthermore, high humidity may result in greater thermal discomfort due to increased friction between skin and clothing caused by increased sweat production. Low humidity, on the other hand, has been associated with the development and exacerbation of respiratory symptoms such as asthma, and irritation of the eyes, nose, and throat.

Children Are More Vulnerable to Temperature and Humidity Extremes: Young children have higher metabolic rates, higher core body temperatures, and are less able to regulate their body temperatures compared to adults, and thus are more vulnerable to the effects of extreme temperatures and ambient humidity levels. Furthermore, children in pre-K and kindergarten may have difficulty expressing their thermal discomfort and are less able to adapt to their thermal environment by adding or shedding layers of clothing and/or requesting temperature adjustments.

Classroom Temperature Affects Student Performance: Both temperature and humidity greatly influence thermal comfort. Students cannot perform at their best if they are not thermally comfortable. Studies have consistently shown that children prefer cooler environments and are particularly vulnerable to the effects of higher temperatures, which in turn can impact their performance in school. In fact, higher classroom temperatures have been associated with lower test scores and reduced cognitive speed.

THERMAL ENVIRONMENT EXPOSURES

1 **Temperature:** Indoor air temperatures can greatly impact the thermal comfort and performance of students in schools. For example, a study of 75,000 high school students in New York City found that students were 12.3% more likely to fail an exam on a 90°F (32°C) day versus a 75°F (24°C) day. A generally accepted ideal thermal environment ranges between 68-79°F (20-26°C). However, many schools are not equipped with functioning HVAC systems or operable windows (or lack windows in classrooms altogether) that can help mitigate extreme temperatures.

Hotter school days were associated with reduced test scores, with extreme heat being particularly damaging, in a study linking daily local weather data to the test scores

of 10 million high school students. Furthermore, in schools without air-conditioning, a 1°F (0.56°C) hotter school year was shown to reduce that year's learning by one percent.

Student performance on arithmetic and language-based tests were shown to improve significantly, specifically in terms of speed, when classroom temperature decreased from about 77°F to 68°F (25°C to 20°C). Based on these results, the researchers calculated that reducing classroom air temperature by 1.8°F (1°C) could improve student performance speed by about 4%.

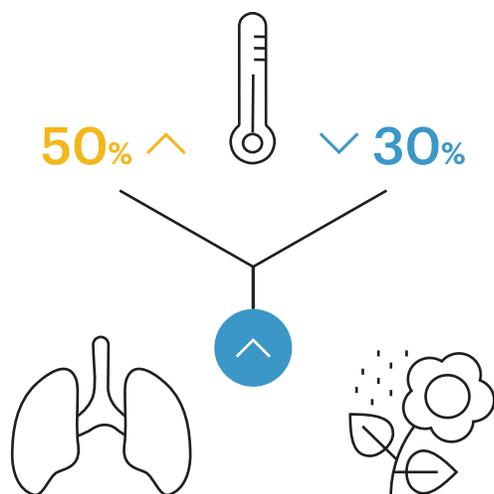
2 **Humidity:** Avoiding extreme humidity levels can help control mold, dust mites, and pests—along with related health issues—while also



providing thermally comfortable conditions for students, teachers, and staff. The U.S. Environmental Protection Agency (EPA) recommends that schools keep indoor relative humidity (RH) levels between 30 and 50%, or at minimum, under 60% RH.

TEACHERS

Prolonged exposure to high or low classroom RH was associated with increased risk of both asthma and cold/allergy symptoms



SCHOOL SOLUTIONS

Reliable Heating and Cooling Systems:

Investing in reliable heating and cooling systems in schools is essential to creating a thermally comfortable environment, and can also lead to health improvements.

Humidifiers or Dehumidifiers:

Investing in humidifiers or dehumidifiers can help to maintain optimal humidity levels, thereby ensuring a thermally comfortable environment. Schools should consider installing a whole-building humidification system, which is a humidification unit that is installed into the HVAC system, or using portable humidifiers and/or dehumidifiers. While opening windows can also help to adjust humidity levels, this may not be feasible during extreme weather conditions such as summer or winter.



Noise

NOISE

In a French study conducted among children aged 8-9 years old, ambient noise exposure was significantly associated with lower scores in math and French. For each 10 dB increase, the French and math scores decreased by an average of 5.5 points.



Noise Can Affect Students' Physical and Psychological Health. Sound is the energy that is transferred from the air and detected in our ears, enabling us to hear the world around us. However, sound can sometimes be unwanted or harmful, and is then defined as noise. Chronic exposure to noise has been linked to hearing loss, elevated blood pressure, and changes in heart rate as well as annoyance, increased levels of irritability, and stress. In one study, college students ranked the aural environment as the most important factor determining their overall satisfaction of indoor environmental quality.

Noise is associated with poorer academic performance, such as difficulty performing cognitive tasks, decreased attentional focus, and impaired performance on a range of literacy, numeracy, and speed tests. In a landmark study conducted in the 1970s, researchers found that students in classrooms next to raised subway tracks were nearly a year behind their classmates on the other side of the building; when sound-controlling measures were implemented, the students caught up.

NOISE EXPOSURES

CLASSROOM NOISE

Lower SNR in classrooms has been associated with decreased academic performance.



FIRST AND THIRD GRADERS



Echoes are measured by reverberation time (RT); an RT greater than 0.6 seconds is considered difficult to understand

1 **Ambient Noise:** Background noise in the classroom can originate from outside the building (e.g., aircraft noise), inside the building (e.g., noise from the hallway), or from students in the classroom itself. It can make it more difficult for students to hear teachers, and for teachers to speak without raising their voices and suffering fatigue as a result. Background noise can also adversely affect performance due to the irrelevant sound effect – a phenomenon in which background sounds reduce memory retention, even if that sound is irrelevant and low-volume. Research indicates that students’ (especially younger students’) ability to recognize speech sounds is impaired in the presence of even low levels of background noise.

Experts recommend that classrooms have a signal-to-noise ratio (SNR) of +15 db to help both students and teachers hear and understand the speaker. The SNR is the difference between the source sound signal and the background noise, and can help to measure speech intelligibility. The higher the signal-to-noise ratio, the greater the speech intelligibility. An SNR of +15 db means that the intentional sound (e.g., teacher speaking) is 15 dB greater than the background noise of the classroom, and is determined to be the level at which ambient noise will not be a barrier to classroom learning.

2 **Reverberations:** Hard building materials and surfaces present in classrooms may create more echos, which can impair speech intelligibility.

A study conducted among first and third-grade students found that students were more impaired by background noise (such as classroom noise and background speech) when performing tasks in a classroom with an unfavorable RT (mean RT of 1.1) vs. a favorable RT (mean RT of 0.47). Exposure to classroom noise increased impairment by 14%, while exposure to background speech increased impairment by 15% when the speech perception task was performed in the unfavorable room.



SCHOOL SOLUTIONS

Sound Insulation: Walls and windows with adequate sound insulation can help minimize noise intrusion from outdoors. Schools should consider installing sound-absorbing panels higher up on the walls inside classrooms, sealing or installing sound-reducing windows, adding good quality seals and gaskets on the doorways, and replacing ceiling tiles with high-noise reduction coefficient (NRC) rated acoustical tiles.

Address Noise from HVAC Systems: Noisy HVAC systems may contribute substantially to overall background noise. Schools should service noisy HVAC systems or replace older, noisier systems with quieter models.

Adapt School Timetables: Consider setting aside certain periods of the day and designate specific areas of the school for noisy activities, which may help to maintain a peaceful working environment for other students.



Greenery (Biophilia)

Exposure to greenery and nature has been associated with improved physical and mental health

Interaction with Nature Is Essential for Our Health and Performance. Biophilia is our innate tendency to seek connections with nature and other forms of life. Substantial evidence shows that our physical, social, and psychological well-being—including mental awareness, recovery from stress, and happiness—depend on our interaction with nature. Exposure to greenery and nature has been associated with improved physical and mental health such as increased recovery from mental fatigue and stress, improved ADHD symptoms, reduced aggression, and even higher standardized test scores and restored attention capacity among students. However, many children and adolescents are losing their connection with nature. In one study, parents of children (8-12 years old) reported that their kids spend three times as many hours watching TV or on the computer as they do playing outside.



GREENERY EXPOSURES

1

Lack of Greenery: Due to financial and spatial constraints, many schools have insufficient access to greenery, particularly schools located in low-income urban areas. A study conducted among high school students found that campuses lacking greenery such as trees and shrubs had a negative effect on standardized test scores and future four-year college plans. Another study found that children engaged in higher levels of physical activity and had higher rates of positive social interactions when playing on grass and playground areas as compared to blacktop and hard surfaces such as asphalt, which are more commonplace in schools located in urban environments.

SCHOOL SOLUTIONS

Bring Nature into the Classroom: Integrating natural elements into the classroom can enhance our ability to focus. A study conducted among 5-6th grade students found that the presence of plants in the classroom may increase academic performance. Students in schools with no previous biophilia programs saw a 10-15% improvement in their test scores after introducing plants.

Bring Nature to Your Students: Nature-based education and the practice of being outdoors has been associated with improved cognition, mood, and social skills. Field trips are a great way to reinforce contact with nature and the outdoors. A



study conducted among middle school students found that participating in field trips to informal science education institutions, such as the zoo, botanical gardens, and museums, had a positive effect on science test scores and proficiency.

Virtual Biophilia: If bringing in living greenery is not possible, schools can consider introducing virtual biophilia to the classrooms. For example, projectors or computers can be used to display images and videos of nature. Even just 40 seconds of observing a picture of a flowering green roof, compared to a bare concrete roof, has been shown to boost attention and task performance.

Outdoor Views: School building design should aim to make views to the outdoors visible to students whenever possible. This can include views to gardens, trees, flowers, or water fountains. Spaces should also be designed so that visual access to outdoor views is not obstructed when sitting. Students in classrooms with access to green views have demonstrated a significantly faster recovery from stress and mental fatigue and performed significantly higher on tests of attentional functioning, compared to students in classrooms with no windows or windows looking out onto other buildings facades.

School Garden Programs: School garden programs can help students connect with nature. School gardens have been associated with higher test scores, with many studies showing the largest improvements in sciences.



Materials

Chemicals in Our Schools: Building materials and cleaning products that are commonly present in schools can contain a number of different chemicals: some are benign, while others are known to be hazardous. Furthermore, pollutants from these sources can remain present indoors for a long time due to tightly sealed buildings and long-term use of materials.

What are the Chemicals of Concern?

- Lead and asbestos are well-known examples of hazardous building materials that are still found in schools today. Lead exposure has been linked to damage to the central and peripheral nervous system, learning disabilities, and in rare cases even death among children.
- Volatile organic compounds (VOCs) include a range of organic chemicals that are emitted as gases from many common cleaning products, building materials, finishes, and furniture through a process called “chemical off-gassing”. These gaseous chemicals may have detrimental effects on human health, ranging from skin irritation to neurological issues, and in extreme cases, cancer. For example, indoor exposure to VOCs has been

associated with asthma-like symptoms in schoolchildren as well as with eye, nose, and throat irritation; headaches; and nausea, among others.

- Semi-volatile organic compounds (SVOCs) are a group of chemicals related to VOCs, which can attach to indoor surfaces. Some of them are also endocrine disruptors that mimic human hormones and alter their function.

MATERIAL EXPOSURES

- 1 Cleaning Products:** Commonly used cleaning products, such as cleaning sprays, air fresheners, waxes, and polishes, may contain hazardous chemicals and pollutants including VOCs and endocrine disruptors. The use of such products has been linked to eye, nose, throat and lung irritation, as well as an increased risk of respiratory issues such as asthma.,
- 2 Furniture Materials:** Floor coverings and furniture items can contain harmful chemicals. For example, materials like vinyl, halogenated flame retardants, and stain-guard coatings that are often used in furnishings can contain SVOCs which can off-gas into the surrounding environment.
- 3 Building Materials:** Many building components and finishings—from pipes and insulation to doors and paints—can be constructed from

materials containing substances such as lead or asbestos, or can contain materials that off-gas chemicals.

SCHOOL SOLUTIONS

Conscious Construction Practices: During construction, builders can avoid products and materials with harmful heavy metals such as lead, and can utilize low-emissions options, when possible.

Non-Toxic Material Selection: Effective, safer, and non-toxic substitutes are often available for toys, cleaning products, furniture, and building materials. For example, some paint formulas are specifically designed to reduce or eliminate toxic material off-gassing. Product certification standards can be helpful for choosing healthy materials.

Ventilation: Ventilation bringing in fresh outdoor air can help reduce concentrations of some indoor airborne contaminants, such as VOCs.

EXAMPLES OF PRODUCT CERTIFICATIONS THAT HELP IDENTIFY LESS HARMFUL ALTERNATIVES INCLUDE:

- GREENGUARD GOLD
- CDPH METHOD V1.1
- GREENSEAL
- GREENSCREEN
- EPA SAFER CHOICE
- BIFMA E3



Neighborhood Environment

What surrounds schools can also influence our health and well-being

Neighborhoods Matter: It's not just what's inside our schools that matters; what surrounds them can also influence our health and well-being. The neighborhoods in which we live, play, work, and learn impact us in many ways, from the resources we have access to (e.g., opportunities for physical activity) to the exposures we experience (e.g., air pollutants from local roads or facilities—as previously discussed in the air pollution section).

Some Neighborhoods Are Healthier Than Others: Unfortunately, neighborhoods don't offer equal opportunities to be healthy, as indicated by the fact that life expectancy varies significantly—by as many as 20.1 years—across different U.S. ZIP codes.

NEIGHBORHOOD EXPOSURES

1

Climate Resiliency: Our built environment can help protect students from, or exacerbate, the effects of climate change, natural disasters, and extreme weather. However, neighborhood protectiveness varies. Scientists in Richmond (VA), Baltimore (MD) and Washington (D.C.) found that the air temperature in some areas of the city was up to 17°F hotter than other areas during the same time of day. These hotter areas are commonly referred to as “urban heat islands”, as buildings and unshaded surfaces (such as major roadways and parking lots) amplify heat, thereby significantly increasing the local air temperature relative to more vegetated or shaded areas. In fact, some of the highest temperatures recorded were in dense residential neighborhoods with more asphalt and little tree coverage. Impervious surfaces and lack of tree cover can increase land surface temperature, therefore posing a heat risk for people.

Another national-level study found that land surface temperatures in formerly redlined areas (which largely consist of low-income communities and BIPOC communities due to historical segregation) were

approximately 3.7°F (2.6°C) higher than in non-redlined areas. Ambient temperatures not only impact students when they are outside, such as during recess or during lunch in outdoor spaces, but can also influence the temperature of the indoor environment, especially in the absence of reliable cooling systems.

2

Neighborhood Safety: Exposure to community violence has been shown to impact students’ mental and physical health as well as academic performance. For example, a study conducted among 3rd-5th graders in the Baltimore Public School System found that schools in neighborhoods with higher violence ratings saw a 4.2-8.7% decrease in math and reading achievement, while those in neighborhoods with greater perceived safety saw increases from 15.4% to 22.8%. Perceived safety in residential neighborhoods and exposure to community violence have generally been linked to physical health outcomes, and likely apply to students, as many children attend schools in their residential neighborhoods.



BEHAVIORAL FACTORS THAT IMPACT STUDENT GROWTH AND PERFORMANCE

Beyond the physical environment, a variety of social and psychological factors can significantly impact students' success as they progress through their formal education and beyond. The abrupt shift to remote learning due to the Covid-19 pandemic has brought about a number of new challenges for students, such as lack of structure and routine, limited social interactions with peers and educators (both within the classroom as well as happenstance interactions around the schoolyard), and increased uncertainty as schools continue to close and reopen in response to the ongoing pandemic.

While mitigating the challenges of remote learning is essential, identifying and addressing key behavioral factors that impact student performance is also critical in order to optimize in-person learning. In this section, we identify student attention, stress, and social development as major behavioral factors that can impact growth and development, and provide actionable solutions to help address these factors and foster greater academic success.



Attention

Classroom Attention and Academic Achievement: Paying attention in school is essential to successful learning; however, maintaining attention for long periods of time can be difficult for many students, especially young children. Studies have also shown that inattention and distractibility among younger students has long-term consequences and may impact academic achievement in high school. Teachers play an important role in not only detecting signs of inattention and distractibility among students, but also in creating more productive learning environments, helping students establish better habits to improve inattention in the classroom, and referring students to professionals for further intervention when necessary.

According to one study, children who display increasing levels of inattention at age 7 are at risk for worse academic outcomes in their high school final exams. For every one-point increase in inattention symptoms at age 7, there was a two to three-point reduction in high school final exam scores and a 6-7% increased likelihood of not achieving a “good” final exam score (equivalent of A to C grade), at age 16.

The Attentional System: An effective attentional system is marked by the following abilities: quickly identify and focus on relevant information in a complex environment; sustain attention on important information while ignoring distractors; access existing memories that may be relevant to the information in current focus; and shift attention when new information is introduced. While certain attentional functions develop fairly early, such as the ability to identify important information, other components—such as sustained attention—continue to develop as children mature. Teachers must be able to recognize students’ limitations and adapt teaching methods to support attentional processes for effective learning and retention of new information.

SCHOOL SOLUTIONS

Passive screen time has been associated with worse physiological outcomes, poorer health outcomes, and lower educational outcomes

Balance Screen Time: Use of technology and screens can be an invaluable educational tool and facilitate social connectedness during a time when students may be feeling increasingly isolated. However, passive screen time (such as TV) has been associated with worse physiological outcomes, poorer health outcomes, and lower educational outcomes. Furthermore, school age children are particularly vulnerable to excessive social media use (also known as “doomscrolling”) which may contribute to worse mental health outcomes such as depression, and has been linked to poorer sleep quality and poorer academic performance. Teachers and parents should encourage both social media breaks and phone/device breaks, as screen time should not displace either sleep or active time. Teachers can also foster active discussion, employ interactive educational games, and build in time to walk away from the screen to help break-up video (e.g. Zoom) lectures and avoid passive screen time. Audiobooks and podcasts can also be utilized to break-up screen time, as students can listen as they take a walk outside.



Visual Cues: Audio cues such as raised voices can be easily drowned out in a noisy classroom or lost on a video (e.g. Zoom) call. Using visual cues can help direct students' attention. Consider using visual cues such as turning lights on and off, or flashing lights on the video screen to refocus students' attention.

Focus-based Activities in the Morning: Consider scheduling focus-based activities earlier in the day, when students' attention is less fatigued, and leaving more creative and collaborative activities—which most students find more easily engaging—for the afternoon.

Regular Breaks: Adolescents are generally only able to maintain focus for about 15 to 20 minutes at a time before their mind starts to wander. For younger children this time is shorter. Consider breaking up the lecture components of a class with discussion, questions, and even short breaks where students can stretch their legs or move around.

Make Learning Fun: Integrating play and fun activities into lesson plans can help maintain attention. For example, games are a great way to teach STEM subjects to both older and younger kids. Gamification is recognized as a powerful learning tool that helps students work towards a goal/reward, experience and learn from failure, and improve prosocial behavior.

Physical Activity: Allow students to be physically active during the day as it helps to enhance their attentional processes. Physical activity around green spaces can be particularly effective in helping replenish students' fatigued attentional resources.



Stress Management

Impact of Stress on Health and Academic Performance:

Stress is the body’s natural response to a potentially threatening situation. While certain forms of short-term stress—such as an upcoming deadline for a class project—can be beneficial and increase productivity by focusing attention on the stressor, unmanaged chronic stress can have serious consequences that may carry into adulthood. Chronic stress can also negatively impact productivity and performance, as well as how students cope with new challenges. It is important for schools to recognize that chronic stress disproportionately impacts low-income students and students of color, and take this into consideration when developing new programs and interventions aimed at mitigating the effects of chronic stress.

Schools Can Be a Source of Stress: While schools can help to buffer stressful life events, they can also be a source of stress for many students—due to both academic and social aspects. While schools alone cannot fix or reduce the potential life stressors that students experience, they can employ effective strategies to help mitigate stress. In the School Solutions section below, we list some strategies to help address student stress.

Finally, schools must also recognize and support positive family relationships and family engagement. Research shows that positive family relationships are linked to better mental health in adolescents, while family engagement is associated with higher grades and test scores, improved attendance, and improved student behavior. In a survey conducted among 15 year old students across 18 countries, students whose parents engaged in parent-child activity at least once a week (such as eating their main meal with their child, spending time talking with their child, and discussing how well their child is doing at school every day or almost every day) scored higher in their science tests and reported higher levels of life satisfaction. Moreover, spending time “just talking” was the parent-child activity most strongly associated with students’ life satisfaction.

INCREASE IN TEST SCORES

was higher for low-achieving students whose third-grade teachers engaged in active parental outreach compared to those who did not

**3-5
GRADE**



STRESS IN SCHOOL

83%

of teens (aged 13-17) reported that school is somewhat of a source or a significant source of stress

42%

of teens reported that they are either not doing enough or are not sure if they are doing enough to manage their stress

SCHOOL SOLUTIONS

Mindfulness and Meditation Practices: Introduce mindfulness and meditation practices during class time. Consider dedicating quiet spaces for students to engage in mindfulness.

Student Wellness Checks: Consider scheduling regular individual check-ins with all students, particularly those learning remotely.



Mediation and De-escalation: When a child is placed in a stressful or overwhelming situation (e.g., confrontation with another student), remove the child from the situation and de-escalate unproductive behaviors before having the student return to schoolwork.

Foster a Growth Mindset: Remote learning can cause additional stress, with students feeling as if they are falling behind. Teachers can work to reframe lack of progress or “failure” and adopt a growth-focused mindset, where improvement happens with persistence—by setting expectations around improvement and overcoming challenges.

Family Engagement: Encourage families to get involved in their children’s education. Teach parents and/or guardians some educational games to play with their children (e.g., math games, etc.), provide workshops on topics suggested by parents, such as how to effectively discuss

difficult issues or how to actively engage children during remote learning sessions. Teachers should consider meeting every family face-to-face or via video call (e.g. Zoom), sending materials home for parents to use to help their kids, and staying in regular touch with families on their child’s progress. Schools can also consider partnering with community groups to offer more basic services to students’ families, such as providing weekly grocery bags, as this type of foundational support can alleviate stress in the home.

Establish a Routine: Establishing predictable routines and schedules offers stability during unpredictable times, and may help children manage their stress and anxiety, particularly during remote learning.

Clear and Constant Communication: Schools must create clear and constant communication on how they plan to keep students and their families safe as schools begin to reopen.



Social-Emotional Development

Socio-emotional Development in Schools: In addition to preparing students academically, schools play a critical role in children’s and adolescents’ socio-emotional development. Beyond providing academic instruction, schools can also teach students how to regulate their emotions. Returning to in-person instruction is ideal, as teachers often serve as important role models, while peer interactions help to increase a child’s sense of belonging, identity, and community. However, schools must also employ strategies to help mitigate the current loss of social contact, and strive to create an environment where students feel physically and emotionally safe.

One study found that kindergarteners with better social-emotional skills were more likely to graduate high school on time, complete a college degree, and obtain stable employment by age 25



SCHOOL SOLUTIONS

Peer Mentorship: Consider establishing a peer mentorship program. Peer mentorship can help to provide social connection in addition to emotional and/or academic support.

Student Check-ins: Pair students with teachers who they feel close to in order to check in on them. For students who require more help, consider daily check-ins to work on socio-emotional development skills. Encourage students to discuss their feelings and emotions.

Social and Emotional Learning (SEL) Activities: Consider incorporating SEL activities into the classroom. SEL is a methodology that helps students to better comprehend their emotions, experience those emotions, and demonstrate empathy for others. Students participating in SEL programs have been shown to improve their academic performance and social behaviors, and lower their levels of distress. Activities may include reading a book out loud and discussing how the characters might think and feel, daily journal prompts centered around SEL skills, or practicing problem-solving.

CONCLUSION

School environments can shape students' health, well-being and learning in profound ways. We owe it to the next generations to study the science and develop our understanding of how and why to make schools healthier places to be. Based on available research and best-practice recommendations, schools can take the following actions to ensure that they provide the best possible environments to help students thrive:

- 1 Upgrade and use adequate ventilation and filtration systems and monitor the air quality indoors and outside to help improve the air quality in schools and reduce exposure to harmful pollutants.
- 2 Install and maintain water stations that are free, easily accessible and provide cleaner water to all students. Water quality should be regularly tested throughout the school, implementing filtration measures if and as needed.
- 3 Implement tunable lighting to promote daytime focus and healthier sleep cycles. Keep window shades open during the day to maximize daylight exposure, and utilize blackout shades to block out light when young children are napping.
- 4 Regulate temperature and humidity levels to support student comfort and performance by investing in reliable heating and cooling systems and humidifiers and dehumidifiers throughout the school.
- 5 Minimize noise pollution using sound insulating materials and strategies in order to mitigate student anxiety and distraction.
- 6 Integrate elements of nature into classrooms and teaching practices, add virtual biophilia and aim to make views to the outdoors visible to students whenever possible to aid in their performance, focus, and recovery from stress and mental fatigue.
- 7 Aim for conscious construction/renovation practices, choose non-toxic building and furniture materials, and ensure adequate ventilation to reduce concentrations of harmful contaminants indoors.
- 8 Support students' attentional processes, socio-emotional development and stress management for more effective learning and better well-being, both in and outside the classroom.



Delos bridges the gap between evidence-based science and everyday awareness to support its mission of promoting enhanced health and well-being in the environments where we live, learn, work, and play. In collaboration with the Mayo Clinic, Delos developed the Well Living Lab to study the effect of indoor environments on human health, and shares the findings of this research with the public. Through the process of continuous learning, sharing our knowledge, and research-informed development of innovative products and solutions, Delos is committed to promoting healthy indoor environment solutions for people everywhere.

APPENDIX

Air Filtration Technology Comparison

	Delos Powered by Healthway Compact Air Purification System	Mechanical Filtration	Sorbent Media Filtration	Bipolar Ionization	Ultraviolet Germicidal Irradiation (UVGI)
Deactivates Bacteria and Viruses (antimicrobial treatment)	✓	✗	✗	Varies ¹	✓ ²
Captures Bacteria (> 0.3 µm)	✓	✓ <small>(requires MERV 13 or higher rating)</small>	✗	Varies ^{1,3}	✗
Captures Viruses (> 0.005 µm)	✓	✓ <small>(requires HEPA filter)</small>	✗	Varies ^{1,3}	✗
Removes PM10 (particle size 2.5 µm - 10 µm)	✓	✓	✗	✓	✗
Removes PM2.5 (particle size 0.1 µm - 2.5 µm)	✓	✓ <small>(requires MERV 13 or higher rating)</small>	✗	✓	✗
Removes Ultrafine particles (particle size <0.1 µm)	✓	✓ <small>(requires HEPA filter; testing is needed to determine efficacy)</small>	✗	Varies ³	✗
Removes Volatile Organic Compounds (VOCs)	✓	✗	✓	✓	✓
Meets Ozone Emission Standards ⁴	✓	✓	✓	⚠ ⁵	Varies ⁶

1. Laboratory and real-world efficacy testing would need to be evaluated to determine if they support claims of antimicrobial efficacy.
2. Deactivates microorganisms on-the-fly as they pass through the irradiated zone. However, due to limited exposure time, this process requires high doses of UV light. This makes the implementation of UV irradiation in the HVAC system complicated.
3. As a result of bipolar ionization, bacteria, viruses, and ultrafine particles may stick together, becoming larger particles, and fall from the air to surfaces more quickly. While this process may remove the particles from the air (which in effect is similar to particle capture), the particles may then still be transmittable if encountered on the surface.
4. Ozone generation/emission testing is required for air purifiers in order to satisfy applicable safety requirements (e.g., ozone safety limits required by CARB).
5. Different designs and modes of engineering of bipolar ionization technologies vary in ozone emissions. In addition, the ions released into the air can react with oxygen and other particles, leading to additional production of ozone, as well as generation of ultrafine particles.
6. UV-C technologies may generate ozone.

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