Classroom Air Purifiers

Their Role in Improving Air Quality in K–12 Classrooms

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Students in schools with poor indoor air quality breathe in contaminants such as chemicals and viruses, which can reduce student learning and increase sick days. Portable HEPA filter air purifiers are a simple, cost-effective way to reduce student and staff exposure to air pollutants as part of a comprehensive approach to improving K–12 classroom indoor air quality.

How Classroom Air Quality is Managed in the U.S.

In the United States many schools use mechanical heating, ventilation, and air conditioning (HVAC) systems to refresh indoor classroom air by periodically bringing in outside air. The number of times outside air is brought into the classroom during one hour is called the air change rate, also known as the ventilation rate. ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) recommends an air change rate of at least three to six times per hour (Setty et al. 2023). Most U.S. schools do not meet this standard, even if they have a renovated or new HVAC system, because filters are not changed often enough or because the system was not properly installed (Batterman et al. 2017; Fisk 2017; Chan et al. 2020; Corsi et al. 2021).

Other schools, particularly in temperate areas of the country or in older school buildings, naturally ventilate the building by opening windows and doors rather than using HVAC (McNeill et al. 2022). Although natural ventilation can be effective in improving air quality, it is not always feasible if outdoor air quality is poor because of vehicle emissions, wildfire smoke, or rainy weather (Martins and Carrilho da Graça 2018).

Increased Interest in Classroom Air Quality

The COVID-19 pandemic placed renewed attention on indoor air quality and methods for reducing the spread of the COVID-19 virus in schools. The federal government created the Elementary and Secondary School Emergency Relief Fund (ESSER Fund) to help schools address the impacts of the pandemic. Yet school personnel can be deterred by the amount of complicated paperwork involved to apply for money to improve ventilation. Air quality might also not be a priority within school districts compared to competing demands for funding and attention.

Indoor air quality matters. Studies conducted over the last 30 years have shown that many indoor air pollutants, not just the COVID-19 virus, negatively impact student academic performance and both student and staff

health (Annesi-Maesano et al. 2013; Haverinen-Shaughnessy et al. 2015; Marcotte 2017; Sadrizadeh et al. 2022). Volatile organic compounds emitted from furniture, cleaning chemicals, paints, and carpets; high carbon dioxide (CO_2) levels from poor ventilation; and particulate matter pollution from outdoor sources such as wildfire smoke and vehicle exhaust that infiltrates classrooms are among the more common indoor air pollutants (Sadrizadeh et al. 2022).

"What I want people to understand is that school building, that school building facility, is a part of the curriculum."

Tracy Enger
Program analyst at the Indoor Environments Division of the U.S. Environmental Protection Agency (Merod 2022)

This white paper explores the role portable air purifiers can play in reducing harmful air particles within K–12 classrooms.

How Air Quality is Measured

What is good air quality compared to poor air quality? Good air quality is often associated with a high air exchange rate per hour in HVAC systems or adequate natural ventilation, which dilutes indoor contaminants. CO_2 levels are another commonly used measure of air quality (Fisk 2017). People exhale CO_2 when they breathe and CO_2 levels can accumulate to high levels when there is inadequate ventilation.

Some studies measure levels of specific pollutants such as volatile organic compounds, mold, or bacteria and viruses (Sadrizadeh et al. 2022). Because exposure to fine air particulate matter smaller than 2.5 µm ($PM_{2.5}$) can increase respiratory illness and cardiovascular problems, $PM_{2.5}$ is another commonly used air quality measure. $PM_{2.5}$ includes the fine particles from sources such as vehicle exhaust and wildfire smoke that infiltrate indoor spaces (Forehead et al. 2020; Wang et al. 2020).

Poor Air Quality Effects on Children's Health and Learning

Because children have developing lungs and breathe in more air relative to their body weight compared to adults, they are particularly susceptible to poor air quality (Goldizen et al. 2016; Garcia et al. 2021). It is unclear if the

physical effects of poor air quality are long-term or reversible, but studies have indicated short-term effects such as increased respiratory illnesses and reduced lung function (Garcia et al. 2021). Poor classroom air quality can diminish student performance in simple learning tasks (math and language exercises) and exam grades (Sadrizadeh et al. 2022).

Some studies show low ventilation rates and high CO_2 levels also increase absenteeism (Mendell 2013; Eitland et al. 2017). Students who are frequently absent in earlier grades, regardless of the reason, are at higher risk of dropping out of high school (Eklund et al. 2022). Improving air quality may be one way to reduce absenteeism. In a recent study of 144 grade school classrooms in the Midwestern U.S., higher ventilation rates significantly reduced student illness-related absences (Deng et al. 2023).

Wildfire Smoke

Wildfire smoke can worsen indoor quality when smoke infiltrates buildings. On smoke-impacted days indoor concentrations of $PM_{2.5}$ from wildfire smoke can even exceed Environmental Protection Agency outdoor $PM_{2.5}$ standards (Dell et al. 2023). According to a meta-analysis of multiple studies, increased wildfire smoke is associated with more asthma emergency department visits and hospitalizations for children; the increase is even greater for adults (Borchers Arriagada 2019).

Photo by Pixabay: https://www.pexels.com/photo/forest-covered-by-smoke-266558/

Subsequent studies have found increases in respiratory visits from all causes, not just asthma (Doubleday et al. 2023). Increased asthma symptoms are likely from the fine particulate matter ($PM_{2.5}$) associated with wildfire smoke (Holm et al. 2021). As the drier and hotter conditions

associated with climate change cause more wildfires, more people may be impacted by wildfire smoke in coming years (Holm et al. 2021).

Portable Air Ionizers

Some companies have promoted portable air ionizers, also known as electronic air cleaners, ion generators, or negative ion air purifiers, as a method to purify classroom air (Weber and Jewett 2021). These devices produce negatively charged ions that attach to air particles. The weight causes the pollutants to fall through the air or stick to surfaces like carpets and curtains that have a positive charge from static electricity (Afshari and Seppänen 2021).

However, a downside of air ionizers is that they often generate byproducts such as ozone, which is a lung irritant and serious public health problem (Siegel 2015; Weber and Jewett 2021). Ionizers can also negatively influence heart rate and heart rate variability (Dong et al. 2019). The American Heart Association recommends "electrostatic precipitators and electronic air filters that contain ionizers can produce ozone and should be avoided" (Rajagopalan et al. 2020).

Chemical Fogging

Other companies promote chemical fogging, or spraying a fine mist of chemicals to remove bacteria and viruses from a room (Lee et al. 2015; Yang et al. 2022). However, because the effect of fogging on reducing pathogens can be short-lived, it needs to be repeated regularly (Yang et al. 2022).

Like ionizers, chemical foggers add chemicals into the air. Because of this, the American Lung Association is concerned about using foggers or other technology that can contribute to indoor air pollution in schools (American Lung Association 2023). In her presentation "School Ventilation: A Vital Tool to Reduce COVID-19 Spread" at the 2022 National Academies of Sciences, Engineering, and Medicine virtual workshop on Indoor Air Management, Paula J. Olsiewski, PhD recommended that schools not use chemical foggers.

Germicidal UV Radiation

For several decades UV-C radiation (100–280 nm in wavelength) has been used to inactivate pathogens by damaging their DNA and RNA. The radiation technology is typically emitted from a ceiling-mounted UV-C light fixture or installed in the air ducts of HVAC systems (Hongying et al. 2023). Because

this level of radiation can damage mammalian skin and eyes, the technology is most safely used in unoccupied spaces.

According to recent research, within this range of wavelengths far UV-C radiation (200–230 nm in wavelength) is less harmful to mammal skin and eyes and is effective in reducing microbial air contamination (Messina et al. 2022; Blatchley III et al. 2023). Yet the potential long-term health and environmental risks of this lower level of radiation are controversial and poorly understood (Pereira et al. 2023).

HVAC System HEPA Filters

Pleated high-efficiency particulate air (HEPA) filters consist of randomly arranged fibers that are typically composed of fiberglass or a flexible type of plastic called polypropylene. Fans draw air from the room, push air through the filter, and recirculate the cleaned air back into the room. HEPA filters can capture over 99.97% of particles larger than 0.3 microns, including bacteria, viruses, mold spores, dust, and allergens (EPA 2023a).

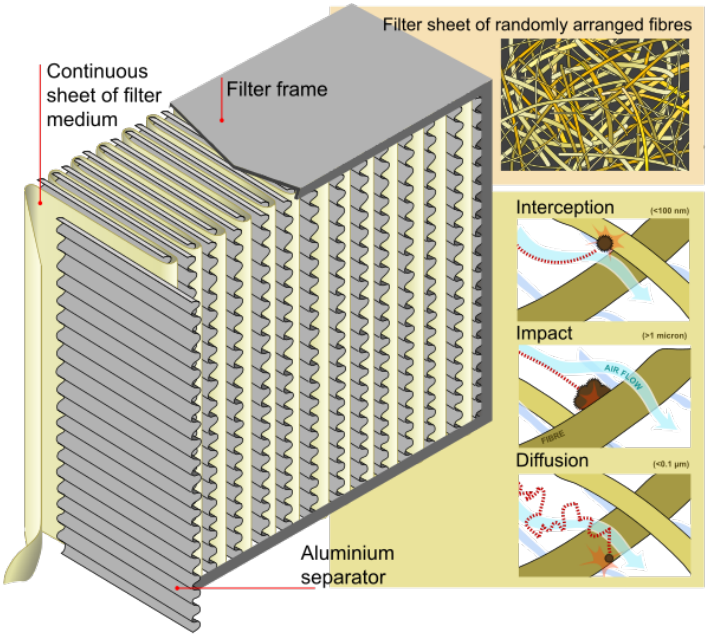

Image of a HEPA filter. The blue lines in the smaller diagrams represent air flow over light or dark brown fibers. The dark circle represents a particle such as dust or bacteria and the red dotted line indicates the path of the particle. Small (100 nm to 1 micron) or large (>1 micron) particles may collide with the fiber (interception and impact, respectively). Very small particles (<100 nm) move randomly as they collide with molecules; some of these molecules may knock the particle into the fiber. Source: Mariana Ruiz Villarreal.

However, HEPA filters in HVAC systems may increase energy use because the blower has to work harder to push air through the dense filters. An aspiration efficiency reducer that passively reduced air pollution and the particulate accumulation in HEPA filters can reduce how much energy the fan consumes (Morgan et al. 2017). Using higher-rated filters such as MERV 13–16 can also reduce the indoor amount of outdoor ultrafine particles and reduce the energy needed to filter indoor air (Stephens and Siegel 2013). School systems must balance the benefits of improved air quality against the

possible tradeoff of increased energy use and costs of the materials needed to improve energy efficiency.

Portable HEPA Air Purifiers

Efficacy and Safety

Portable air purifiers that contain HEPA filters are relatively inexpensive and easy to set up; they can be purchased or even built with readily available materials. Similar to HEPA filters in HVAC systems, fans in portable air purifiers draw in air from the room, push the air through the filters that trap fine and ultrafine particles, and release clean air back into the room. Models differ in the amount of clean air released into the room. Filters will need to be regularly changed, typically at least twice per year.

Portable air purifiers are safer than portable air ionizers and chemical fogging because they do not release chemicals or contaminants like ozone into the air. Some purifier models might contain an ionizing option but it is important not to use this option to avoid unwanted respiratory side effects from ozone that may be released during ionization.

In a 2018 report the Environmental Protection Agency recommended HEPA air purifiers as having the fewest adverse health consequences compared to other air cleaning technologies (EPA 2018). According to Glenn Morrison, a professor of environmental science and engineering at the University of North Carolina, "A cheap portable HEPA filter would work many times better and have fewer side effects (possibly ozone or other unwanted chemistry)." (Weber and Jewett 2021). The filters on portable air purifiers, whether commercial or homemade, need to be changed at least twice a year for them to function well.

Portable air purifiers with HEPA filters have reduced total $PM_{2.5}$ and other air particle concentrations in classrooms, homes, and offices (Cheek et al. 2021; Azevedo et al. 2022; Granzin et al. 2022; Laumbach and Cromar 2022). Effectiveness can be affected by the size of the classroom and the purifier's flow rate, with higher flow rates of air through the purifier increasing the amount of particles removed (Lowther et al. 2022). Their effectiveness can depend on the size of the classroom and the targeted pollutants.

Do-It-Yourself Portable Air Purifiers

Because one portable HEPA filter air purifier can be constructed with around $70–120 worth of materials in less than an hour, they can be an affordable option to improve air quality (Emanuel 2021). Online websites include

instructions for how to create a do-it-yourself air purifier (e.g., https://edgecollective.io/airbox/). A common design is the Corsi–Rosenthal box, named after its creators, environmental engineer Richard Corsi and Tex-Air Filters CEO Jim Rosenthal. The materials needed to construct a DIY purifier include a box fan, four filters, cardboard, and duct tape.

Research to date indicates do-it-yourself air purifiers can reduce indoor $PM_{2.5}$ from wildfire smoke (Turner et al. 2022) and indoor air particles (Dal Porto et al. 2022). The clean air delivery rate of homemade air purifiers can vary widely but can be comparable to commercial air purifiers if the design includes a four-inch-thick filter, uses two filters in wedge shape, or uses the four filters characteristic of the Corsi-Rosenthal design (Holder et al. 2022; Eykelbosh 2023).

University of California, Davis students participate in a Corsi-Rosenthal box building competition in February 2022. Supplies were sponsored by the Department of Electrical and Computer Engineering and Texas Instruments. (Katherine Hung/UC Davis).

Educational Value

Teachers can guide their classes through constructing HEPA air purifiers as a science lesson. Some students have even experimented with ways to make their homemade purifiers more effective (Day 2023).

Whether commercial or DIY, portable air purifiers have an added benefit in that they are a visible addition to the classroom. They can encourage

discussion among staff, parents, and students about other methods for removing pollutants such as addressing aging HVAC systems and incorporating natural ventilation when feasible.

Some communities have constructed HEPA air purifiers as a short-term solution to address immediate air quality issues. For example, a group of Philadelphia parents, teachers, and students created 24 Corsi-Rosenthal boxes when damaged asbestos was discovered within some schools (Roth 2023). As one community member acknowledged, "[keep] in mind, this is a band-aid" (Roth 2023).

Indoor Air Quality Plans and Grants

Portable HEPA filter air purifiers are best used as part of a larger strategy for improving air quality throughout the entire school. The EPA's Creating Healthy Indoor Air Quality in Schools website includes comprehensive resources for addressing indoor quality and case studies of how school districts have improved conditions within their schools (EPA 2023b).

Grants and technical assistance are also available from the following sources:

EPA funding to address indoor air pollution at schools (EPA 2023b)
Department of Energy's Renew America's Schools (DOE 2023)
21st Century School Fund (21st Century School Fund 2023)

Summary

The COVID-19 pandemic accelerated interest in improving indoor air quality to reduce the transmission of viruses and illness in schools. Pollutants from indoor building materials and cleaning agents, outdated HVAC systems, and the fine particles from wildfire smoke and vehicle exhaust will also continue to diminish indoor air quality in many schools.

Implementing effective air cleaning technologies will be essential to improving classroom air quality. Portable HEPA air purifiers are a safe and cost-effective method for removing pollutants from the air. Adding them to classrooms is a key initial step in keeping K–12 students and staff healthy.

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