Best Practices for Reducing Near-Road Pollution Exposure at Schools

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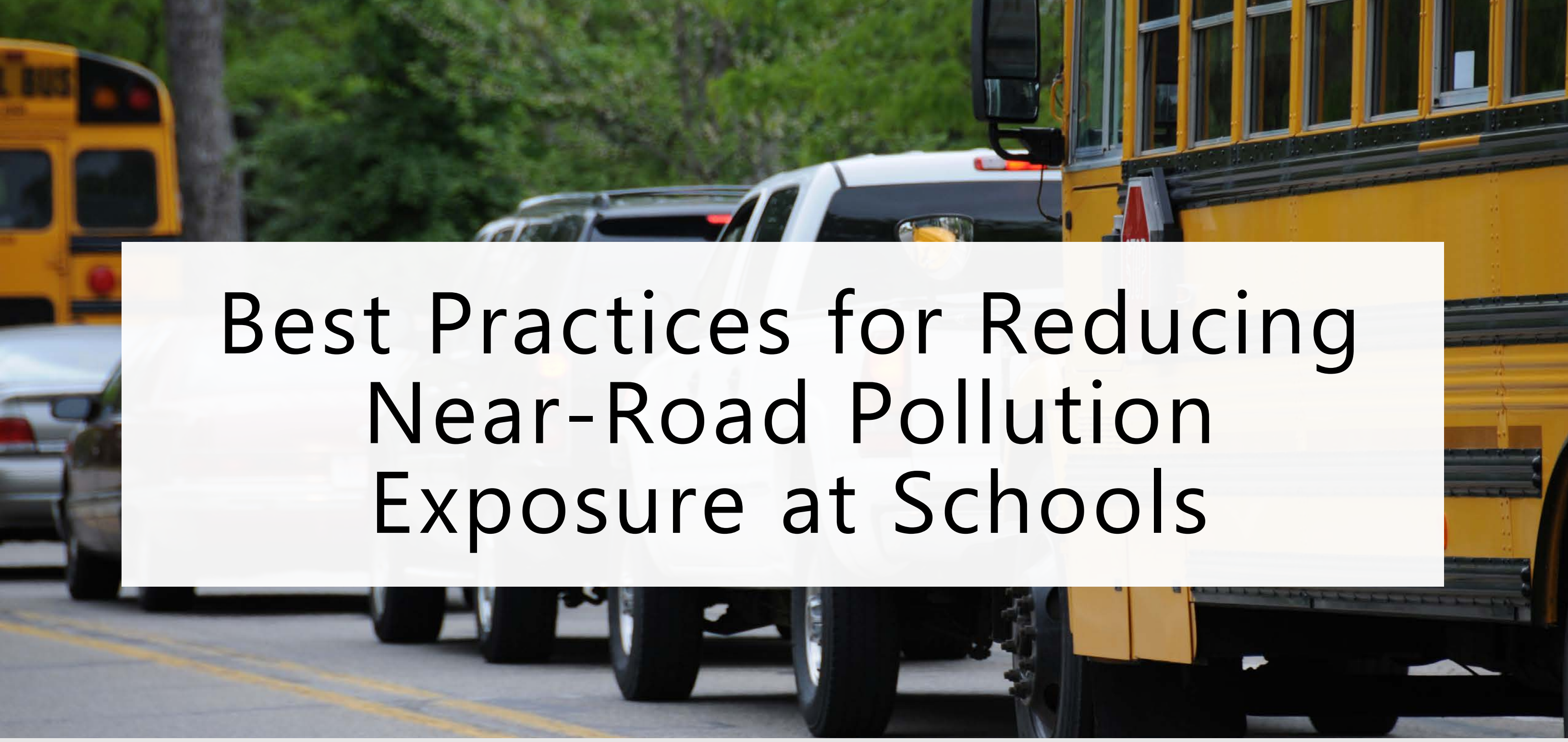

Best Practices for Reducing Near-Road Pollution Exposure at Schools

U.S. Environmental Protection Agency

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South Coast Air Quality Management District

Southern California Green, Clean and Healthy Schools Partnership

Contents

Introduction

Purpose of This Publication

This publication can help 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 trucking traffic, or near other traffic or vehicular 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 other 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 rail yards, ports, and industrial facilities.

Contact your **state or local air pollution agency** for assistance in evaluating the impacts, if any, that traffic-related air pollution may have on your school. EPA's *School Siting Guidelines* also include information on evaluating impacts of nearby sources of air pollution. 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 who are concerned about traffic-related air pollution exposure due to a school's proximity to a heavily traveled roadway or trucking corridor and who want to understand potential approaches to reduce exposures. Other audiences that may find this resource applicable to their work include community-based environmental and health organizations; 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, and tribal agencies.

Other EPA Resources for Schools

The EPA website (**www.epa.gov/schools**) 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

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. 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 pollution exposure and offers strategies to reduce students' exposure in new and existing schools.

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

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.

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.

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

- Respiratory systems that are not fully developed. Studies show exposures to air pollution in childhood can result in decreased lung function.[2]
- Higher rates of exposure than adults because they are more active and they breathe more rapidly.

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.[3] Exposure to traffic-related pollution is a concern both indoors and outdoors—

[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] 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 http://pubs.healtheffects.org/view.php?id=334

[3] 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).

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.[4,5] In addition, diesel-powered school buses can be a significant source of pollution near schools.

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

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 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 importance of PM in general, and diesel PM specifically as 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. 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 particulate air pollution (e.g., railyards, industry) 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.[6]

Elevated PM concentrations in schools have been linked to:

- Poor ventilation;
- Ineffective or nonexistent air filtration;
- Proximity to 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.[7,8]

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, ventilating, and air conditioning (HVAC) system.

[4] 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

[5] 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

[6] 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*. Available at http://www.epa.gov/iaq/schools/pdfs/Energy_Savings_Plus_Health_Guideline.pdf

[7] Stranger, M., Potgieter-Vermaak, S. S., & Van Grieken, R. (2008). Characterization of indoor air quality in primary schools in Antwerp, Belgium. *Indoor Air, 18*(6), 454-463.

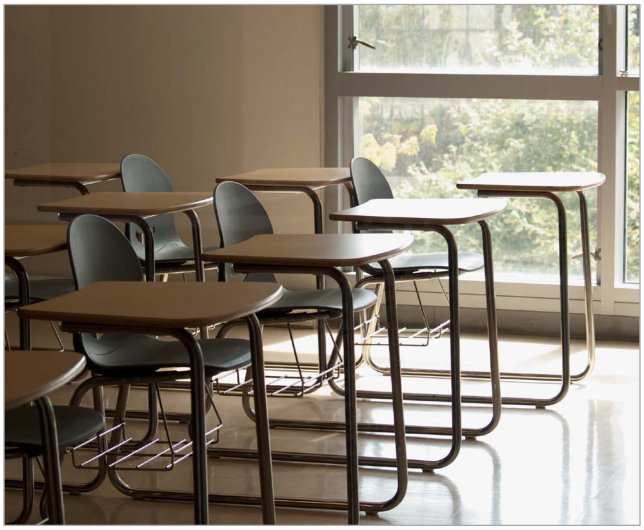
[8] McCarthy, M. C., Ludwig, J. F., Brown, S. G., Vaughn, D. L., & Roberts, P. T. (2013). Filtration effectiveness of HVAC systems at near-roadway schools. *Indoor Air, 23*(3), 196-207. doi:10.1111/ina.12015

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.[9]

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

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. Strategies for reducing pollution exposure in naturally ventilated classrooms include reducing indoor sources of air pollution 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 section for more information).



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

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.

Mechanical Ventilation

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 imbalance in a building's HVAC system can result in the building becoming 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. Therefore, pressure relief dampers that allow air to exit the building or exhaust fans that draw air out are typically recommended.

The U.S. Environmental Protection Agency (EPA) recommends[10] 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

[9] 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.

[10] U.S. Environmental Protection Agency. (2012). *Heating, ventilation and air-conditioning (HVAC) systems*. Available at www.epa.gov/iaq/schooldesign/hvac.html

quality, the necessary ducting and registers tend to increase system cost. Ductwork in central ventilation systems should be kept clean and tested regularly for leaks. Regardless of the type of system used, mechanical ventilation systems are typically more reliable than natural methods because airflow rates are controllable.

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.
- With a properly performing mechanical ventilation system, 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, bus idling, drop-off zones, and other pollutant sources, such as designated smoking areas.[11]

Filtration

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.[12] 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 inlet and outlet locations; 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 removed (for instance, particles entering the classroom through open doors or windows, through leakage in the building envelope, from indoor sources, or from re-suspension from floors). In addition, removal of gaseous pollutants by filtration is typically less effective than particle removal; filters that are able to remove gaseous pollutants are costly and are not commonly used in schools.

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.[13]

Schools undertaking energy efficiency upgrade projects may wish to consider concurrent opportunities to improve indoor air quality.[14]

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

[12] 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

[13] 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 http://www.arb.ca.gov/research/indoor/aircleaners/certified.htm

[14] U.S. Environmental Protection Agency. (2014). *Energy savings plus health: Indoor air quality guidelines for school building upgrades.* Available at http://www.epa.gov/iaq/schools/energy_savings_plus_health.html

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.

Studies examining filtration systems in schools have found that all types of 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 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.[15] 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%.[17] 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.[18]

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%.[16]

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. In some systems, the addition of a high MERV-rated filter can result in

[15] 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

[16] 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

[17] 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

[18] 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

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-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.[19] 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 capacity 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 air sensor to monitor ventilation needs, and thereby help optimize ventilation rates, could offset long-term, higher energy costs due to over-ventilation.

Recommendations

- For classrooms relying on passive/natural ventilation, use quiet, portable, stand-alone filtration systems to reduce indoor concentrations.
- 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, including the installation of pre-filters, if necessary.
- Inspect and replace filters regularly according to manufacturer recommendations.
- Where possible, locate air intakes away from pollution sources.

Actions for Building Occupants

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 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

[19] 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

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).

Exposure outdoors may be reduced by carefully 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. In addition, many schools implement the Air Quality Flag program to raise awareness of the daily air quality forecast. The school flags, combined with information on current air quality from www.airnow.gov, can be used to help plan outdoor activities.

Raising awareness about indoor and outdoor air quality issues and providing training for staff on optimal building operating practices (including HVAC operation) specific to the design of their school are inexpensive strategies that can supplement upgrades to the ventilation and filtration system and building and site design. EPA's *IAQ Tools for Schools* program provides an easy-to-use framework and set of tools to train staff on indoor air quality (IAQ) management (www.epa.gov/iaq/schools). Training is recommended as a complementary strategy and should not be considered an alternative to ventilation upgrades.

Recommendations

Train teachers and school staff 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.

Plan strenuous outdoor activities during times with lower amounts of traffic.

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.

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 on page 15. Once a baseline 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. Ventilation systems versus mitigation strategies. HVAC/ventilation system types are listed from generally less effective to more effective, and mitigation strategies are listed from the simplest (and least costly) to implement to those that require a higher level of effort.

HVAC/Ventilation Type	Mitigation Strategies				
	Educate Staff	Air-Seal Building	Improve Air Intake	Use Filtration	Upgrade System
Passive/natural ventilation	✓	May be an option if adequate ventilation to dilute and remove pollutants from indoor sources	Avoid bringing in air during periods of high traffic	Use a portable stand-alone filtration system	Switch to a mechanical ventilation method
Single-classroom HVAC unit (e.g., window unit)	✓	✓	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
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
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	N/A

Site-Related Strategies for Reducing Near-Road Pollution Exposure

Transportation Policies

Establish Anti-Idling and Idle Reduction Policies

Bus operation and idling can produce large amounts of PM and other air pollutants. Some schools 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.

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. 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, including biodiesel blends. Engines certified to operate on alternative fuels such as liquid petroleum gas (LPG), compressed natural gas (CNG), and liquefied natural gas (LNG) can also reduce emissions. Discuss potential funding options for bus fleet upgrades with your state or local environmental or air quality agency.[20]

[20] U.S. Environmental Protection Agency. (2010). *Clean school bus.* Available at http://www.epa.gov/cleandiesel/sector-programs/csb-overview.htm

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%.[21]

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.[22]

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.[23] When considering walking and biking routes to school, impacts on safety, lighting, access, and maintenance requirements should be considered. The Safe Routes to School National Partnership provides many resources on promoting safe walking and biking (**www.saferoutespartnership.org**).

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.

Recommendations

- Limit school bus 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 certain alternative fuels, including biodiesel blends. Engines certified to operate on alternative fuel such as LPG, CNG, and LNG can also reduce emissions.
- 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.

Site Location and Design

In response to concerns about the impacts of near-road air pollution, several agencies, including EPA and several state agencies in California, have established siting guidelines for new schools that recommend reducing traffic-related air pollution exposure (**Table 2**). While California guidelines recommend that new schools should not be located within 500 feet or more of major roads, 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

[21] 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

[22] 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

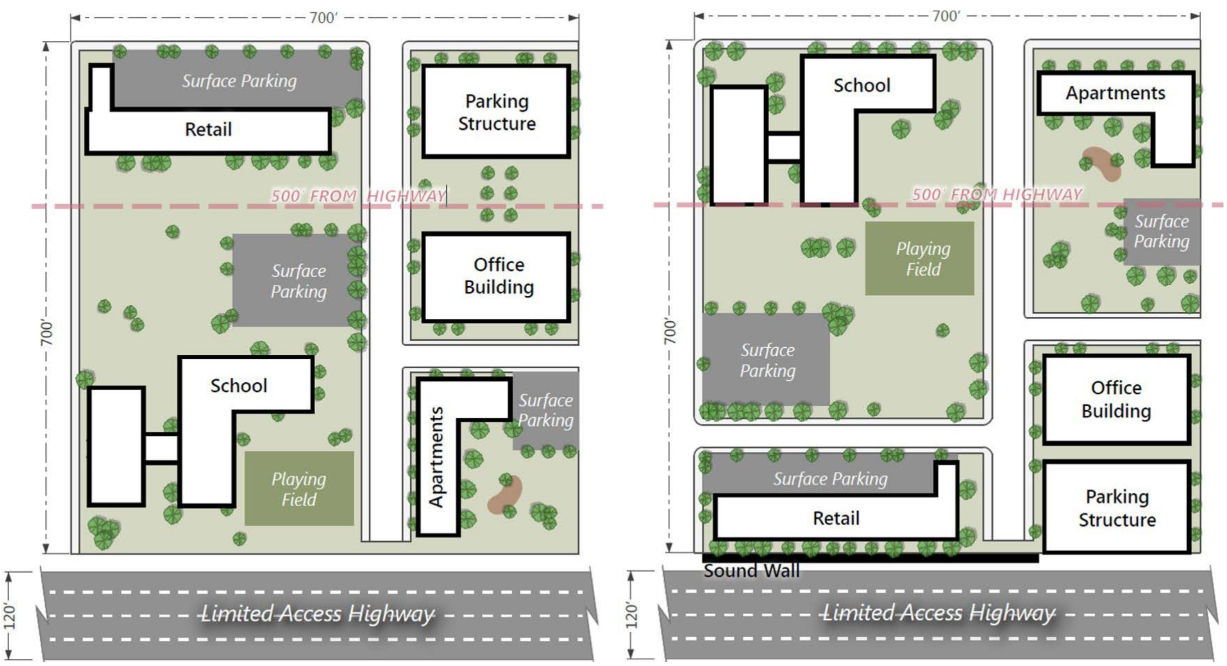
[23] National Center for Safe Routes to School. (2013). *Starting a walking school bus.* Available at http://www.walkingschoolbus.org

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. Overall, EPA recommends multiple strategies, as described in this document, to reduce students' overall exposure.

School sites include of a variety of land use types, such as classrooms, playgrounds, athletic fields, offices, and maintenance and storage facilities. For new school developments near roadways, there may be opportunities to reduce traffic-related pollution exposure through careful site design. By

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	Air Quality and Land Use Handbook (2005)	Recommends that new schools are not located within 500 feet of 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).



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).

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.

Recommendations

- For new school developments, consider locations farther from major roads and other areas with heavy truck traffic, but still within the community.
  - A quantified evaluation of post-mitigation air quality impacts may be appropriate and/or required.
- 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.

Roadside Barriers

Sound Walls

Pollutant concentrations behind a barrier located downwind of a roadway 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%.[24]

The effectiveness of sound walls 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. Sound walls can be considered for schools located adjacent to highways and other busy, high-traffic roadways.

In situations where school authorities do not have jurisdiction or ownership over 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).

[24] 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.

The combined use of vegetation and sound walls has shown promise in reducing vehicle pollution downwind of roadways by up to 60%.[25]

Vegetation

Trees and plants along roadways can reduce particle concentrations by acting as a physical barrier between roadways and schools (similar, in effect, to sound walls), or by filtering particles as they pass through and accumulate on leaf surfaces. The amount of removal depends on season, plant species, leaf size and density, and pollutant type. The effectiveness of trees and plants as physical barriers also depends on the density and height of the greenery. Mature vegetation tends to be more effective than young vegetation, evergreen species are typically more effective than deciduous species, and vegetation with needle-like greenery (e.g., 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 20 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 in-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 chosen should also maintain its structure during all seasons; thus, coniferous trees would be preferable to hardwood species. The vegetation types chosen should also not be emitters of air pollution or high levels of pollen. Schools can use the U.S. Department of Agriculture's (USDA's) i-Tree Species tool[26] to begin the process of choosing appropriate vegetation, in consultation with other experts from plant nurseries, local cooperative extensions, city government, 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.

Recommendations

- Use a solid roadside barrier (only along highways) and/or vegetation to block traffic-related pollutants from influencing air quality near the school.
- Minimize gaps in solid and vegetative roadside barriers.
- For vegetative barriers, use an evergreen species with mature, dense greenery and locate the barrier downwind and close to the roadway.
- Choose species appropriate for region and site, consulting with plant nurseries, local cooperative extensions, city governments, or the U.S. Forest Service.

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.[27]

[25] 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.

[26] USDA's i-Tree Species is designed to aid users in selecting proper species given the tree functions they desire. The tool is available at www.itreetools.org/species.

[27] 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.

Summary of Recommendations

Table 3 outlines 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., $PM_{2.5}$) but not others (e.g., volatile organic compoundss). These mitigation strategies reduce risks, but do not eliminate them.

Strategy	Ventilation/ HVAC System Type	Benefits	Drawbacks	New/ Existing Schools
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	Effectiveness may decrease over time; results depend on training quality and staff cooperation	Both
Air-seal around windows, doors, HVAC ducts, etc.	Mechanical ventilation systems	Reduces the amount of unfiltered air entering the building	Indoor pollutant concentrations may build over time if ventilation is insufficient, especially if indoor pollutant generation is high	Both
Relocate air intake or source if roadway/pollution source is near intake vent	Central HVAC systems; single classroom HVAC units	Reduces particle and gaseous concentrations in incoming air; can increase lifespan of filters	Cost	Both
Use filtration	All	Reduces particle concentrations from both outdoor and indoor sources	Maintenance and replacement required; may require system upgrades	Both
Improve HVAC system design to be compatible with high-efficiency filtration	Central HVAC systems	Larger reductions in particle concentrations are possible	Cost	Both
Implement anti-idling/idle reduction policies	All	Reduces emissions of particles and gases	Lack of vehicle climate control during hot/cold weather	Both
Upgrade school bus fleet	All	Reduces emissions of particles and gases	Cost	Both
Encourage active transportation (e.g., walking and biking) to school	All	Reduces emissions of particles and gases; improved health with exercise	Walkers/bicyclists may be exposed to traffic-related pollution or other hazards during trips	Both
Locate school site away from pollution sources	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 bus or car	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	New
Design school site to minimize exposure to pollutant sources	All	Reduces student exposure to particles and gases	Effectiveness is site-specific; may be costly for existing schools	Both
Use solid and vegetative barriers	All	Reduces concentrations of particles and gases near schools; vegetative barriers may increase shade and improve aesthetics	Cost; optimal design may be site-specific; maintenance and water needs for vegetative barriers	Both

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?
        - Is the school downwind of the road?
    - 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.
    - Is ventilation achieved passively or mechanically?
    - If mechanical:
        - Is a central HVAC system used or a single-classroom unit?
        - Are filters being used?
        - What is the blower capacity?
        - Is filtration being used? If so, what is the MERV rating of the filter(s)?
3. Assess ventilation operation.
    - 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?
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.
    - Is air intake located near a roadway, loading zone, or other pollutant source, such as designated smoking areas?[28] Are supply and exhaust vents unobstructed?
    - Can the air intake be relocated to an area that is less influenced by pollutant sources?

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

Additional Resources

Information regarding air quality and pollution mitigation in schools is available on the EPA website:

- General information about indoor air quality: **www.epa.gov/iaq**
- Creating healthy indoor environments in schools: **www.epa.gov/iaq/schools**
- Energy Savings Plus Health: Indoor Air Quality Guidelines for School Building Upgrades: **www.epa.gov/iaq/schools/energy_savings_plus_health.html**
- EPA School Siting Guidelines: **www.epa.gov/schools/guidelinestools/siting/download.html**
- Exhibit 5: Factors Influencing Exposures and Potential Risks: **www.epa.gov/schools/guidelinestools/siting/downloads/Exhibit_5_Factors_Infl encing_Exposures_and_Potential_Risks.pdf**
- Exhibit 6: Screening Potential Environmental, Public Health and Safety Hazards: **www.epa.gov/schools/guidelinestools/siting/downloads/Exhibit_6_Screening_Potential_Environmental_Public_Health_and_Safety_Hazards.pdf**
- HVAC systems in schools: **www.epa.gov/iaq/schooldesign/hvac.html**
- EPA Clean School Bus Program: **www.epa.gov/cleanschoolbus/csb-overview.htm**
- The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions: **http://archive.epa.gov/nrmrl/archive-appcd/web/pdf/baldauf.pdf**
- EPA School Flag Program: **http://cfpub.epa.gov/airnow/index.cfm?action=fl g_program.index**

Other useful resources include:

- California Air Resources Board, Air Quality and Land Use Handbook: **www.arb.ca.gov/ch/handbook.pdf**
- South Coast Air Quality Management District, Air Quality Issues in School Site Selection: Guidance Document: **www.aqmd.gov/docs/default-source/planning/air-quality-guidance/school_guidance.pdf**
- South Coast Air Quality Management District, Near-Road Mitigation Measures and Technology Forum Materials: **www.aqmd.gov/home/library/technology-research/technology-forums**
- California Department of Education, School Site Selection and Approval Guide: **www.cde.ca.gov/ls/fa/sf/schoolsiteguide.asp**
- Los Angeles Unified School District, Distance Criteria for School Siting: **www.lausd-oehs.org/docs/Misc/DistanceCriteriaTable%20Rev12_10_08.pdf**
- ASHRAE Standard 62.1-2013, Ventilation for Acceptable Indoor Air Quality, 2013: **www.techstreet.com/ashrae/products/1865968**
- ASHRAE Indoor Air Quality Guide: Best Practices for Design, Construction, and Commissioning, 2009: **www.ashrae.org/resources--publications/bookstore/indoor-air-quality-guide**

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