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Minimizing children's non-residential exposure to traffic-related pollution

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evidence review

Summary

- A significant portion of children's exposure to traffic-related pollution occurs in and around schools and daycares and in transit to these locations.
- New schools and daycare facilities should be located at least 150 m from major roads (15,000 or more vehicles/day) and should incorporate appropriate ventilation systems to reduce infiltration of outdoor pollutants.
- Interventions for existing schools and daycare facilities near major roads (such as banning of idling vehicles or adding filters to ventilation systems) can reduce children's traffic-related pollution exposures.
- New vehicle technologies and pollution control retrofits for older vehicles can reduce bus self-pollution, but traffic-related pollution from other vehicles is still an important source of bus passenger exposure.

- Whether travelling by bus or active transportation, traffic-related pollution exposures during school commutes can be reduced by choosing routes that avoid pollution hotspots.
- More research is needed to fully examine the costs and benefits of interventions used to reduce children's exposure to traffic-related pollution.

Introduction

Air pollution exposure represents a significant human health risk and is associated with outcomes ranging from minor respiratory irritation to premature death. Motor vehicles are a major source of air pollutants, and people who spend significant amounts of time near high-traffic roads are often exposed to elevated levels of traffic-related pollutants. In order to understand how to mitigate the health risks posed by traffic-related pollution, it is vital to understand the interactions between susceptible population groups and the environments in which exposure to the pollutants occurs.

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Children represent a population of particular interest when assessing the impacts of traffic-related pollution. They are highly susceptible to air pollution health impacts due to biological characteristics such as narrow airways, high breathing rates, developing lung structures and immune systems, and because they often spend large amounts of time outdoors.[1] Studies have shown that childhood exposures to traffic-related pollution are associated with chronic respiratory symptoms,[2] reduced lung function,[3] impaired lung development,[4, 5] development of asthma,[6] increased asthma incidence,[7] respiratory infections,[8, 9] and middle ear infections.[10] Recent research also shows that traffic-related pollution exposure is associated with decreased cognitive performance,[11] and language abilities in children.[12]

Studies assessing the impact of traffic-related pollution on children's health have typically focused on residential location as the key determinant of exposure. However, children spend a significant portion of their time at locations other than their homes, where they may be exposed to high levels of traffic-related pollution. This document provides an overview of the research, examining children's non-residential exposure to traffic-related pollution and available interventions to reduce this exposure and resulting health effects.

Non-Residential Exposure to Traffic-Related Pollution

Exposure occurs any time a person comes into contact with a pollutant in their immediate environment. In urban areas there is typically significant variation in the concentration of traffic-related pollutants across microenvironments (e.g., residential indoor, residential outdoor, occupational, recreation, transportation). As a result, both the time spent in the microenvironments and the pollutant concentrations within the microenvironments are important determinants of total exposure to traffic-related pollution.

Children, especially of school age (5-12), spend significant portions of their time at school or in transit to or from school. Behrentz et al.,[13] found that Los Angeles school children spent 45% of their weekday time away from the home (30% indoors at school, 5% outdoors at school, 10% in transit to school). In this same study, 49% of children's' exposure to black carbon and 39% of children's' exposure to PM2.5 occurred inside and outside schools and in transit to schools.[13] Younger children not of school age (less than 5) typically spend much of their lives at home,[14] but may also attend daycare regularly, and can in some cases spend as much time away from home as school age children.

While most studies of the health effects of air pollution have used exposure estimates derived from the home location, a small number of studies have tested the association between traffic-related pollution levels measured outside and inside schools and a variety of children's health outcomes.[2, 3, 15, 16] In all cases, the measured school exposures were used as a proxy for total exposures (both residential and non-residential), but the study findings of negative health associations with higher school pollution levels reinforce the importance of understanding and managing children's exposures outside the home.

Table 1 summarizes key exposure metrics and findings from the peer reviewed literature covering children's non-residential exposure to traffic-related pollution.

The literature on traffic-related pollution levels outside schools shows that proximity to major roads is an important determinant of outdoor pollution concentrations. Studies have shown that elevated traffic-related pollutant concentrations near roads decline to near background levels within 150 m (~500 ft) of the road, and this near-road area is commonly cited as the interval of most concern for elevated exposures and associated health risks.[17] However, a recent meta-analysis[18] indicates that the spatial extent of impact of pollutants from a given road may range from 100 m up to 500 m away from the road.

Table 1. *Summary of the peer reviewed literature for children's non-residential exposure to traffic-related air pollution occurring in different microenvironments*

Microenvironments			Exposure Metrics	Key Findings
Microenvironments	School/Daycares	A – Outdoors	- Traffic-related air pollutant concentrations outside schools and at playgrounds and sports fields. - Differences in traffic-related air pollution concentrations between schools located near and far from major roads.	- Schools located near major roads consistently have higher traffic-related air pollution concentrations than schools located away from major roads.[16, 27, 28] (see table footnote *) - Traffic-related air pollutant concentrations outside schools are associated with distance to roads, traffic density, and vehicle composition.[15, 16, 29] - Air pollution concentrations outside schools can reach levels that exceed legislated air quality guidelines.[30] - School buses significantly contributed to children's outdoor exposure to particulate matter near schools.[31, 32]
	School/Daycares	B – Indoors	- Traffic-related air pollutant concentrations inside schools. - Comparisons of indoor traffic-related air pollutant concentrations, with and without mechanical ventilation systems and air filters.	- Traffic-related air pollutant concentrations inside schools are associated with distance to roads, traffic density, and vehicle composition.[15, 16, 29] - Outdoor particulate matter may pose a potential health risk for sensitive individuals during physical education in naturally ventilated gyms in urban areas with high traffic volumes.[33] - Concentrations of traffic-related air pollutants found inside schools vary greatly, and are influenced not only by outdoor pollutant concentrations, but also a wide variety of other factors including building age, construction style, and ventilation type.[34-36] - Schools with mechanical ventilation have significantly reduced indoor concentrations of outdoor-source particulate matter.[37, 38] - Electrostatic air cleaners significantly reduce the concentration of particulate matter in classrooms.[39]
	Transportation	C – In-Vehicle	- Traffic-related air pollutant concentrations inside school buses. - Comparison of traffic-related air pollutant concentrations within different types of school buses.	- Children commuting on school buses may be exposed to high levels of traffic-related air pollution.[13] - High air pollution concentrations in buses are a result of both ingress of the bus's own emissions into the passenger cabin (self-pollution), and ingress of pollutants emitted by other vehicles.[40] - Diesel buses without emissions controls have significantly elevated in-cabin air pollution concentrations relative to similar buses with emissions control retrofits.[40-43]
	Transportation	D – Active	- Children's personal exposure (mass of air pollutants collected by a sampler) while walking or biking to school. - Comparison of personal exposures between different commuting modes.	- Exposure to traffic-related air pollution may be increased for children walking to school along roads compared to children who are driven to school along the same route.[26] - Choice of route to avoid traffic-related pollution hotspots can significantly reduce air pollution exposures during active transportation.[44]

Note: * In these studies, "near a major road" is defined as within 1,000 m of 50,000+ vehicle/day road[16], or within 100 m of 45,000+ vehicle/day road.[27]

Children spend the majority of their time at school indoors, so outdoor pollution levels alone are often poor surrogates of school exposures. The proportion of indoor pollution in schools due to infiltration from outdoors is difficult to ascertain since many outdoor pollutants also have indoor sources. However, the evidence indicates that indoor levels of many pollutants are well-correlated to both outdoor levels and factors such as distance to roads, traffic levels, etc.[19-23] Because traffic-related pollution infiltrates into buildings, construction style, building age, and ventilation type are important determinants of children's exposure at school. Further, exposure to high levels of traffic-related pollution has been shown to occur within school buses due to self-pollution and infiltration of exhaust from other vehicles. Exposures may also occur when children walk or ride bicycles to school. Studies in the United States estimate that 13-16% of children regularly travel to school via active transportation (e.g., walking, cycling).[24, 25] If active commuting routes are along roads, children may experience significantly higher exposures than if they were driven to school.[26]

Children of lower socioeconomic status or ethnic minority background are potentially at increased risk for higher non-residential traffic-related pollution exposure. Studies in the United States indicate that non-white children and children from economically disadvantaged families and regions are more likely to attend schools and daycare facilities located near major roads with high traffic volumes[45] and experience the highest relative levels of air pollution exposure at school locations.[46-48] In Sweden, traffic-related pollutant concentrations at schools were found to increase as the socioeconomic status of a child's neighbourhood of residence decreased.[49] No similar data for Canada were found in the literature.

Reducing Non-residential Exposures

Künzli et al.,[50] lay out a suite of strategies for reducing children's exposure to traffic-related pollution that emerged from a review of the Southern California Children's Health Study.[51, 52] These interventions are organized into Primary strategies, which reduce total emissions of air pollutants (e.g., reduce vehicle emissions), and Secondary strategies, which reduce exposure without targeting emissions directly (e.g., siting schools farther from roadways). In general, Primary strategies for reducing emissions do not specifically target children's non-residential exposures, but instead assume that lower traffic-related pollutant emissions will lead to lower exposures in all environments. In contrast, many Secondary strategies for reducing exposures are targeted specifically at non-residential environments such as schools.

Table 2 provides a subset of the strategies detailed by Künzli et al.,[50] focusing on the reduction of children's non-residential exposure to traffic-related pollution. The strengths and weaknesses of each strategy are outlined, as well as indications of the efficacy of interventions in different microenvironments. While all strategies discussed are grounded in research findings regarding air pollution emissions, environmental concentrations, and the factors affecting children's pollution exposure, few intervention studies directly test the efficacy of particular strategies in reducing pollution exposures and health effects.

Schools and Daycares - Outdoors

As detailed above, there is significant evidence indicating that schools located close to major roadways have higher outdoor levels of traffic-related pollution than those located far from major roads. This evidence formed the basis for a California law[58] that prohibits the construction of new schools within 500 ft (152 m) of major roads (greater than 50,000 vehicles/day). Much of the evidence for this California law is based on studies in California where traffic levels and school pollution levels are likely higher than most observed in Canada. Some research indicates that roads with traffic levels of about 25,000 vehicles/day (common in Canadian urban areas) can be problematic.[63-65] A review conducted by the BC Ministry of Environment[17] defines a lower traffic volume threshold, recommending that new schools be set back at least 150 m from any road with 15,000 or more vehicles per day. Recent research suggests that even greater distances (400 m or more) may be required to reduce traffic-related exposure to acceptable levels.[59]

Table 1. *Interventions for reducing children's non-residential exposure to traffic-related pollution. Left-hand columns illustrate the efficacy of each intervention at reducing microenvironmental exposures. Dark shading = strong evidence, light shading = limited evidence, no shading = no effect. (following Künzli et al.,[50]).*

Microenvironments				Intervention	Strengths	Weaknesses
School / Daycare -Outdoors	School/Daycare -Indoors	Transportation –In vehicle	Transportation -Active			
				Purchase new school buses with emissions control technologies.[53]	Emissions reductions for the lifetime of the vehicles.	Higher maintenance requirements of emissions control equipment; potential for lower fuel economy. Also, may be relatively minor contributor to total personal exposure. High capital costs or long implementation period associated with fleet turnover.
				Retrofit existing school buses with emissions controls.[41, 43]	Emissions reductions without replacing existing bus fleet; relatively low capital cost.	Limited ability to retrofit older high polluting buses; higher maintenance requirements of emissions control equipment; potential for lower fuel economy.
				Use clean fuels (school buses).[54-56]	Emissions reductions at the combustion source.	Typically require changes in vehicle technology; higher fuel prices; limited availability of fuels; infrastructure requirements (e.g., CNG fuelling stations). Tradeoffs may exist between levels of pollutants produced by different fuels (e.g., CNG NO_x vs. diesel PM). Increased safety risks of fuels (CNG).
				Condition or filter air in buses.[40]	Reduce the levels of ambient and roadway air pollution within buses.	Easily confounded if buses have operable windows. Filtration is only effective for particulate matter, but not for gaseous pollutants (NO_x, CO).
				Route buses to avoid high traffic roads and "caravanning" of buses.[40]	Reduce the levels of outdoor air pollution infiltrating into buses.	Potential to lengthen commute, possibly increasing total bus fleet emissions, and hence ambient pollutant concentrations.
				Ban idling of school buses and other vehicles near schools.[31, 32]	Reduction of emissions in the proximity of school buildings; reduction of fuel use and GHG emissions savings.	Bans may be difficult to enforce, and impractical during periods of low winter temperatures.

Microenvironments				Intervention	Strengths	Weaknesses
School / Daycare -Outdoors	School/Daycare -Indoors	Transportation –In vehicle	Transportation -Active			
				Use buses or active transportation to commute to schools instead of private vehicles.[57]	Reduction of emissions in the proximity of school buildings; reduction of traffic congestion.	Potential to increase exposure to traffic-related pollution, especially if walking near major roads.
				Limit private vehicles near schools and daycares.[31, 32]	Reduction of emissions in the proximity of school buildings; reduction of traffic congestion; reduction of injury risk due to car-pedestrian collisions.	Objections and resistance from parents and school employees.
				Separate schools and daycares from major roadways.[45, 48, 58, 59] (see table footnote *).	Reduction of emissions in the proximity of school buildings; reduction of injury risk due to car-pedestrian collisions.	Many existing schools and daycares are currently close to roads; availability of land for new facilities is limited, and often more expensive away from major roads.
				Condition or filter air in schools and daycares.[37-39]	Reduction of exposure to both traffic-source and indoor air pollution. Buffer indoor environment from highly variable levels of outdoor pollution.	Filtration is effective for particulate matter, but not for gaseous pollutants (NO_x, CO). Capital and operating costs of air conditioning and filtration systems may be high. Potential for “sick building syndrome” if buildings are tightly sealed and improperly ventilated.
				Reduce outdoor activity at schools and daycares when pollution levels are high.[37, 60, 61]	Avoids exposure during high risk periods, easy to implement.	Could lead to further reductions in physical activity and thus increase health risks associated with inactivity.
				Avoid streets with heavy traffic when commuting to schools and daycares.[26, 44, 62]	Reduction of injury risk due to car pedestrian collisions.	Potential to lengthen commute; efficacy of exposure reduction is questionable. Difficult to formally encourage or enforce.

Note: * There is no universal definition of what constitutes a “major” road, with literature using thresholds of anywhere from 15,000-50,000 vehicles/day. Further, there are varying opinions on the appropriate distance of separation from major roads, with literature values ranging from 100-500 m.

In addition to the location of schools, a variety of other measures exist for reducing levels of traffic-related pollution near schools, including traffic restrictions on existing roads and anti-idling policies, especially for buses.[31, 32] Exposure reduction interventions that limit children's outdoor activities on days with poor air quality have also been implemented[37, 60, 61]; however, the efficacy of such interventions is unclear, as research to date has focused on the educational component of such programs, rather than on actual exposure reductions achieved.

Schools and Daycares – Indoors

As indicated above, outdoor levels of traffic-related pollution strongly influence levels found inside schools, but building age, construction, and the type of ventilation system are key determinants of the rate of infiltration of outdoor pollution. Interventions such as ventilation system upgrades and policies limiting natural ventilation (e.g., open windows) can reduce infiltration and indoor concentrations of traffic-related pollution.[37-39] At the same time, it is also important to ensure adequate air exchange within school buildings, as indoor-generated pollution is also a health concern. Simply sealing buildings against outdoor infiltration would likely have detrimental impacts on indoor air quality.

Transportation – In Vehicle

Due to bus self-pollution[66] and outdoor pollution that infiltrates into passenger cabins[40], travelling on school buses may lead to large traffic-related pollution exposures for children. Strategies such as employing bus emissions controls and fuel switching can have positive impacts on in-cabin exposures[43, 53], and also lower overall population exposure to bus emissions.[54] However, even for low emitting buses, infiltration of on-road pollution from other vehicles remains an important contributor to exposures.[40] As such, bus air filtration and air conditioning remains an important exposure mitigation strategy, as do routing approaches that avoid areas of high pollution concentrations[44], and policies limiting bus "caravanning".[40]

Transportation – Active (walking and cycling to school)

A shift in the mode of transportation used by children from walking and bussing to being driven by parents has been implicated as a both a source of additional greenhouse gas and traffic-related pollutant emissions, and as a cause of increased child inactivity.[57] However, the use of active transportation modes (walking, cycling, etc.) by children commuting to and from school may increase their exposure to traffic-related pollutants.[26, 62] Siting schools away from major roads may help decrease exposure when active transportation modes are used by limiting the time children spend in highly polluted microenvironments. Research also indicates that route choice can significantly reduce air pollutant exposures by avoiding pollution hotspots.[44]

Key Gaps

- Few studies have directly associated children's health outcomes with non-residential air pollution exposures. Studies that attempt to disaggregate the health impacts of residential and non-residential air pollution exposures would improve the understanding of the relative importance of each exposure environment.
- Little intervention research directly tests the efficacy of children's non-residential exposure reduction strategies. Areas of particular interest for exposure reduction intervention studies include examining the effectiveness of:
  - Outdoor activity restrictions;
  - Building ventilation and air filtration strategies;
  - Idling reduction campaigns and near-school traffic limitations; and
  - Designated "active commuting routes" which avoid pollution hotspots.
- The relationship between the risks and benefits of different school transportation modes is unclear. Further study is required to develop guidelines regarding policies on the promotion of active commuting as an alternative to bus or car transport to and from schools.

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