A Source-to-Outcome Approach to Address Near-Road Air Pollution

Motor vehicle emissions have been an environmental and public health issue in the United States for many decades, despite substantial emission reductions since the 1970s. The pollutant burden from motor vehicles has been reduced even with increases in traffic volume (measured as vehicle miles traveled [VMT]) over this time period (see Figure 1). However, mobile source-related pollution is still a public health concern for people spending significant amounts of time near roadways. This article provides a broad overview of the issues associated with human exposure to traffic pollutants and illustrates the complex nature of near-road pollution issues.
Nearly 30% of the U.S. population lives, works, or goes to school within 300 m of busy or congested roadways. This percentage of the population is likely to continue to expand due to increased urbanization and changing land-use patterns that tend to increase motor vehicle use. As such, the potential health outcomes related to elevated exposures to motor vehicle emissions near roads are quite large. According to recent estimates more than 40 million people in the United States live within 300 ft of major roadways and other significant sources of mobile-source emissions, such as four-lane thoroughfare, railroad, or airport operations. Likewise, approximately 120 million people in the United States drive to work and are exposed to vehicular emissions during their daily commute.

Emissions from traffic contribute to pollutant concentrations at the local, urban, and regional levels and are the principal source of intra-urban variation in the concentrations of pollutants in many cities. A number of studies report a spatial profile of pollutant concentrations associated with large roadways, with concentrations elevated near the road and generally decreasing exponentially with distance from the road as they mix with the atmosphere and reaching “urban background” levels within approximately 300-500 m from the edge of the nearest travel lane. These studies have shown that the magnitude and spatial distribution of near-road concentrations depend on the specific pollutant and ambient factors, such as time-of-day, meteorology (e.g., season, wind direction), topography, roadway design, and traffic patterns. The primary traffic patterns affecting pollutant concentrations include traffic count over time, fleet mix (cars vs. diesel trucks), and vehicle speed, which is often a function of traffic congestion. Additional factors affecting near-road pollutant concentrations include regional fuel compositions, prevailing weather conditions, and local congestion-mitigation programs implemented to reduce traffic emissions.

The air pollutants most commonly used in epidemiologic studies as a surrogate for an individual’s exposure to traffic emissions are carbon monoxide (CO), nitrogen dioxide (NO₂), particulate matter (PM), PM-associated elemental carbon (EC), and benzene. Pollutant levels are either measured through monitoring or estimated by modeling techniques that combine measurements of pollutant emissions or concentrations with additional parameters, such as meteorology, land use data, and traffic volume. Indicators of traffic exposure such as proximity of the residence to a busy major road or traffic volume in a buffer area around the residence are also frequently used.

Many epidemiological studies, a large number of them conducted in recent years, have shown associations between proximity of residence to major roadway and elevated concentrations of traffic-related pollutant and health effects. For a recent review of the literature see Special Report 17 by the Health Effects Institute. This review indicated that a number of epidemiological studies provide strong suggestive evidence that exposure to traffic emissions may adversely impact human health. The most consistent associations were observed in children between asthma incidence and prevalence of asthma symptoms and traffic pollution. These associations were found in studies that used modeled pollutant concentrations, as well as proximity to traffic as exposure metrics.

An example is the study by McConnell et al. in children from various communities in Southern California, which found that residence within 75 m of a major road was associated with an increased prevalence of asthma (1.50, CI 1.16–1.95) and wheeze (1.40, CI 1.09–1.78) relative to those children who lived at more than 300 m from the road. The confidence interval (CI) is a measure of the precision of the relative risk estimate. The more narrow the interval, the more precise the relative risk estimate. The associations were stronger in long-term residents with no parental history of asthma.

For other important health outcomes (e.g., all-cause and cardiovascular mortality, cardiovascular morbidity, asthma incidence, non-asthma respiratory

**Figure 1. Trends in VOC, PM, and NOₓ emissions vs. VMT for highway vehicles in the United States, 1970-2005.**

*Source: EPA*
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**Challenges in Understanding the Science**

While many studies indicate or suggest causal relationships between exposure to emissions from traffic and adverse health outcomes, it is not yet clear what pollutant species from motor vehicle emissions may be responsible. To address this issue, better data on exposure to vehicle emissions for people near or on roadways are needed that can capture the spatial variability in individual vehicle emissions and pollutant dispersion in a complex urban environment. Such data can be obtained from studies that measure traffic pollutant concentrations at a very fine spatial scale, either using fixed-site or personal-exposure monitoring; however, collecting detailed ambient data for long periods of time is complex logistically and requires a resource-intensive effort. Apportioning measured concentrations to individual sources is also difficult because unique tracers of combustion, brake and tire wear emissions, and road dust are difficult to identify.

In the absence of detailed field data, estimation of pollutant exposures using models presents other challenges. These models require data on vehicle emissions, vehicle activity, pollutant transport, atmospheric processes, and human activity. However, the magnitude and characteristics of vehicle emission profiles vary with a number of factors, including vehicle type, vehicle age and speed, fuel type used, drive patterns, ambient and vehicle temperature, and emissions control technologies. The increased use of renewable fuels and future implementation of vehicle control technologies will likely lead to additional complexity in identifying emission impacts in the future.

In addition, traffic activity models, including direct measures of traffic, are still limited by the quality of the input data and need to be validated more extensively. Moreover, air pollutant transport and dispersion is subject to atmospheric processes, including initial dilution, chemical transformation, transport, dispersion, and deposition; each of which may be influenced by vehicle emission characteristics and site-specific conditions. Similarly, exposure estimates are difficult to ascertain because of population mobility patterns that are time- and space-dependent and may vary from person to person.

There are also uncertainties in interpreting the associations between exposure and health effects in the epidemiologic studies. Not all the studies have adequately controlled for potential confounders (i.e., factors that correlate with both traffic pollution and the health outcomes), such as environmental tobacco smoke, noise, and socioeconomic status, which can introduce bias in the estimated effects.

**Multidisciplinary Research to Inform Decision-Making**

To identify the most effective strategies for reducing risks from exposure to traffic-related pollutants near roads, regulators need to understand what components or combinations of components in the pollutant mixture relate to adverse health outcomes. As stated, there are many types of pollutants that result from motor vehicle emissions and there are many potential health effects that might result from near- and/or on-road exposures. Since these exposures do not occur in isolation, the relative contributions of different sources and human activities to those pollution exposures must be considered. Air quality managers need to understand and model the relationship among traffic emissions, ambient concentrations, and population exposures to better protect sensitive subpopulation and resolve environmental justice concerns.

The relevance of near-roadway impacts has become more pronounced with recent developments such as the U.S. Environmental Protection Agency’s (EPA) revision of the NO2 National Ambient Air Quality Standard (which includes requirements to monitor NO2 levels near roads) and requirements to analyze PM “hotspots” as part of transportation conformity. Furthermore, transportation agencies are under increased pressure to address air toxics, as well as criteria pollutant impacts of transportation projects in environmental assessments required by the National Environmental Policy Act.

The research community must move beyond traditional approaches that involve a single or few relevant scientific disciplines to better understand the link between emissions from specific sources and public health impacts. It is imperative to draw on the expertise from diverse scientific disciplines.
to inform the development of effective risk reduction strategies that account for the interaction among multiple pollutants and health outcomes. The most effective solutions to risk reduction can be achieved through an integrated transdisciplinary approach that considers the full extent of the problem and the potential uses of the information when developing the study. This approach must also utilize the various scientific disciplines necessary to understand the full extent of the problem and find sustainable solutions.

**Potential Risk Reduction Strategies**

Risks associated with exposure to near-road pollution can be mitigated in several ways. First, emissions associated with motor vehicles can be reduced through exhaust and evaporative emission standards. EPA’s MOBILE emissions model indicates that since 1970, average per-vehicle emissions in the United States have been reduced by more than 90% for volatile organic compounds (VOCs) and 80% for PM$_{10}$ and oxides of nitrogen (NO$_x$). However, motor vehicles still significantly contribute to pollution in urban areas due to increases in vehicle use offsetting per-vehicle emission reductions. Also, older, poorly maintained vehicles disproportionately contribute to air pollution emissions estimates. Improving maintenance on these older vehicles and providing incentives for their replacement can improve air quality. Furthermore, emissions from some vehicle-associated sources are not regulated (e.g., brake and tire wear), and pollutants from these sources may potentially increase in the future with increased vehicle use. Strategies to reduce these emissions should be considered.

In addition to national-level regulatory programs, other opportunities exist for states and local communities to improve air quality. Improvements in transportation planning can reduce VMT and congestion, lead to improvements in fuel economy, and be considerate of the location of roads relative to populations. Moreover, recent research suggests that air pollution impacts near roads may be reduced through roadway design, such as sufficiently mature and thick vegetation near a road or depressed roadways with vertical or sloped walls. Land-use planning can reduce exposures to near-road pollution, particularly among sensitive subpopulations, through appropriate siting of schools, day care facilities, and nursing homes.

Voluntary programs can achieve substantial emission reductions as well. For example, the National Clean Diesel Campaign has established innovative strategies to reduce diesel vehicle emissions by switching to cleaner fuels and retrofitting engines with emission controls. The Clean School Bus USA program has developed partnerships to retrofit school buses and use cleaner fuels, as well as replace older buses with newer cleaner ones. The Smartway Transport Partnership is achieving reductions in roadway emissions by encouraging more efficient shipment of goods and through innovative financing to make loans available for truck replacement. Multipollutant strategies such as Smartway will also help reduce greenhouse gases.

Strategies to change behaviors can also be quite effective. Existing incentive programs include strategies to promote and use mass transit, ride share, practice trip-chaining, improve vehicle maintenance, and encourage telecommuting. Avoiding high speeds can also reduce vehicle emissions, as well as using overdrive gear at appropriate speeds. National and local incentive programs promoting cleaner, alternative fuels, as well as alternative technologies, may also improve near-road air quality. For example, the promotion of plug-in electric hybrids may reduce near-road pollutant concentrations, although other air quality impacts should also be considered.

**References**

7. Transportation Conformity Guidance for Qualitative Hot-Spot Analyses in PM$_{2.5}$ and PM$_{10}$ Nonattainment and Maintenance Areas; EPA420-B-06-902; U.S. Environmental Protection Agency and Federal Highway Administration, 2006.
9. More information on voluntary programs can be found at www.epa.gov/otaq/voluntary.htm.
10. More information on behavior change strategies can be found at www.epa.gov/otaq/consumer.htm.