United States Environmental Protection Agency

Office of Transportation and Air Quality
EPA-420-R-21-022
October 2021

Best Practices for Reducing Near-Road Pollution Exposure at Schools

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U.S. Environmental Protection Agency

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Introduction

Purpose of This Publication

The U.S. Environmental Protection Agency (EPA) created this document to help existing and planned school communities identify strategies for reducing traffic-related pollution exposure at schools located downwind from heavily traveled roadways (such as highways), along corridors with significant truck traffic, or near other sources of significant particulate air pollution sources. Many of these strategies are already being used by schools across the country to reduce exposures to traffic-related air pollution.

We hope that this compilation of best practices will help schools that want to take steps to address concerns about traffic-related pollution exposure.

Many of the best practices outlined in this publication may also be effective in reducing exposure at schools near other sources of particulate air pollution, such as railyards, ports, industrial facilities, and wildfires. Additionally, many of the best practices targeting indoor air quality may also be beneficial for reducing exposure to airborne viruses such as COVID-19 or other respirable pathogens. Resources regarding COVID-19 and air quality can be found in the associated Resources Guide.

For existing schools located near heavily traveled roads, school officials should contact their state or local air pollution agency or their EPA regional office for assistance in evaluating any impacts of traffic-related air pollution exposure at your school. For schools that are being constructed in new locations near major roads, refer to EPA's School Siting Guidelines. The School Siting Guidelines is a companion to this publication and includes information on evaluating impacts of nearby sources of air pollution, like highways and other transportation facilities, when siting new schools or examining existing schools for potential renovations or upgrades. Evaluating the potential impact of traffic-related air pollution may be performed as part of an overall environmental evaluation for your school.

Intended Audience

This publication was designed for school administrators, facility managers, school staff, school nurses, school-based health centers, parents, students, and others in the school community to address traffic-related air pollution exposure due to a school's proximity to a heavily traveled roadway or trucking corridor. This guide aims to outline multiple potential approaches to reduce exposures. The publication should also be useful to these same audiences located near other sources of particulate and gaseous air pollution, such as railyards, ports, industrial facilities, and wildfires.

Other audiences that may find this resource applicable to their work include community-based environmental and health organizations; heating, ventilation, and air conditioning (HVAC) professionals, architects, design engineers, and construction contractors who can apply the principles of this document during facility siting, design, and construction; and other federal, state, local, tribal, and international agencies.

Other EPA Resources for Schools

The EPA website offers many documents and tools to help states, districts, schools, teachers, parents, and students create or enhance productive and healthy learning environments. These resources address a broad range of issues that affect children's health in schools, from selecting appropriate locations for schools to maintaining the buildings and grounds. Some of these resources may address strategies that are discussed in this publication. You can use these comprehensive resources to assess your school's environmental health efforts and implement or improve related programs, policies, and procedures. If you have questions about EPA's resources for schools, contact your **regional school coordinator**.

Reducing Near-Road Pollution Exposure at Schools

Primary and secondary school-aged children's exposure to traffic-related air pollution while at school is a growing concern because many schools are located near heavily traveled roadways. This document briefly introduces the health risks associated with traffic-related air pollution exposure and offers strategies to reduce students' exposure in new and existing schools.

17,000 schools in rural and urban areas across the U.S. are located within 250 meters (~820 feet) of a heavily traveled road.

Kingsley, S. L., Eliot, M. N., Carlson, L., Finn, J., MacIntosh, D. L., & Suh, H. H. (2014). Proximity of US schools to major roadways: A nationwide assessment. Journal of Exposure Science and Environmental Epidemiology, 24, 253–259. doi:10.1038/jes.2014.5. This study defines major roadways as those with a Census Feature Class Code classification of A1 (primary road with limited access or interstate highway) or A2 (primary road without limited access).

Near-Road Air Pollution and Children's Health

Pollutants directly emitted from cars, trucks, and other motor vehicles are found in higher concentrations near major roads. In some areas, other transportation sources like trains, ships, and planes, as well as industrial sources, can add to the local pollution burden. Examples of directly emitted pollutants include particulate matter (PM), carbon monoxide, oxides of nitrogen, and benzene, though hundreds of chemicals are emitted by motor vehicles.

Motor vehicles also emit compounds that lead to the formation of other pollutants in the atmosphere, such as nitrogen dioxide (NO_2), which is found in elevated concentrations near major roads, and ozone, which forms further downwind. Beyond vehicles' tailpipe and evaporative emissions, roadway traffic also emits brake and tire debris and can throw road dust into the air.

Studies show that concentrations of traffic-related air pollutants can be elevated inside classrooms, and that traffic is one of the most significant sources of air pollution in both the indoor and outdoor school environments.

Exposure to traffic-related air pollution has been linked to a variety of short- and long-term health effects, including asthma, reduced lung function, impaired lung development in children, and cardiovascular effects in adults.

Individually and in combination, many of the pollutants found near roadways have been associated with adverse health effects.

Motor vehicle pollutant concentrations tend to be higher closer to the road, with the highest levels generally within the first 500 feet (about 150 meters) of a roadway and reaching background levels within approximately 2,000 feet (about 600 meters) of a roadway, depending on the pollutant, time of day, and surrounding terrain.[1] Many scientific studies have found that people who live, work, or attend school near major roads appear to be more at risk for a variety of short- and long-term health effects, including asthma, reduced lung function, impaired lung development in children, and cardiovascular effects in adults. Studies show that certain ethnic groups and people who are in a low socioeconomic position often experience an increased burden from traffic emissions.[2,3,4] EPA has concluded that diesel exhaust is likely to be carcinogenic to humans at environmental levels of exposure, and the International Agency for Research on Cancer classifies diesel exhaust as a known human carcinogen.[5,6]

Nationally, the overall prevalence of asthma in children is approximately 8%. Asthma is a particularly complex respiratory disease with many factors, genetic and environmental, that interact to influence its development and severity. Extensive evidence links four common air pollutants (particulate matter, ground-level ozone, oxides of nitrogen, and sulfur oxides) to respiratory diseases in children. The mixture of pollution from traffic-related sources appears to pose particular threats to a child's respiratory system.[7] Children can also be exposed to air pollution inside homes, schools, and other buildings. Indoor air pollutants from biological sources (such as mold, dust mites, or pet dander) can lead to allergic reactions, can exacerbate existing asthma, and have been associated with the development of respiratory symptoms. For more information, see **America's Children and the Environment (ACE)**.

Children are particularly susceptible to health problems resulting from air pollution exposure due to:

- Having respiratory systems that are not fully developed. Studies show exposures to air pollution in childhood can result in decreased lung function.[8]
- Having higher rates of exposure than adults because they are more active and they breathe more in proportion to their body size.
- Typically spending more time outdoors than adults.

Children spend a lot of time at school, and nearly 17,000 schools in rural and urban areas across the U.S. are located within 250 meters (~820 feet) of a heavily traveled road.[9] While there is no national definition or threshold for a heavily traveled road, several organizations have denoted roads as "high-volume" when they experience over 50,000 (Federal Highway Administration and rural California roads), 80,000 (New York), and 100,000 (urban California roads) vehicles per day.[10,11] Smaller volume roads

[1] Karner, A.A., Eisinger, D.S., & Niemeier, D.A. (2010). Near-roadway air quality: Synthesizing the findings from real-world data. *Environmental Science & Technology*, 44(14), 5334-5344. doi:10.1021/es100008x

[2] Rowangould, G.M. (2013) A census of the near-roadway population: public health and environmental justice considerations. *Trans Res D* 25: 59-67. http://dx.doi.org/10.1016/j.trd.2013.08.003

[3] Tian, N.; Xue, J.; Barzyk. T.M. (2013) Evaluating socioeconomic and racial differences in traffic-related metrics in the United States using a GIS approach. *J Exposure Sci Environ Epidemiol* 23: 215-222.

[4] Boehmer, T.K.; Foster, S.L.; Henry, J.R.; Woghiren-Akinnifesi, E.L.; Yip, F.Y. (2013) Residential proximity to major highways – United States, 2010. *Morbidity and Mortality Weekly Report* 62(3): 46-50.

[5] https://www.iarc.who.int/pressrelease/iarc-diesel-engine-exhaust-carcinogenic/

[6] https://www.epa.gov/national-air-toxics-assessment/nata-frequent-questions

[7] Boothe, V.L. and Baldauf, R.W., 2020. Traffic emission impacts on child health and well-being. In *Transport and Children's Wellbeing* (pp. 119-142). Elsevier.

[8] Health Effects Institute. (2010). Traffic-related air pollution: A critical review of the literature on emissions, exposure, and health effects. Special Report 17. Available at https://www.healtheffects.org/publication/traffic-related-air-pollution-critical-review-literature-emissions-exposure-and-health

[9] Kingsley, S.L., Eliot, M.N., Carlson, L., Finn, J., MacIntosh, D.L., & Suh, H.H. (2014). Proximity of US schools to major roadways: A nationwide assessment. *Journal of Exposure Science and Environmental Epidemiology*, 24, 253–259. doi:10.1038/jes.2014.5. This study defines major roadways as those with a Census Feature Class Code classification of A1 (primary road with limited access or interstate highway) or A2 (primary road without limited access).

[10] https://ww3.arb.ca.gov/ch/rd_technical_advisory_final.pdf

[11] https://www.fhwa.dot.gov/policyinformation/hpms/volumeroutes/ch5.cfm

with large numbers of trucks, however, may also have large amounts of air pollution impacting air quality near the road. In addition, diesel-powered school buses can be a significant source of pollution near schools if there are numerous buses staged close to school buildings during pick-up and drop off or if excessive idling is permitted.

Exposure to traffic-related pollution is a concern both indoors and outdoors—concentrations tend to be higher outdoors, yet numerous studies have found that concentrations of traffic-related pollutants can also be elevated inside classrooms, where children spend most of the school day.[12,13]

How Can Near-Road Pollution Exposure Be Reduced in Schools?

This document addresses the following mitigation strategies that can be implemented by local school authorities: ventilation, filtration, actions for building occupants, transportation policies, site location and design, and the use of roadside barriers. Many of these strategies may also be effective at reducing exposure at schools near other sources of outdoor particulate and gaseous air pollution (e.g., railyards, industry, wildfires) and near facilities that have increased truck and car traffic (e.g., warehouses, ports). In planning, implementing, and evaluating mitigation strategies, it may be valuable to assemble a diverse project team that is committed to ensuring a healthy environment for children and staff.[14]

Over the past several decades, emission control technologies and regulations have led to large decreases in emissions per vehicle. Pollutant concentrations have also declined, though at a slower rate, because there has been growth in both the

Elevated PM concentrations in schools have been linked to:

- Poor ventilation;
- Ineffective, poorly maintained, or nonexistent air filtration;
- Proximity to major roadways;
- Open windows and doors allowing entry of polluted outdoor air during rush hours;
- Infrequent and incomplete cleaning of indoor surfaces; and
- High occupancy levels.

Stranger, M., Potgieter-Vermaak, S.S., and Van Grieken, R. (2008) Characterization of indoor air quality in primary schools in Antwerp, Belgium. *Indoor Air*, 18: 454–463.

McCarthy M.C., Ludwig J.F., Brown S.G., Vaughn D.L., and Roberts P.T. (2013) Filtration effectiveness of HVAC systems at near-roadway schools. *Indoor Air*, 23(3), 196-207. Available at https://pubmed.ncbi.nlm.nih.gov/23167831/.

[12] Mejia, J.F., Choy, S.L., Mengersen, K., & Morawska, L. (2011). Methodology for assessing exposure and impacts of air pollutants in school children: Data collection, analysis and health effects - A literature review. *Atmospheric Environment*, 45(4), 813-823. doi:10.1016/j.atmosenv.2010.11.009

[13] Mullen, N.A., Bhangar, S., Hering, S.V., Kreisberg, N.M., & Nazaroff, W.W. (2011). Ultrafine particle concentrations and exposures in six elementary school classrooms in northern California. *Indoor Air*, 21(1), 77-87. doi:10.1111/j.1600-0668.2010.00690.x

[14] For more information on developing a project team, see EPA's Energy Savings Plus Health guidelines (Appendix A). U.S. Environmental Protection Agency. (2014). Energy savings plus health: Indoor air quality guidelines for school building upgrades. At http://www.epa.gov/iaq/schools/pdfs/Energy_Savings_Plus_Health_Guideline.pdf

number of vehicles and vehicle miles traveled. Government and industry are still working to reduce the amount of pollutants emitted by motor vehicles. In the meantime, several strategies are being used by communities and schools across the country to reduce traffic-related pollution exposure. Some of these strategies aim to reduce indoor exposure at the individual building level, while others target reductions indoors and outdoors on a larger scale. Given the health implications of children breathing in PM (and specifically diesel PM, a harmful pollutant), the focus of this document is on strategies that can be used to mitigate PM exposure, although some techniques may be applicable to gaseous pollutants (e.g., carbon monoxide, benzene) as well.

Building Design and Operation Strategies for Reducing Near-Road Pollution Exposure

Ventilation, Filtration, and Indoor Air Quality in Schools

Proper building ventilation is crucial for maintaining healthy indoor air quality. Ventilation in schools is achieved passively (e.g., via open windows and doors) or mechanically by a building's heating, ventilation, and air conditioning (HVAC) system. Studies have shown that in addition to reducing health effects related to air pollution exposure, proper ventilation contributes to a comfortable learning environment associated with better test scores and attendance.[15]

However, improved ventilation does not always improve air quality. For example, if filtration is not used, higher ventilation rates can increase pollutant levels indoors if outdoor pollutant concentrations are higher than indoor concentrations.

Passive/Natural Ventilation

Recommendations

- Keep windows and doors closed during peak traffic times (e.g., morning and evening rush hours).
- Minimize indoor sources of air pollution.
- Use a stand-alone filtration unit or upgrade to a mechanical ventilation system.
- Ensure minimum outside air ventilation rates are maintained throughout occupancy as required by code.

In passive or natural ventilation systems, air is supplied to a classroom through open windows or doors or by leaks in the building envelope (e.g., gaps around windows and doors). Passive systems rely on dilution of indoor air contaminants by mixing indoor air with outdoor air. This approach is only effective if the outdoor air is less polluted than the indoor air.

It is often challenging to achieve proper ventilation using passive methods because assessing ventilation needs and outdoor air quality, as well as controlling ventilation rates, can be difficult for building occupants to carry out since there is limited ability to manage some air movement. Strategies for reducing pollution exposure in naturally ventilated classrooms include reducing indoor sources of air pollution[16] and, at schools near heavily traveled roads, timing air intake (i.e., opening and closing doors and windows) to avoid bringing in outdoor air during peak travel times (see Actions for Building Occupants below for more information).

Additionally, there are filtration-related options for schools with passive systems, which are described in the sections that follow.

[15] Mendell, M.J., & Heath, G.A. (2005). Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air*, 15(1), 27-52.

[16] https://www.epa.gov/indoor-air-quality-iaq/indoor-pollutants-and-sources

Mechanical Ventilation

Recommendations

- Use mechanical ventilation if possible. Central HVAC units that serve multiple classrooms are typically more effective than single-room unit systems.
- In classrooms where sufficient mechanical ventilation can be ensured
  - Seal the building envelope to prevent infiltration of polluted air through cracks around windows, doors, and HVAC ducts.
  - Keep windows and doors closed to avoid bringing in polluted outdoor air.
- Ensure that HVAC systems are properly maintained and operated.
- Locate air intakes away from roadways, buildings, drop-off zones, and other pollutant sources, such as designated smoking areas.

The Centers for Disease Control and Prevention recommends that schools prohibit all tobacco use at all school facilities and events at all times. See https://www.cdc.gov/healthyschools/health_and_academics/tobacco_product_use.htm for more recommendations on tobacco use prevention through schools.

In mechanical ventilation systems, air is circulated through a building by air intake and/or exhaust fans. Mechanical systems used in schools can be grouped into two categories: units that serve a single room without air ducts (such as a unit ventilator or individual heat pump) and central air handling units that serve multiple rooms via ductwork. The effectiveness of mechanical ventilation depends on HVAC system type, design, maintenance, and operation. An improper balance in a building's HVAC system can result in the building becoming incorrectly pressurized. Negative pressure can allow outdoor contaminants to enter the building through the building envelope, while positive pressure prevents infiltration of outdoor air but can force moisture into the walls of the building. In cold climates, moisture can condense in walls and promote mold growth, posing an environmental hazard with health consequences, in addition to structural consequences. Therefore, pressure relief dampers that allow air to exit the building or exhaust fans that draw air out are typically recommended.

An additional consideration when sealing building envelopes is ensuring that proper mechanical ventilation is maintained such that carbon dioxide (CO_2) concentrations do not exceed the recommended indoor limit of 1,000 ppm set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).[17] Previous studies have shown that this may occur if the building is tight and there is substandard or no mechanical ventilation.[18]

EPA recommends[19] that central HVAC air handling units be used when possible, as they are often quieter (and therefore less likely to be turned off), easier to maintain because of the reduced number of individual units, and compatible with higher efficiency filtration.

While central units typically achieve higher air exchange rates and therefore better indoor air

[17] ASHRAE Ventilation for Acceptable Indoor Air Quality Standards, https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2

[18] https://www.tandfonline.com/doi/full/10.1080/10962247.2019.1629362

[19] https://www.epa.gov/iaq-schools/heating-ventilation-and-air-conditioning-systems-part-indoor-air-quality-design-tools

quality, the necessary ducting and registers tend to increase system cost. For more information regarding recommended air exchange rates, see the [ASHRAE Ventilation for Acceptable Indoor Air Quality Standards]. Ductwork in central ventilation systems should be evaluated, cleaned if needed, and tested regularly for leaks by an HVAC professional. Regardless of the type of system used, mechanical ventilation systems are typically more reliable than natural methods because airflow rates are controllable.

Filtration

Recommendations

- For schools with mechanical ventilation systems, use high-efficiency filtration to reduce particle pollution exposure inside classrooms.
- Upgrade filtration to the highest MERV-rated filters that the HVAC system can handle.
- Consider HVAC system upgrades to accommodate high-efficiency filtration, such as MERV-13 and above, including the installation of pre-filters, if necessary. MERV-13+ can trap smaller particles, including viruses. MERV-16+ is preferred when possible.
- Inspect and replace filters regularly according to manufacturer recommendations.
- Where possible, locate air intakes away from pollution sources.
- Keep air vents clear of items that may block airflow.
- Consider also including an activated charcoal filter to remove gaseous pollutants.

Although diluting air contaminants through ventilation is sometimes adequate, many buildings (including schools) require additional air treatment to achieve suitable indoor air quality. Studies have shown that filtration in schools can improve indoor air quality by reducing particle concentrations by as much as 97% relative to outdoor levels.[20] Achieving maximum performance of filtration systems requires:

- Proper installation;
- Continuous operation;
- A tight building envelope (i.e., minimal air leaks);
- Effective air distribution;
- Careful placement of air inlets and outlets to face away from major roadways and to avoid pulling air into the school from parking lots where buses and cars are idling;
- Ensuring vents are free from items that may block filtered air from reaching the room; and
- Regular maintenance, including replacement of filters.

Filtration has some practical limitations. Filtration is only effective at removing particles that enter the system through an outside air intake and particles that enter through the return air ducts usually located at ceiling level. Particles entering the school through other pathways may not be exposed to the filtration system and removed (for instance, particles entering the classroom through open doors or windows, through leakage in the building envelope, from indoor sources, or from dust being kicked up from floors).

[20] McCarthy, M.C., Ludwig, J.F., Brown, S.G., Vaughn, D.L., & Roberts, P.T. (2013). Filtration effectiveness of HVAC systems at near-roadway schools. *Indoor Air*, 23(3), 196-207. doi:10.1111/ ina.12015

Portable Classrooms

Due to the structural nature of portable and mobile classroom buildings, they can be susceptible to multiple issues including poorly functioning HVAC systems, loud ventilation systems, water entry and mold growth, pollution from nearby parking lots or loading areas where they are often located, and less securely sealed building envelopes.

Recommendations to improve air quality in portable classrooms include:

- Siting portable classrooms away from major roadways or bus zones where idling may occur
- Using portable standalone filter units for classrooms that are not equipped with a central filtration system
  - Care should be taken to ensure they are appropriate for the occupancy and room size
- If window filtration units or HVAC are available, using the highest MERV-rated filter the system will allow
- Upgrading any existing HVAC or filtration systems to accommodate higher MERV-rated filters
- Locating HVAC and air handler units away from teaching areas to minimize noise
- Tightening the building envelope
  - Ensuring sufficient total ventilation to address mold issues and maintain appropriate humidity levels

For more information regarding guidelines for establishing and maintaining indoor air quality in portable classrooms, see the Portable Classroom section on the Indoor Air Quality Design Tools for Schools website.

Indoor air filtration is typically incorporated into a building's HVAC system, although portable, stand-alone air cleaners are also available. Both system types typically employ filters that remove air contaminants based on particle size.[21]

The degree of indoor air quality improvement from filtration depends on the filter's Minimum Efficiency Reporting Value (MERV) rating. Filters with MERV ratings from 1 to 4 are effective at removing large particles (e.g., pollen, dust mites, paint dust), but are less effective at removing small, traffic-related particles that can enter the respiratory system and cause adverse health effects. Filters with higher MERV ratings are increasingly more effective at removing very small particles. It is also important to note that filters not rated as MERV are often only used to protect the HVAC equipment and do not provide air quality benefits.

> **Schools planning** energy efficiency upgrade projects may consider simultaneous upgrades to improve indoor air quality.
>
> U.S. Environmental Protection Agency. (2014). *Energy savings plus health: Indoor air quality guidelines for school building upgrades.* Available at https://www.epa.gov/iaq-schools/protecting-iaq-during-school-energy-efficiency-retrofit-projects-energy-savings-plus

[21] Some portable, stand-alone air cleaners use alternate technologies to remove contaminants, such as electrostatic precipitators. While effective at removing particles, electrostatic precipitators tend to be more expensive than traditional filters, require more maintenance over time, and can generate small amounts of ozone as a by-product of air purification. In addition, some air cleaners are designed to intentionally generate ozone and are not recommended. The California Air Resources Board maintains a list of air cleaning devices tested and certified by the State of California to meet California's electrical safety and ozone emission requirements. See https://ww2.arb.ca.gov/list-carb-certified-air-cleaning-devices

In a pilot study of high-performance filtration in schools, the South Coast Air Quality Management District found that the combined use of register-based and high-performance panel filters was most effective at reducing particle concentrations, with reductions of 87-96%, while the use of the high-performance panel filter alone reduced particle concentrations by close to 90%.[23]

Studies examining filtration systems in schools have found that all types of air pollution filtration systems improve air quality conditions inside classrooms and can be used to reduce exposure to traffic-related pollutants indoors. Central HVAC systems equipped with MERV filters tend to be more effective than unit systems (e.g., window units) with filters. In schools with central HVAC systems, medium-efficiency filters (MERV 6–7) tend to reduce particle concentrations by approximately 20% to 65%, while higher performance filters (MERV 11–16) can reduce particle concentrations from 74% to 97% relative to outdoor concentrations.[22] Higher MERV ratings are generally associated with higher particle removal rates. Stand-alone systems, although slightly less effective, are well-suited for classrooms that are not equipped with a central HVAC system and can achieve removal efficiencies close to 90%.[23] However, performance depends on the amount of air that can be processed by the unit and other classroom layout features that influence airflow to the system. A downside of some stand-alone units is that they can be noisier than HVAC-based filtration. However, quieter stand-alone units are available that meet the noise level requirements for new classroom equipment.[23]

It is important to maintain HVAC filtration performance through regular maintenance and proper HVAC system operation. Excessive depressurization can be avoided by routine cleaning and filter replacement as necessary. Monitoring the system pressure can help identify when filter replacement is needed and can maximize performance, minimize energy costs, and prevent early disposal of useful filters. Inexpensive pre-filters can be used to remove a majority of particle mass and extend the life of the more expensive main filter. Filter performance and lifetime can also be improved by locating outdoor air intakes away from potential pollution sources so that cleaner air is drawn into the system.

Some schools may be able to incorporate high-efficiency filtration into their existing HVAC system. However, not all HVAC systems are compatible with high MERV-rated filters. For example, the filter rack size needs to be considered; some higher-MERV-rated filters are too thick to fit into existing filter racks, and some HVAC systems may not have enough power to adequately push air through more efficient filters. In some systems, the addition of a high MERV-rated filter can result in a large drop in system pressure. The magnitude of the pressure drop varies by filter type and not all high-efficiency filters result in a large drop in pressure. For example, the South Coast Air Quality Management District's school air filtration program uses high-performance panel filters that have air resistance properties similar to conventional filters, do not require the use of a pre-

[22] McCarthy, M.C., Ludwig, J.F., Brown, S.G., Vaughn, D.L., & Roberts, P.T. (2013). Filtration effectiveness of HVAC systems at near-roadway schools. *Indoor Air*, 23(3), 196-207. doi:10.1111/ ina.12015

[23] Polidori, A., Fine, P.M., White, V., & Kwon, P.S. (2013). Pilot study of high-performance air filtration for classroom applications. *Indoor Air*, 23(3), 185-195. doi:10.1111/ina.12013

filter, and do not reduce airflow through the HVAC system. In addition, these filters have longer lifespans than the medium- efficiency MERV filters typically in use, requiring replacement approximately once per year rather than every four months.[24] Depending on the HVAC system, installing the highest MERV-rated filter that the current system can handle may be a cost-effective way to improve indoor air quality. In other cases, improving or replacing the existing HVAC system may be required to achieve the pumping power necessary to accommodate high-efficiency filtration because of limited airflow.

Capital and/or increased operating costs may pose limitations to these improvements; however, potential savings associated with any system upgrades should also be considered. For example, the cost of purchasing an integrated air sensor to monitor ventilation needs, and thereby help optimize ventilation rates, could offset long-term, higher energy costs due to over-ventilation. Air sensors for ventilation monitoring should be installed by a professional.

Indoor Air Cleaners

Recommendations

- Choose a unit that is appropriate for the size of the room where it will be used.
- Choose a unit that removes particles and/or volatile organic compounds based on need.
- For classrooms relying on passive/natural ventilation, use quiet, portable, stand-alone filtration systems to reduce indoor concentrations.
- Where possible, locate air cleaner intake away from pollution sources for maximum efficacy.
- Ensure maximum energy efficiency by choosing a portable unit with an EPA ENERGY STAR designation.

In addition to minimizing sources of air pollutants and proper ventilation, air filtration can help to reduce indoor air pollution. If HVAC air filtration is not available, or if additional filtration is required, portable air cleaners might be a suitable option. Portable air cleaners (also known as air purifiers) are designed to help reduce indoor air pollution in a specific area or a single room.[25]

There are several factors to consider when choosing an appropriate portable air cleaner for a given space. These include:

- Ensuring the unit is appropriate for the size of the room it will be used in by checking its Clean Air Delivery Rate (CADR).[26]

  Note: To remove PM using portable air cleaners, choose units that have a high CADR rating for "smoke."[27]

[24] Polidori, A., Fine, P.M., White, V., & Kwon, P.S. (2013). Pilot study of high-performance air filtration for classroom applications. *Indoor Air*, 23(3), 185-195. doi:10.1111/ina.12013

[25] EPA guidance on air cleaners and air filters: https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home

[26] CADR, as described by ASHRAE, is the rate of particle removal from air passing through a filter and is approximately equal to the product of airflow rate and the contaminant removal efficiency. For more information, see the ASHRAE Position Document on Filtration and Air Cleaning: https://www.ashrae.org/file%20library/about/position%20documents/filtration-and-air-cleaning-pd.pdf

[27] https://www.epa.gov/sites/production/files/2019-09/documents/harriman_stephens_brennan_-_new_guidance_for_residential_air_cleaners_-_ashrae_journal_sept-2019._web_version.pdf

- Deciding if the unit needs to remove volatile organic compounds (VOCs) as well as particles. If so, choosing one with an activated carbon charcoal filter might be necessary. VOC filters are helpful at schools near heavy passenger vehicle traffic; where indoor cleaning and maintenance involves solvents, where dry-erase white board markers emit strong odors; or where there are other indoor or outdoor pollution sources involving chemicals or liquid fuels.
- Ensuring the lowest noise rated cleaner is used if noise will be an issue.
- Careful consideration of the placement of the portable air cleaner for maximum efficacy.
- Choosing a portable air cleaner with an EPA ENERGY STAR designation to conserve energy and optimize efficiency.
- For more information about these factors and other important considerations, see the EPA Guide to Air Cleaners. Care should be taken to ensure that regular maintenance is performed, as directed by the manufacturer, on portable air cleaners. It is also important to keep in mind that longer air cleaner operating hours provide better particle removal, which, in turn, increases the potential for health benefits.[28]

Actions for Building Occupants

Recommendations

Train teachers, school staff, and students (where appropriate) on best ventilation practices, including:

- Keeping windows and doors closed in mechanically ventilated classrooms to prevent entry of polluted outdoor air.*
- Keeping windows and doors closed in naturally ventilated classrooms during peak commute times.*
- Keeping HVAC systems turned on throughout the day.
- Keeping air vents clear of items that may block airflow.
- Understanding the importance of indoor pollutant sources and how to reduce emissions from indoor sources.
- Planning strenuous outdoor activities during times with lower amounts of traffic.
- Consider how school buildings are used on weekends that may require changes to HVAC operation. This may include:
  - Sporting events in athletic facilities
  - Adult extension education
  - Classes taking place on weekends

* Adhere to local, school, and health department recommendations regarding outside ventilation due to pandemic conditions.

The actions of building occupants can greatly affect near-road pollution exposure indoors. For instance, opening windows or doors for ventilation in classrooms can allow polluted air to enter into the classroom and overwhelm the air quality benefits of an HVAC filtration system. Keeping windows and doors closed is especially important during periods of peak traffic (e.g., morning and evening rush hours) when near-road

[28] EPA guidance on air cleaners and air filters: https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home

pollutant concentrations are typically highest. Although the classroom is a noise-sensitive environment, it is important that HVAC systems are not turned off during the day.

For naturally ventilated classrooms, there may be opportunities to time air intake to avoid bringing in outdoor air during peak concentration times.

Although the focus of this document is traffic-related pollution exposure, it is important to note that indoor sources can largely impact (or even dominate) indoor concentrations of PM and gaseous pollutants. Indoor sources include combustion sources, secondhand smoke, dust from student activity (PM), and (gaseous) emissions, such as from building materials, furniture, carpets, air fresheners, personal care products, biologically derived emissions from mold and bacteria, and classroom supplies (e.g., dry erase markers and some cleaners). Indoor pollution sources should be reduced as much as possible and should also be considered when considering ventilation upgrades, filtration methods, and other mitigation strategies.

Raising awareness about indoor and outdoor air quality issues and providing training for staff on optimal building operating practices (including HVAC operation) are inexpensive strategies that can supplement upgrades to the ventilation and filtration system and building and site design. EPA has many resources to address indoor air quality (IAQ) management in schools, including the IAQ Tools for Schools program. This program provides an easy-to-use framework and set of tools to train staff on IAQ management and can be found, along with the other school IAQ resources, on the EPA IAQ school website. Training is recommended as a complementary strategy and should not be considered an alternative to ventilation upgrades.

Outdoor exposure may be reduced by timing outdoor activities to avoid times of peak pollution. Ozone pollution is often worse on hot, sunny days, especially during the afternoon and early evening. Particle pollution can be high any time of day, but higher levels can be found near idling cars, trucks, and buses and near busy roads, especially during rush hour. If possible, plan strenuous outdoor activities outside of rush hour and drop-off/pick-up times, and consider locating activities farther from roads and loading zones. Resources are available to help teachers plan when students should stay indoors based on current air quality.[29] In addition, many schools implement the Air Quality Flag Program to raise awareness of the daily air quality index (AQI). The school flags, combined with information on current air quality from AirNow, can be used to help plan outdoor activities.

Summary

Ventilation and filtration needs vary by school according to occupancy, proximity to roadways or other pollutant sources, and the prevalence of indoor sources. School administrators can improve indoor air quality by modifying ventilation and filtration systems, yet it can be difficult to identify which strategies will yield the most significant improvements for the level of effort and cost required.

[29] The Utah Recess Guidance for Schools, https://health.utah.gov/asthma/airquality/recess.php

To evaluate which (if any) actions may be needed to help reduce exposure to traffic-related pollution, school staff can begin by making a preliminary assessment. A brief guide to assist in the assessment of a school ventilation and filtration system is **provided in this document**. Once an initial assessment of the current ventilation system is complete, mitigation strategies suitable for the system can be evaluated. **Table 1** offers mitigation strategies for different types of ventilation systems typically found in classrooms.

Table 1. Mitigation strategies for different HVAC/ventilation types. HVAC/ventilation system types are listed from more effective to generally less effective, and mitigation strategies are listed from the simplest (and least costly) to implement on the left to those that require a higher level of effort on the right.

HVAC/Ventilation Type	Mitigation Strategies					
	Educate Staff	Air Seal Building	Adjust Air Intake	Use Filtration	Upgrade System	
Central HVAC system serving multiple classrooms; high-efficiency filtration use **not** limited by airflow	✓	✓	Change air intake locations if near pollution source(s) (e.g., roadway, drop-off zone, parking)	Use MERV-16+ filter Use pre-filters		More effective ↑
Central HVAC system serving multiple classrooms; high-efficiency filtration use limited by airflow	✓	✓	Change air intake locations if near pollution source(s) (e.g., roadway, drop-off zone, parking)	Use highest compatible MERV-rated filter Use pre-filters or high-performance panel filters	Modify airflow to be compatible with higher efficiency filtration	
Single-classroom HVAC unit (e.g., unit ventilator)	✓	✓	Avoid airflow obstructions Use quiet systems	Use highest compatible MERV-rated filter Use pre-filters or high-performance panel filters	Upgrade to a central HVAC system	
Passive/natural ventilation	✓	May be an option if adequate ventilation to dilute and remove pollutants from indoor sources is a challenge	Avoid bringing in air during periods of high traffic	Use a portable stand-alone filtration system	Switch to a mechanical ventilation method	

Site-Related Strategies for Reducing Near-Road Pollution Exposure

Transportation Policies

Recommendations

- Limit school bus and passenger vehicle idling by instituting anti-idling or idle reduction policies.
- Upgrade school bus fleets by
  - Retrofitting buses with PM filters or oxidation catalysts; and
  - Replacing older buses with newer models.
- Emissions may be reduced by using improved bus technologies like electric or some alternative fuels, including LPG, CNG, and LNG.
- Discuss funding opportunities for bus fleet upgrades with your local or state environmental or air quality agency.
- Provide walking and biking paths to promote active transportation and reduce the number of buses and passenger vehicles near the school.

Establish Anti-Idling and Idle Reduction Policies

Bus and passenger vehicle operation and idling can produce large amounts of PM and other air pollutants. Some schools, states, and localities have instituted anti-idling or idle reduction policies to reduce the impact of pollution from buses and passenger vehicles near schools. Anti-idling policies can result in large decreases in particle concentrations, particularly at schools operating multiple diesel school buses. For more information, see the **idle-free schools toolkit**.

Upgrade Bus Fleets

Pollution from school buses can also be reduced by upgrading bus fleets. Fleet turnover for diesel school buses is low, with buses typically operating for 20 to 30 years. Older buses emit high levels of PM and other air pollutants. However, technological advances and tighter PM emissions standards for new buses, set by EPA, have resulted in new buses (manufactured during or after 2007) that are 60 times cleaner than buses produced prior to 1990.[30] Emissions can be reduced by retrofitting older school buses with PM filters or oxidation catalysts, or by replacing older buses with newer models.

Emissions may be reduced by using certain alternative fuels. Examples include engines certified to operate on alternative fuels such as liquid petroleum gas (LPG), compressed natural gas (CNG), and liquefied natural gas (LNG). A co-benefit of upgrading older school buses, for children who use them as transport, is reduced in-vehicle exposure. Discuss potential funding options for bus fleet upgrades with your state or local environmental or air quality agency.[31]

[30] https://www.edf.org/sites/default/files/cleanbuses_14_screen.pdf

[31] U.S. Environmental Protection Agency. (2010). Clean school bus. Available at https://www.epa.gov/sites/production/files/documents/CleanSchoolBus.pdf

Encourage Active Transportation

Promoting active transportation, such as walking and bicycling to and from schools, can help reduce traffic-related pollution by reducing the number of buses and passenger vehicles nearby. For example, the addition of walking/biking paths at Roosevelt Middle School in Eugene, Oregon, reduced traffic volumes near the school by 24%.[32]

While active transportation may contribute to improved air quality near schools, students walking or biking to school may be exposed to roadway pollution and other traffic hazards because of their proximity to motor vehicle traffic. When safe alternatives exist, biking and walking to school along routes with lower traffic volumes may help reduce exposure to pollution and safety hazards.[32]

Parallel and off-street walking/biking paths through parks or other off-road areas can also provide a good alternative to traveling along a road with many motor vehicles. Pursuing pedestrian and bicycle infrastructure improvements can help provide safer routes for students to walk and bike to school. This could include installing or improving sidewalks, crosswalks, signs, markings, and countdown timers, as well as encouraging "walking" school buses.[33] When considering walking and biking routes to school, impacts on safety, lighting, access, and maintenance requirements should be considered. The U.S. Department of Transportation Safe Routes to School Programs website provides various links to resources, like the Safe Routes to School National Partnership, which contains information about programs that promote walking and biking to school.

Despite the potential for increased exposure associated with active transportation, walking and biking have been shown to improve health, and people who live in highly walkable neighborhoods are generally more physically active than those who live in less walkable neighborhoods. Promoting walking and biking to school along routes or paths with lower traffic volumes (relative to other roads) will increase the likelihood that the health benefits of exercise outweigh the health risks associated with increased air pollutant exposures.

Site Location and Design

Recommendations

- For new school developments, consider locations farther from major roads and other areas with heavy truck traffic, but still within the community.
- Consider unintended consequences of any location, such as increased commute distances and decreased opportunity for walking and biking.
- Consider opportunities to locate playgrounds, athletic fields, and classrooms farther from the roadway, or other areas with heavy truck traffic, by locating maintenance, storage, parking, and office facilities in the area closest to the roadway.
- Locate bus and passenger vehicle loading zones away from classrooms, play areas, and building air intakes.

In response to concerns about the impacts of near-road air pollution, several agencies, including EPA and several state agencies, have established siting guidelines for new schools that recommend reducing traffic-related air pollution exposure (Table 2).

[32] Safe Routes to School National Partnership. (2012). Safe routes to school and traffic pollution: Get children moving and reduce exposure to unhealthy air. Available at http://www.saferoutespartnership.org/sites/default/files/pdf/Air_Source_Guide_web.pdf

[33] National Center for Safe Routes to School. (2013). Starting a walking school bus. Available at http://www.walkingschoolbus.org

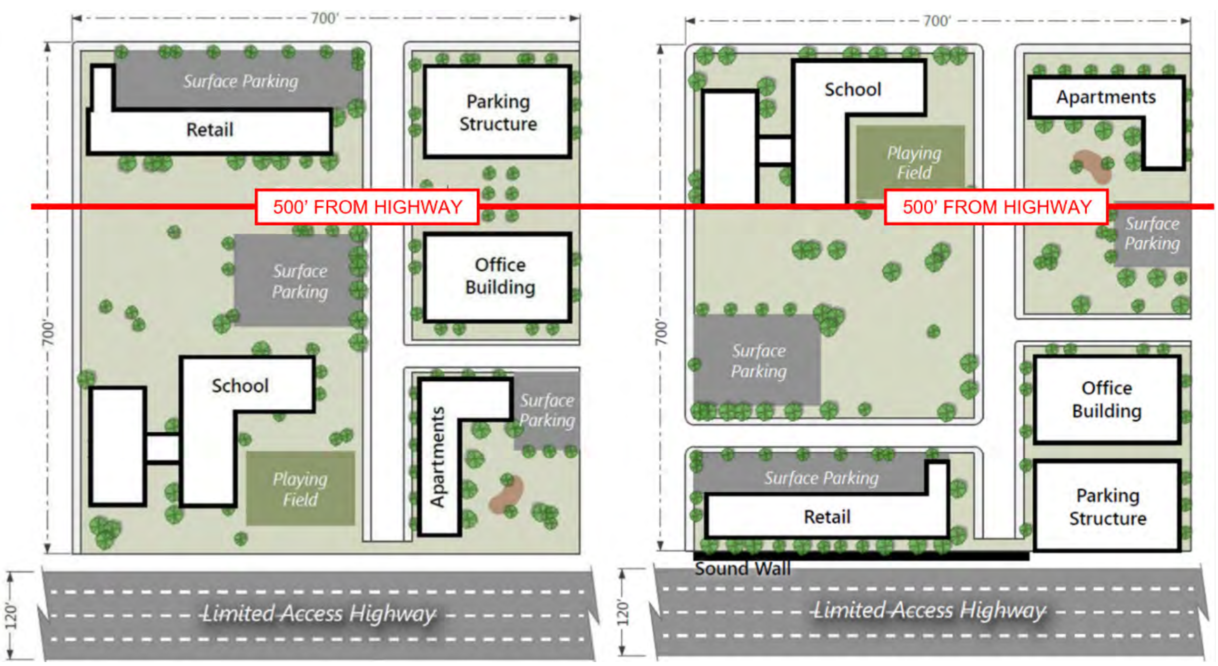
Table 2. School siting documents developed by various agencies.

Agency	Guidance	Key Outcomes
U.S. EPA	School Siting Guidelines (2011)	Recommends considering many factors in evaluating locations for new schools, including proximity to the community (including community amenities and infrastructure), distance from major transportation facilities, exposure to air pollutants during student commutes, feasible mitigation on site, and accessibility by walking or biking.
California Air Resources Board	Strategies to Reduce Air Pollution Exposure Near High-Volume Roadways (2017)	Recommends that new schools are located more than 500 feet from major roadways (>50,000 vehicles/day).
California Department of Education	School Site Selection and Approval Guide (2000)	Recommends distancing schools 2,500 feet from major roadways where explosives are carried and at least 1,500 feet from roads where gasoline, diesel, propane, chlorine, oxygen, pesticides, or other combustible or poisonous gases are transported.
South Coast Air Quality Management District	Air Quality Issues in School Site Selection: Guidance Document (2005, updated 2007)	Recommends a buffer zone of no less than 500 feet, and as much as 1,000 feet, between schools and major roadways.
Los Angeles Unified School District	Distance Criteria for School Siting (2008)	Recommends that new schools are not built within 500 feet of a freeway or major transportation corridor (>100,000 vehicles/day).
State of Oregon	School Siting Handbook (2005)	Recommends locating schools away from major arterial roads and railroads as these are dangerous to cross and reduce safe walking and biking access to schools. Ensure good connections between school and nearby neighborhoods to encourage walking or biking to school.
Ohio Department of Health	Smart School Siting (2018)	Recommends considering remote student drop off locations, locating parking lots farther from school, and creating separate entrances for motorized and non-motorized modes of transport.

While California guidelines recommend that new schools should not be located within 500 feet of major roads (those with >50,000 vehicles per day in rural areas or >100,000 vehicles per day in urban areas),[34] EPA's [School Siting Guidelines] note the need to consider multiple issues associated with exposure and health. For example, a school sited far from a major road that requires long commutes by bus or car may result in higher overall exposure for students, compared to a school site near a major road that does not require long commutes.[35] Overall, EPA recommends multiple strategies, as described in this document, to reduce students' overall exposure.

School sites include a variety of land use types, such as classrooms, playgrounds, athletic fields, offices, and maintenance and storage facilities. For new or remodeled school developments near roadways, there may be opportunities to reduce traffic-related pollution exposure through careful site design. By locating land uses such as maintenance, storage, parking, and office facilities in the area closest to the roadway, classroom and play areas can be located farther from the roadway in areas where air pollutant concentrations tend to be lower. Some of these strategies may also be applicable to existing school sites near roadways, or to sites located near other sources of diesel particulate air pollution such as warehouses, truck routes, railyards, and ports.

Exposure to traffic-related pollution can also be reduced by locating onsite transportation-related sources, especially school bus drop-off and pick-up locations, as far from classrooms, play areas, and building air intakes as possible. Optimal placement of offices, playgrounds, athletic fields, and classrooms within a school site depend on a variety of factors, including typical wind patterns, the amount of time spent and activities performed outdoors versus indoors, and indoor ventilation conditions.



Sample layouts for a large land parcel with a school and other land uses. A less desirable layout (left) with the school located close to the highway is compared to an improved layout (right) with the school more than 500 feet from the highway (red dotted line).

[34] https://ww3.arb.ca.gov/ch/rd_technical_advisory_final.pdf

[35] Wolfe, M.K., McDonald, N.C., Arunachalam, S., Baldauf, R. and Valencia, A., 2020. Impact of school location on children's air pollution exposure. *Journal of Urban Affairs*, pp.1-17

Roadside Barriers

Recommendations

- Use a solid roadside barrier and/or vegetation to block traffic-related pollutants from influencing air quality near the school along highways or very large local roads.
- Minimize gaps in solid and vegetative roadside barriers.
- For vegetative barriers, use mature, dense greenery (conifers preferred) and locate the barrier downwind and close to the roadway.
- Consult with a specialist or use one of the resources identified in the text of this document to choose species that do not change by season (e.g., conifers) and that are appropriate for the region and site.
- Vegetation should be properly maintained to ensure vegetative health and to prevent gaps from forming.

In situations where school authorities do not have jurisdiction over or ownership of the immediate roadside environment, consider discussing the use of roadside barriers to reduce traffic-related pollution exposure with the relevant authority (e.g., state department of transportation, city planning department).

Solid Barriers

Pollutant concentrations behind a solid barrier located downwind of a roadway, such as a sound wall or fence, are typically lower than concentrations in the absence of a barrier. Studies show that reductions in downwind pollutant concentrations within approximately 500 feet of a highway in the presence of a well-designed sound wall can be on the order of 15% to 50%.[36,37,38]

The effectiveness of solid barriers at mitigating near-road pollution exposure depends on roadway configuration, local meteorology, and barrier height, design, and endpoint location. For example, pollutant concentrations may be higher downwind of a wall if there are gaps in the wall that allow pollutants to pass through. Solid barriers can be considered for schools located adjacent to highways and other busy, high-traffic roadways.

[36] Baldauf, R.W., Khlystov, A., Isakov, V., Thoma, E., Bowker, G.E., Long, T., & Snow, R. (2008). Impacts of noise barriers on near-road air quality. *Atmospheric Environment*, 42, 7502–7507.
[37] Baldauf, R.W., Isakov, V., Deshmukh, P., Venkatram, A., Yang, B., and Zhang, K.M., 2016. Influence of solid noise barriers on near-road and on-road air quality. *Atmospheric Environment*, 129, 265-276
[38] Lee, E.S., Ranasinghe, D.R., Ahangar, F.E., Amini, S., Mara, S., Choi, W., Paulson, S. and Zhu, Y., 2018. Field evaluation of vegetation and noise barriers for mitigation of near-freeway air pollution under variable wind conditions. *Atmospheric Environment*, 175, 92-99

Vegetation

Trees and plants along roadways can reduce particle and some gaseous pollutant concentrations by acting as a physical barrier between roadways and schools (similar, in effect, to solid walls and fences), or by filtering particles as they pass through and accumulate on leaf surfaces. The amount of removal depends on plant species, leaf type and size, and pollutant type.

The effectiveness of trees and plants as physical barriers also depends on the density and height of the greenery. In general, evergreen species are typically more effective than deciduous species because they keep their greenery all year, and the wax-covered, needle-like greenery of conifers tends to be more effective than broad-leaved trees. Particle removal rates tend to be higher when vegetation is located close to the pollutant source and when wind speeds are low.

The vegetation types chosen for roadside barriers should be appropriate for the location of interest, including water requirements, non-invasive species, and aesthetics. In general, the vegetation barrier should be thick (approximately 15 feet or more) and have full leaf and branch coverage from the ground to the top of the canopy along the entire length (i.e., no gaps between or underneath the vegetation). In some instances, this type of barrier may require the use of multiple vegetation types such as a combination of bushes and trees. The vegetation types chosen should also not be emitters of air pollution or high levels of pollen.

Schools can use the EPA Recommendations along with the U.S. Department of Agriculture's (USDA's) i-Tree Species Tool to begin the process of designing and choosing appropriate vegetation for barriers, in consultation with other experts from plant nurseries, local cooperative extensions, city government, and/or the U.S. Forest Service. All vegetation that will be located near a road should be sited consistent with state and local safety guidelines.

The combined use of vegetation and solid barriers has shown promise in reducing vehicle pollution downwind of roadways by up to 60%.

Bowker, G.E., Baldauf, R., Isakov, V., Khylstov, A., & Petersen, W. (2007). The effects of roadside structures on the transport and dispersion of ultrafine particles from highways. *Atmospheric Environment, 41,* 8128-8139.

Similar to sound walls, concentrations may be higher behind a vegetative barrier that is located downwind of the roadway if there are gaps in the vegetation such as missing or dead trees, or lack of cover from the ground to the top of the vegetation. In any case, vegetation can be used as a buffer to distance people from the roadway while creating a more attractive and shaded space that encourages active transportation (such as walking and bicycling) as an alternative to vehicle use.[39]

[39] Baldauf, R., McPherson, G., Wheaton, L., Zhang, M., Cahill, T. Hemphill Fuller, C., Withycombe, E., & Titus, K. (2013). Integrating vegetation and green infrastructure into sustainable transportation planning. *Transportation Research News*, September-October, 14-18.

Air Quality Measurements

Air Sensors

Both indoor and outdoor air quality can be measured using air sensors. In comparison to regulatory-grade monitors, non-regulatory air sensors typically require a lower capital cost, are portable, and are easier to operate. There are many air sensors available for purchase, which might lead to confusion over the benefits and accuracy of each option.[40] To assist those interested in using sensors as part of air monitoring projects, EPA, the Air Quality Sensor Performance Evaluation Center (AQ-SPEC), and other organizations conduct performance evaluations of select air sensors on the market either under ambient, fixed-site conditions and/or in a controlled laboratory exposure chamber.[41,42] In these assessments, sensors are evaluated for how well they measure air pollutants in terms of accuracy and reliability as well as how easy they are to use. Additionally, EPA has recommended [Air Sensor Performance Targets and Testing Protocol]() to help users consistently test air sensor devices, calculate performance metrics, consistently report test results, and evaluate sensor performance using recommended target values. For more information on sensor evaluation and performance, see the [EPA Sensor Evaluation Results]() page and [AQ-SPEC](). For more information on sensor operation and data interpretation, see the [EPA Air Sensor Toolbox]().

One application for which air sensors could be used is to monitor inside school buildings. While the performance of individual sensors may vary and studies on the accuracy of the measurement in indoor environments is still being evaluated, results can be used to understand potential presence or trends of certain pollutants. For example, air sensors can be used in schools to assist in understanding pollutants inside classrooms, hallways, or other areas. Broadly, there are two types of air sensors: stationary air sensors (fixed in one location), and portable or hand-held sensors. Stationary sensors may help a user understand how pollution levels change in one location over the school day. Portable air sensors may help users identify indoor hotspots. Another use for portable air sensors is to investigate personal pollution exposure on the way to school or work and use the information to devise a lower-pollution route. Both types of air sensors can be used for educational projects and can help build awareness about indoor or outdoor air quality.

It is important to keep in mind that air sensors are not regulatory-grade air quality monitors, and thus should be used for non-regulatory supplemental and informational monitoring (NSIM) applications only. They may need periodic calibration or maintenance. Refer to the manufacturer's manual and/or the EPA Air Sensor Toolbox for instructions on proper maintenance and calibration procedures to ensure your air sensor data remains of high quality.

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[40] https://www.epa.gov/air-sensor-toolbox

[41] https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-sensor-performance

[42] http://www.aqmd.gov/aq-spec

Summary of Recommendations

Table 3 summarizes mitigation strategies that can be used to reduce traffic-related pollution exposure in schools, including ventilation/HVAC system requirements, benefits, drawbacks, and relevance for new and/or existing schools. Note that some of these mitigation strategies will only serve to reduce pollution exposures indoors (e.g., filtration), or will only effectively reduce some pollutants (e.g., PM) but not others (e.g., volatile organic compounds). These mitigation strategies reduce risks, but do not eliminate them. Mitigation benefits are estimates and actual costs may vary based on location, existing filtration infrastructure, and other factors.

Table 3. Summary of mitigation strategies.

Strategy	Ventilation/ HVAC System Type	Benefits	Drawbacks	Mitigation Benefit	Capital Cost	Ongoing Cost
Educate staff on ventilation and indoor air quality best practices	All	Teachers are less likely to turn mechanical systems off; air vents remain unobstructed; doors/windows are kept closed during peak pollution periods; indoor sources of air pollution are reduced; potential to prolong life of mechanical filters; can be implemented at new or existing schools	Effectiveness may decrease over time; results depend on training quality and staff cooperation; teachers or students may perceive classroom air quality is lowered when windows and doors are closed	medium-low	$	0 - $
Air-seal around windows, doors, HVAC ducts, etc.	Mechanical ventilation systems	Reduces the amount of unfiltered air entering the building; can be implemented at new or existing schools	Indoor pollutant concs. may build over time if ventilation is insufficient, especially if indoor pollutant generation is high	medium-low	$	0
Relocate air intake or source if roadway/ pollution source is near intake vent	Central or single classroom HVAC units	Reduces particle and gaseous concentrations in incoming air; can increase lifespan of filters; can be implemented at new or existing schools	Cost	medium	$$ - $$$	0
Use portable filtration units	Naturally ventilated classrooms	Reduces particle concentrations from both outdoor and indoor sources; can be implemented at new or existing schools	Maintenance and replacement required; may require system upgrades	medium	$-$$	0-$
Improve HVAC system design to be compatible with high-efficiency filtration	Central HVAC systems	Larger reductions in particle concentrations are possible; can be implemented at new or existing schools	Cost; reduced filtration if HVAC system or building envelope is leaky	high	$$$	$
Implement anti-idling/idle reduction policies	All	Reduces emissions of particles and gases; can be implemented at new or existing schools	Lack of vehicle climate control during hot/cold weather	medium	$	$
Upgrade school bus fleet	All	Reduces emissions of particles and gases; potential long-term cost reduction; can be implemented at new or existing schools	Purchase cost; may require training for bus maintenance and upkeep; potential route limitations depending on length of routes and range of buses selected	medium	$$$[a]	$
Encourage active transportation (e.g., walking and biking) to school	All	Reduces emissions of particles and gases; improved health with exercise; can be implemented at new or existing schools	Walkers/bicyclists may be exposed to traffic-related pollution or other hazards during trips	medium	0 to $	0
Locate school site away from pollution sources (Mainly applicable for new schools)	All	May reduce student exposure to particles and gases at the school, although overall exposures may increase if an alternative site requires long commutes by older buses or cars	If alternative sites are limited, there may not be opportunities to locate the school farther from the road; unintended consequences from locating sites far from the community may include a decreased opportunity for walking and biking, increased traffic, and/or increased exposures during commuting	NA[b]	NA[b]	0
Design school site to minimize exposure to pollutant sources	All	Reduces student exposure to particles and gases; can be implemented at new or existing schools if there is flexibility to relocate child-based activities	Effectiveness is site-specific; may be costly or infeasible for existing schools	medium	$$$	$
Use solid and vegetative barriers	All	Reduces concentrations of particles and gases near schools; vegetative barriers may increase shade and improve aesthetics; can be implemented at new or existing schools	Cost; optimal design may be site-specific; maintenance and water needs for vegetative barriers; reduced visibility from street may be security issue or limit access and connectivity; may need support from other stakeholders such as the state department of transportation	medium	$$ - $$$	0 - $$

[a] Local, state, and federal grants or assistance may be available
[b] Consideration for new construction only

School Ventilation and Filtration System Assessment

1. Assess whether near-road pollution may be a problem.
    - Is there a major roadway near the school? If so:
        - How far away is it (at least 500 ft. away from the road is preferred)?
        - Is the school downwind of the road?
        - Is it at grade, above or below the road (at-grade tends to maximize exposure to roadway pollution)?
    - Where does school bus pick-up and drop-off occur?
        - Are there opportunities to reduce bus idling or relocate loading zones away from classrooms and outdoor recreation areas?
2. Assess the current ventilation and filtration system. For a more detailed checklist concerning this topic, see the [Tools for Schools Ventilation Checklist]
    - Is ventilation achieved passively or mechanically?
    - If mechanical:
        - Is a central HVAC system used or a single-classroom unit?
        - What is the blower capacity?
        - Is filtration being used? If so, what is the MERV rating of the filter(s)?
3. Assess ventilation operation. For a more detailed checklist concerning this topic, see the [Tools for Schools Ventilation Checklist]
    - Are teachers leaving windows and/or doors open during the day?
    - Are there opportunities to bring in air during off-peak emission times?
    - Are teachers turning systems off due to noise issues?
    - Are filters being inspected, cleaned, and replaced according to the schedule recommended by the manufacturer?
    - Is the entire ventilation operation following a preventive maintenance system or plan?
4. Assess air-sealing needs to limit infiltration of unconditioned air.
    - Can infiltration of polluted air be reduced by sealing around any of the following:
        - Windows?
        - Doors?
        - HVAC ducting?
5. Evaluate air intake location(s) relative to roadways or other pollutant sources such as school bus drop-off and pick-up locations.
    - Are any air intakes located near a roadway, loading zone, or other pollutant source, such as designated smoking areas?[43] Are supply and exhaust vents unobstructed?
    - Can the air intake be relocated to an area that is less influenced by pollutant sources?

[43] The Centers for Disease Control and Prevention recommends that schools prohibit all tobacco use at all school facilities and events at all times. See https://www.cdc.gov/healthyschools/health_and_academics/tobacco_product_use.htm for more recommendations on tobacco use prevention through schools.

Related Documents

For an overview infographic that summarizes some of the important mitigation strategies and suggestions from this Best Practices Guide, see the **Summary Infographic**.

To access a list of resources that provide more information about various topics covered in this Best Practices Guide, see the **Resources Guide**.

For case studies concerning implementation of various strategies at schools, see the **Case Studies at Schools Document**.

Acknowledgments

EPA would like to acknowledge the following organizations that provided comments on this document:

U.S. Environmental Protection Agency Offices:

- Office of Children’s Health Protection
- Office of Indoor Air & Radiation
- Office of Research & Development
- Office of Community Revitalization
- Region 5

EPA would like to acknowledge the following organizations that provided comments on an earlier version of this document:

- South Coast Air Quality Management District
- Southern California Green, Clean and Healthy Schools Partnership

Office of Children's Health Protection (1107A)
and
Office of Transportation and Air Quality
EPA-420-R-21-022
October 2021

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