Ministry of Environment

Environmental Best Management Practices for Urban and Rural Land Development in British Columbia: Air Quality BMPs and Supporting Information

Recommendations

Specific concern is focused on:

- buildings where people spend large amounts of time – seven to eight hours per day; and
- buildings that primarily house vulnerable populations (infants, children, pregnant women, the elderly and those who are ill).

Buildings: Locating the Site

Recommendations to minimize the health impacts of air pollution associated with proximity to major roads include:

1. **Setbacks:** 150 metre (500 feet) setback from "busy roads[1]" for buildings such as schools, hospitals, long-term care facilities and residences.
2. **Truck Routes**: Special consideration should be applied for buildings located on major truck routes. Avoiding development on truck routes, or additional setbacks, are recommended. Elevated air pollutant concentrations are measurable as far as 750 metres from truck routes. Heavy-duty trucks generally emit larger quantities of air pollutants, including diesel-exhaust particulate, a probable[2] human carcinogen, and likely the most harmful vehicle-related pollutant.

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[1] Busy Roads (Definition): A busy road is defined as a road with greater than 15,000 vehicles/day based on annual daily average traffic counts.

[2] Group 2A – International Agency for Research on Cancer. www.iarc.org

3. **Street Canyons:** Avoid locating buildings within street canyons (Table 3: Street Canyon Definitions), which can trap air pollution. To avoid creating street canyons, stagger buildings that are perpendicular to the predominant wind direction or site high-rise buildings on only one side of the street (when perpendicular to the predominant wind direction).

Site (Outdoor) Considerations

4. **Trees:** On a local scale, trees have little impact on air quality, although on a city-wide, regional scale, they increase carbon dioxide conversion to oxygen and promote cooling. Trees are important from a site-quality and greenspace perspective, however, and should still be considered a valuable feature of land development.

Building Construction/Design

5. **Idling/Loading Dock Locations**: Air intakes for buildings must not be located near loading docks or where vehicles are often idling. Similarly, building intakes should not be located on a side of a building near a busy traffic corridor where vehicles may be idling in traffic congestion. This will help avoid indoor air quality problems.
6. **Filters:** Where proximity to traffic is unavoidable, the use of high-efficiency particulate air (HEPA) filters (room or centralized units) for vulnerable populations will reduce exposure to particulate air pollution.

Supporting Information

Introduction and Rationale

According to a growing body of scientific literature, people living near freeways and major roads (roadways) have a higher risk of developing (or worsening) health problems such as asthma, chronic bronchitis, emphysema, pneumonia and heart disease. Exposure to this pollution has also been found to hamper children's ability to learn. Motor vehicles emit at least 40 different air pollutants, usually concentrated within 150 metres (500 feet) of freeways and busy roadways. The research points to a need for increased awareness of the public health concerns associated with roadway proximity in creating land-use policy and environmental/air quality management programs (1).

Existing air quality management programs related to motor vehicles generally focus on reducing the emissions from individual vehicles (e.g. inspection-and-maintenance programs such as AirCare, in the Lower Fraser Valley). However, less attention has been placed on reducing population exposures to aggregate traffic sources. The above best management practices are intended to provide general advice regarding building placement (including recommended setbacks) and general land use that will reduce exposures and health risks associated with traffic proximity. They can be implemented along with existing, more traditional air quality management strategies to reduce the public health impacts arising from vehicle-related air pollution.

This document reviews existing guidelines that have been implemented in other jurisdictions, along with the evidence that higher concentrations of hazardous air pollutants exist near major roadways. It defines a "major roadway," which roadways should also be considered as street canyons, and the specific levels of traffic that lead to concern. Sources for information on characterizing roads in British Columbia are listed. In addition, the information regarding studies of health effects in relation to roadway proximity is summarized.

Existing Guidelines: Setbacks

To date, only school siting in relation to traffic-related air pollution has been incorporated into legislation. (See a 2005 review entitled *Fifty State Survey of School Siting Laws, Regulations and Policies* (2) by Rhode Island Legal Services with funding from the US EPA. It "surveys state laws, regulations and policy guidance document regarding the siting of schools".) With respect to school siting and air pollution sources, the California legislation (described below) is the most strict and explicit regarding school proximity to traffic. However, at least 10 other states have statements (in legislation) to encourage minimizing exposure to air pollution in school siting.

On September 11, 2003, the State of California passed Senate Bill No. 352 (3), which amends previous legislation on planning and siting public schools. Previous California legislation (Section 17213 of the Education Code and Public Resources code 21151.8) (4;5) essentially required that school sites be selected such that:

a. no pollution-generating facilities (broadly written to specify any hazardous air pollution source) be situated within a ¼-mile radius of any school site; or
b. corrective measures are being used to mitigate all hazardous emissions; or
c. there are no health risks posed to school occupants from the identified facilities.

Bill 352 amends the previous legislation to include "freeways and other busy traffic corridors, large agricultural operations, and rail yards" in the definition of pollution sources. Furthermore, the legislation attempts to prohibit the location of any school site within 500 feet (150 metres) of a freeway or other busy traffic corridor. In the State of California legislation, the definitions of a "freeway or other busy traffic corridor" are "roadways that, on an average day, have traffic in excess of 50,000 vehicles in a rural area … or 100,000 vehicles in an urban area."

The justification for this amendment to the existing legislation pertains to the following (excerpts from the legislation):

a. Higher levels of air pollutants have been detected near freeways and busy traffic corridors; this pollution has been associated with acute health effects (including asthma exacerbation) and negatively impacts the ability of children to learn.

b. Cars and trucks emit at least 40 different air toxics/contaminants; levels are generally concentrated within 500 feet (150 metres) of freeways and busy roadways.
c. A disproportionate number of economically disadvantaged pupils may be attending schools that are close to busy roads; these students are at an increased risk of developing chronic health conditions caused or exacerbated by exposure to traffic-related pollutants.
d. The intent of the legislation is to protect school children from the negative health effects of freeway traffic, as well as other industrial pollution sources.

Dispersion of Pollutants from Roads / across Urban Areas

Vehicles and motor vehicle traffic generate a complex mixture of air pollutants that can vary according to factors such as: the age of the vehicle, type of fuel, engine type, speed of travel, roadway conditions and density of traffic. In general, the concentrations of pollutants decrease away from sources (highways, major roadways) as pollutants are transported and dispersed by wind and turbulence. The amount of transport and dispersion of pollutants is affected by meteorological conditions (weather), temperature, topography and vehicle traffic/movement.

Several studies have measured pollutant concentrations and distributions at different locations in urban and rural areas. Different pollution metrics (indicators) vary when measured at various distances from highways. These are:

- $PM_{2.5}$ (PM or "particulate matter" refers to very small gas and liquid particles in the atmosphere. $PM_{2.5}$ is 2.5 micrometres or smaller in diameter.);
- ultrafine particles (less than 0.1 micrometres in diameter);
- particle number concentrations (the number of particles per volume of air);
- carbon monoxide (CO);
- black smoke (a measure of elemental carbon);
- nitrogen dioxide (NO_2); and
- nitrogen oxides (NO_x).

In general, $PM_{2.5}$ does not decrease much with growing distance from major roads because motor vehicles are not the major source of $PM_{2.5}$ – and usually $PM_{2.5}$ levels do not vary across small distances. For this reason, pollution due to motor vehicles is better represented by NO_2 (or NO_x), particle number concentrations, or ultrafine particles. All these metrics, as well as black smoke, decrease significantly at increased distances from major roads.

Specific Measurement of Traffic Pollutants with Distance from Roads

The World Health Organization (6) recently summarized over 15 different studies in which pollutant concentrations measured at traffic sites were a factor of 1.2 to 2.3 higher than urban-background sites in the same cities. Clearly, pollution concentrations are generally elevated at traffic sites. The gradient of decline of the pollutant concentration when moving away from the traffic site varies with pollutant; however, there are some overall similarities.

As shown in Table 1, various studies reported that black smoke decreased by 80-55% in the first 150 metres away from the road. The black smoke then stabilized, reaching urban-background levels at 150-200 metres away (Figure 1: Black Smoke Concentration Reduction with Distance from Major Roads). In contrast, $PM_{2.5}$ concentrations decreased by only 20-10% in the first 200 metres from the road, with no further decrease at greater distances (Table 2), (Figure 2: $PM_{2.5}$ Concentration with Distance from Major Roads).

Measured NO_2 concentrations decreased by 30-70% in the first 150 metres from the roadside. They then reached urban-background levels by 150-300 metres from the roadside (Figure 3: NO_2 Concentration Reduction with Distance from Major Roads). Particle number concentrations generally had a 50% reduction at 150 metres from roads in several different wind conditions. In addition, the particle number distributions (the numbers of differently sized particles in the air) at 150 metres were comparable to urban background, indicating that little contribution remains (at 150 metres) from vehicle traffic (7).

Several studies have found higher concentrations and gradients near highways with a greater percentage (than normal) of diesel truck traffic – specifically black smoke and ultrafine particles (8). Particle concentrations ($PM_{2.5}$) decrease only slightly with increased distance from busy roads. However, particle number concentrations decrease much more significantly and provide a better measure of decreasing traffic-source pollutant with distance from a road.

Study and Location		% Fraction of Maximum (close to road)	% Above Background (steady-state)	Traffic Data at Nearby Road (vehicles/day)
Singer (LA) (9)	NO_2	0.55	0.5	200,000
Kodama (Tokyo) (10)		0.78	0.15	60,000
Gilbert (Montreal) (11)		0.75	0.3	100,000
Roorda-Knape (Netherlands) (12)		0.6	0.1	100,000
Roorda-Knape (Netherlands)	Black Smoke	0.55	0.1	120,000
Zhu (high diesel) (LA) (8)		0.3	0.3	200,000
Zhu (low diesel) (LA)		0.3	0.5	200,000
Zhu (both) (LA)	$PM_{1.0}$	.15	n/a	200,000

Table 1: Fractions of Pollutant Concentrations (NO_2, Black Smoke, PM1.0) at 150 m from Major Roads

Study and Location	Distance from Busy Road (m)	Fraction of Max. $PM_{2.5}$ at this Distance	Traffic Data at Nearby Road (vehicles/day)
Nitta (Tokyo) (13)	150	0.8	>50,000
Roorda-Knape (Netherlands) (12)	300	0.90	>120,000
Janssen (Netherlands) (14)	1000	0.82	15,000
Hoek (Munich) (15)	>1000	0.84	"traffic site" compared to urban background
Hoek (Netherlands) (15)	>1000	0.79	"traffic site" compared to urban background

Table 2: $PM_{2.5}$ Pollutant Fractions (of Roadside Maximum) at Varying Distances from Traffic Sites

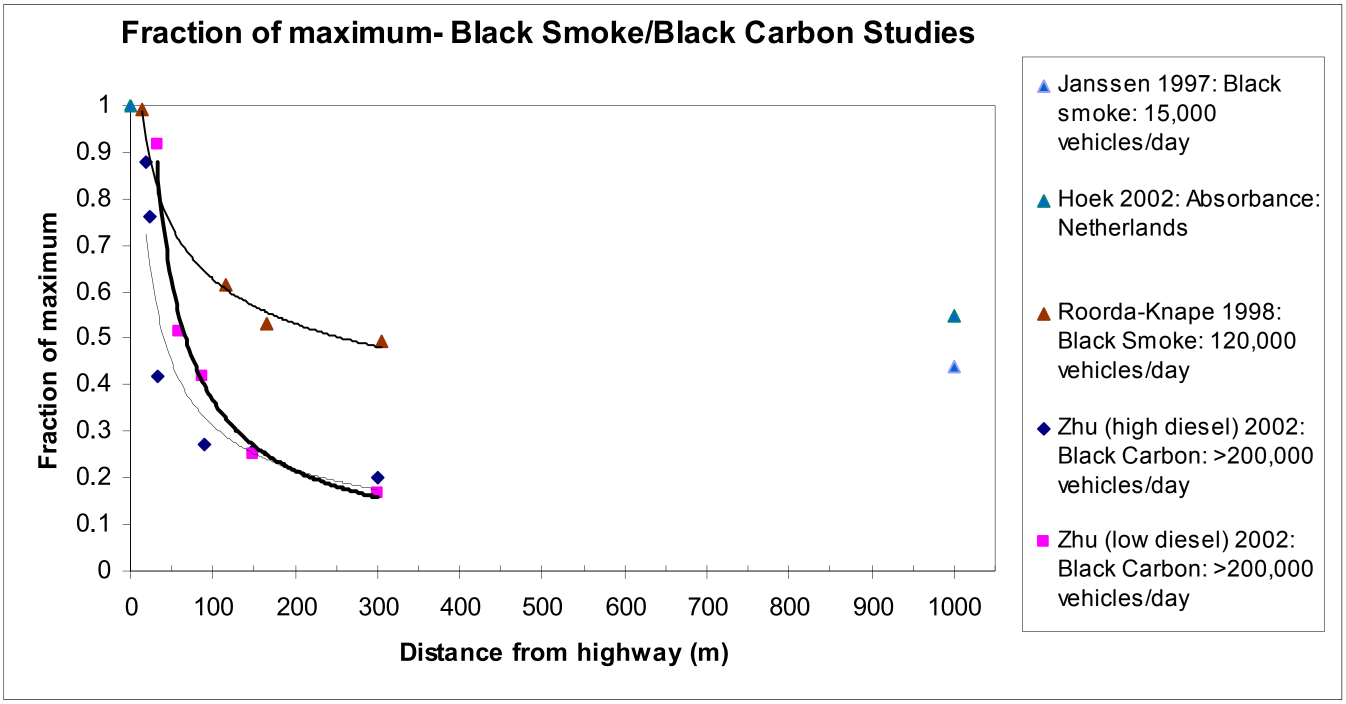

Figure 1: Black Smoke Concentration Reduction with Distance from Major Roads

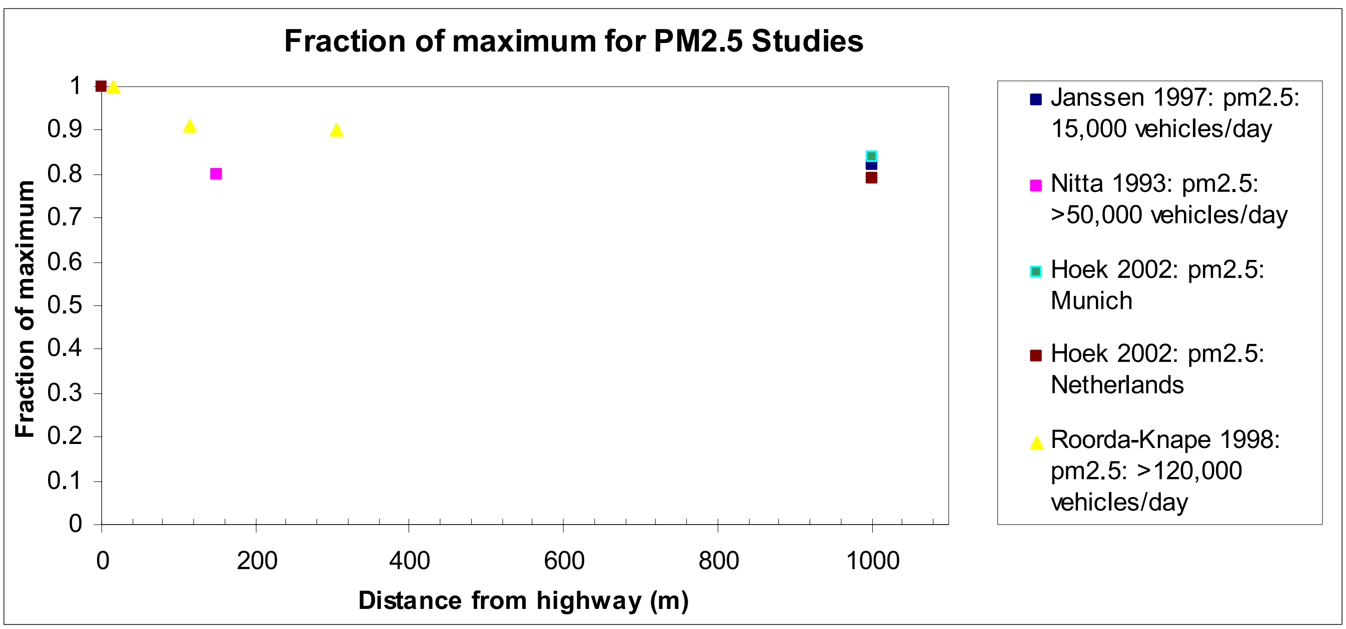

Figure 2: $PM_{2.5}$ Concentration with Distance from Major Roads

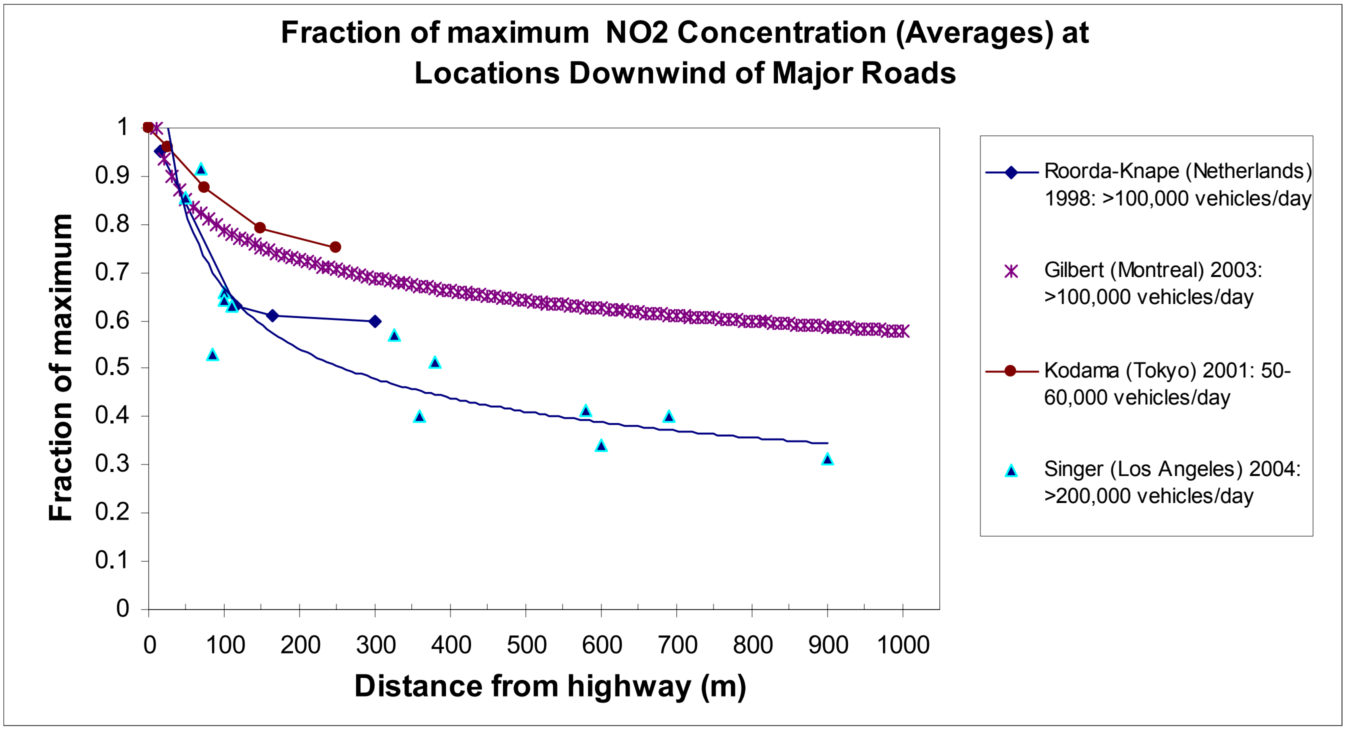

Figure 3: NO_2 Concentration Reduction with Distance from Major Roads

Traffic Volumes and Pollution Gradients

Vehicle traffic (annual daily traffic counts) on the major roads in these studies varied from over 15,000 vehicles per day to 200,000 vehicles per day. Reported gradients of traffic-based pollutants are similar for most roads with more than 15,000 vehicles per day when sampled downwind of the roadway. Measurements upwind of major roads decrease only slightly, or not at all, with distance from road. Increased wind speeds cause pollutants to disperse more rapidly, and background concentrations are reached even closer to the roadway.

Higher traffic volumes generally increase pollutant concentrations at roadside, but the concentration gradient is comparable for both higher and lower traffic volumes. **For most traffic volumes and pollutants, the major decrease in traffic-based pollutants occurs in the first 150-200 metres from the roadside**. Pollutants decline at much slower rates from 150-1000 metres from the roadside. Statistical (regression) models for pollutant concentrations generally found logarithm of the distance from the roadway, wind speed and wind direction to be the greatest predictor of pollutant decline with distance from a major road.

Traffic Speed and Pollution

Similar concentration gradients are measured for both highways (8) and urban "high-traffic" roads (11) with relatively lower traffic speeds. However, few studies to date have measured the effects of idling-traffic pollution as compared to highway pollution.

Topography and Street Canyons

In addition to windspeed and direction, urban topography can significantly alter the dispersion of traffic-based pollution from a major road. A specific type of urban topography is a street canyon: a canyon formed in a street between two rows of tall buildings.

A street canyon is defined by calculating the ratio of the height (H) of the buildings and the width (D) of the street. The following table is used to define a street canyon (16) :

H/D Ratio	Type of Roadway
<0.3	Wide street
0.3 to 0.7	Canyon street **without** risk of pollution accumulation
>0.7	Canyon street **with** risk of pollution accumulation

Table 3: Street Canyon Definitions

Street canyons can trap and limit dispersion of pollutants, due to the lack of wind flow out of the canyon. As a result, the concentration of pollutants in street canyons can be significantly elevated over urban-background levels (17).

Road Type and Traffic Levels (B.C.)

Road classification data for British Columbia are available from the Digital Road Atlas (DRA) (http://bcdra.refractions.net/), as well as from commercial databases such as DMTI Spatial (http://www.dmtispatial.com/).

DMTI uses five classifications:

1. Expressway;
2. Highway Principal;
3. Highway Secondary;
4. Major; and
5. Local.

DRA uses:

1. Freeway;
2. Highway;
3. Arterial;
4. Collector; and
5. Local.

DRA further classifies roads with eight subclasses as shown in Table 4, below.

A measurement program in the Greater Vancouver Regional District linked elevated air pollution levels to locations up to 200 metres from DMTI classification types 1-4 (expressways, principal and secondary highways, and major roads). It also linked elevated pollution concentrations to locations up to 750 metres from a designated truck route (18).

Levels of traffic on these roads have been compared (19) and show the general relationships described in Table 4, below. **The shaded rows are classifications/traffic levels that are considered significant sources in terms of air pollution.**

DMTI Class	*Count data (mean)*	DRA Class	*Count data (mean)*	DRA Subclass	*Count data (mean)*
Local	6,511	Local	3,976	Local	4,126
Major	15,207	Collector	8,953	Collector minor	8,580
				Collector major	9,964
Highway Secondary	18,254	Arterial	18,457	Arterial minor	15,321
				Arterial major	17,407
Highway Principal	21,025	Highway	27,961	Highway minor	22,242
				Highway major	36,684
Expressway	113,789	Freeway	113,789	Freeway	113,789

Table 4: Road Classifications Available for B.C. Roads and Mean Traffic Count Data from (19)

Levels of traffic for highways and selected major roads are available for B.C. from the Ministry of Transportation (http://www.th.gov.bc.ca/publications/planning/Trafficvolumes/index-trafficvolumes.htm); additional data for Greater Vancouver is available from (http://www.city.vancouver.bc.ca/engsvcs/transport/traffic/counts.htm). For other roads, traffic data are available from municipal sources, although typically measurements are made for much shorter averaging periods such as for peak morning (two hours) or evening traffic periods. There is, however, only a moderate relationship between these shorter-term measurements and the longer-term averages that are most relevant for health assessment. For a select number of locations in the Lower Mainland, total daily traffic counts were found to be roughly 11 times higher than peak morning (7:30-8:30 am) hourly traffic counts (18).

Health Impacts of Traffic-Related Air Pollution

Motor vehicle exhaust has long been known as a significant contributor to urban air pollution and its associated health effects. However, only recently have studies demonstrated that people living in areas near major roadways experience increased health effects due to air pollution. Recently, the World Health Organization published a systematic review of the literature on transport-related air pollution that includes an in-depth evaluation of the associated health hazards (6). Overall, the report concludes that transport-related air pollution is associated with an increased risk of cardiovascular deaths and increased nonallergic respiratory disease. The report also states that transport-related pollution may be related to the onset of heart attacks, along with lung cancer, low birth weight and preterm births – although the evidence base is not limited to studies of roadway proximity.

Though only a few relevant studies have been conducted, residing within 100 metres of a freeway or major road is associated with increased deaths. Most studies have focused on childhood respiratory disease. They have linked living near major urban roads or freeways with increased respiratory symptoms (bronchitis, wheeze, chronic cough) and decreased lung function. There is also some evidence suggesting increased risk for asthma development. A growing number of studies have linked living near major roads or freeways during pregnancy to premature births or low-birth-weight babies.

Health effects studies differ in their approach to determining the impact of traffic-related air pollution, but they have relied mainly on simple measures of proximity, measurements or models. In terms of proximity, most studies use distances of 50-300 metres to indicate exposure to traffic-related air pollution. In studies in Holland (20;21), an association between decreased lung function in children and exposure to truck traffic was strongest for children living within 300 metres of motorways. In addition, chronic respiratory conditions (cough, wheeze, runny nose, and doctor-diagnosed asthma) were reported more often for children living within 100 metres from the freeway.

The specific health effects linked to roadway proximity are summarized in this table:

Health Outcome	**Evidence**
Mortality	Strong
Respiratory diseases (nonallergenic)	Strong
Respiratory diseases (allergic)	Unclear (Studies indicate both positive and negative associations.)
Reproductive outcomes	Moderate (Some inconsistencies in studies)
Cardiovascular diseases	Moderate (Relatively few studies)
Cancer	Unclear (Limited evidence)

Table 5: Summary of Health Studies of Air Pollution and Roadway Proximity

As discussed, studies suggest that traffic proximity is linked with adverse pregnancy outcomes, childhood respiratory disease and cardiovascular mortality. The populations at increased risk for health impacts of traffic-related air pollution include pregnant women, children and older adults – especially those with pre-existing cardiac disease.

Glossary

Black Smoke

A measure of the blackness of airborne particulate matter. This is determined by passing the air through standard filter paper and measuring the blackness of the stain that is produced. Blackness is related to the amount of elemental carbon and is an indicator of vehicle-related particulate matter.

Downwind

The direction toward which the wind is blowing. With the wind.

Elemental Carbon

Inorganic carbon, as opposed to carbon in organic compounds, sometimes used as a surrogate measure for diesel particulate matter, especially in occupational health environments.

Freeway (or other busy traffic corridor)

Roadways that, on an average day, have traffic in excess of 50,000 vehicles in a rural area or 100,000 vehicles in an urban area.

Gradient

The rate at which a physical quantity, such as temperature or pressure, increases or decreases relative to change in a given variable, especially distance (in a specified direction).

High-Efficiency Particulate Air (HEPA) Filter

Efficient mechanical filters that remove 99.97% of particles of an aerodynamic diameter of 0.3 micrometres – the most penetrating particle size. Generally, efficiencies are higher for larger and smaller particles . These filters can be portable room filters, or centralized building units.

Highway

A major road within a city, or linking several cities together.

Idling

Running a vehicle while it is sitting still for more than about 10 seconds. Idling can release a substantial amount of pollutants.

Log (Logarithm)

An exponent used in mathematical equations to express the level of a variable quantity.

Metrics

Specific indicators that are measured in order to assess a pollutant's impact on the physical or social environment.

Particle Number Concentration

The number of particles per volume of air.

Particle Number Distributions

The numbers of **differently sized** particles in the air.

Particulate Matter (PM)

Small gas and liquid particles in the atmosphere:

- $PM_{10:}$ particulate matter that is 10 micrometres in (aerodynamic) diameter
- $PM_{2.5:}$ particulate matter 2.5 micrometres and less in (aerodynamic) diameter
- $PM_{1.0:}$ very small particulate matter, 1.0 micrometres and less in (aerodynamic) diameter.

Road, Busy

Busy road is defined as a road with greater than 15,000 vehicles/day, based on annual daily average traffic counts.

Roadway

Road over which vehicles travel (same as "road").

Street Canyon

A canyon formed in a street between two rows of tall buildings. Vehicle exhaust fumes (in particular) are trapped there because the buildings on each side protect the street from the wind. If wind directions do not flow parallel to the street, pollutants can build up to high concentrations.

Turbulence

An instability in the atmosphere that disrupts the wind flow, causing gusty, unpredictable air currents.

Ultrafine Particles

Very small atmospheric particles, 0.1 micrometres and less in diameter.

Upwind

The direction from which the wind is blowing. Against the wind.

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