Task Force on Health Effects of Toll Plaza Air Quality in New York City

Report to the Governor and Legislature

April 2013

New York State Department of Health
Center for Environmental Health

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TEXT ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AET	All Electronic Tolling
ASHD	arteriosclerotic heart disease
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BTEX	benzene, toluene, ethylbenzene and xylene
BTO's	Bridge and Tunnel Officers
C.I.	Confidence interval
cm	centimeter
CO	carbon monoxide
DEC	New York State Department of Environmental Conservation
DEP	diesel exhaust particulates
DOH	New York State Department of Health
EPA	United States Environmental Protection Agency
HEI	Health Effects Institute
HVAC	heating, ventilation and air conditioning systems
IRIS	Integrated Risk Information System
MTA	Metropolitan Transportation Authority
mcg/m^3	microgram per cubic meter
mg/m^3	milligrams per cubic meter
MERV	minimum efficiency reporting value
MSAT	mobile source air toxics
MTBE	methyl tertiary butyl ether
ng/m^3	nanograms per cubic meter
NAAQS	National Ambient Air Quality Standards
NIOSH	National Institute for Occupational Safety and Health
NIC	Notice of Intended Changes
NO_x	nitrogen oxides
NYCDOHMH	New York City Department of Health and Mental Hygiene
OSHA	Occupational Safety and Health Administration
PA	US EPA Policy Assessment
PAH	polycyclic aromatic hydrocarbons
PANYNJ	Port Authority of New York and New Jersey
PELs	Permissible Exposure Limits
PESH	Public Employee Safety and Health
PM	particulate matter
$PM_{2.5}$	fine particulate matter (2.5 micrometers or less)
PM_{10}	particulate matter (10 micrometers or less)
ppm	parts per million
REA	US EPA Risk and Exposure Assessment
RELs	Recommended Exposure Limits
SIP	State Implementation Plan
SMR	standardized mortality ratio
SO_2	sulfur dioxide
TBTA	Triborough Bridge and Tunnel Authority

TLVs	Threshold Limit Values
TWAs	time weighted averages
UFP	ultrafine particulates
VMT	vehicle miles traveled
VOCs	volatile organic compounds

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EXECUTIVE SUMMARY

The Task Force on Health Effects of Toll Plaza Air Quality in New York City (Task Force) was established in 2008 by the addition of §1200 and 1201 of the Public Health Law. The Task Force was charged to:

- Review the existing literature on air quality at toll plazas and any occupational health studies or case reports on those who work at toll plazas and identify gaps in the scientific literature, as they relate to toll plazas in New York City;
- Identify, study, and determine health effects of air quality at toll plazas in New York City including effects on those employed at such toll plazas (to the extent that funds are appropriated);
- Evaluate whether state law sufficiently resolves issues related to the health of those employed at such toll plazas;
- Prepare a report identifying policy options and recommendations regarding health effects of air quality at toll plazas in New York City including effects on those employed at such toll plazas; and
- Prepare a preliminary report to the governor and the legislature of its findings, conclusions, recommendations and activities already undertaken by the task force, not later than April 1, 2010, and a final report of its findings, conclusions, recommendations and activities already undertaken by such task force, not later than April 1, 2011[1], and shall submit with it, legislative proposals and regulatory changes as it deems necessary to implement its recommendations.

The Task Force met in person and by conference calls to review the existing literature on air quality at toll plazas, occupational health studies and case reports on people who work at toll plazas. The Task Force also sought information on complaints from toll plaza employees. The review found a large number of studies addressing air quality measurement at toll plazas and in toll booths, and found health studies of bridge, tunnel and toll booth workers that focused on heart disease, pulmonary disease and respiratory symptoms. The majority of the air sampling and health data were decades old and not considered to be representative of current vehicle emissions or exposures. An eight-year, retrospective records review by the New York State Department of Labor did not identify evidence of employee complaints from the New York City toll plaza workforce.

The Public Employee Safety and Health (PESH) Bureau of the New York State Department of Labor enforces Occupational Safety and Health Administration (OSHA) occupational air quality standards applicable to employees at toll plazas. All air sampling results reported in the literature as well as by the Metropolitan Transportation Authority (MTA) were below acceptable OSHA occupational standards, and also below guidance and recommended occupational exposure levels established by the American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH).

[1] A 2011 amendment to the Public Health Law extended this date to April 1, 2012.

The gaps in the scientific literature identified by the Task Force included the lack of current toll plaza-specific air quality data for most of the major air pollutants, especially two pollutants of recent heightened concern, diesel exhaust particulates (DEP) and ultrafine particulates (UFP). Also lacking were studies that characterize the impact of the new electronic tolling systems on pollutant levels around toll plazas. The Task Force also found limited information about recent employee health evaluations, or health endpoints other than respiratory and cardiovascular effects.

The Task Force identified five conclusions and recommendations as a result of its literature and data review:

A. Positive pressure heating, ventilation and air-conditioning (HVAC) systems have been shown to reduce toll collectors' exposure to mobile source-related air pollutants in several studies of toll booth workers in areas outside of New York City. Despite high levels of volatile organic compounds (VOCs) and particulate-bound polycyclic aromatic hydrocarbons (PAHs) in outdoor air, the levels measured inside toll booths with positive pressure HVAC systems at the Baltimore Harbor tunnel were comparable to those found in urban residential indoor environments (Sapkota *et al.*, 2005). Similarly, sampling showed that carbon monoxide (CO) levels were reduced to levels well below acceptable exposure levels as documented in occupational standards and guidelines (Rossano *et al.*, 1972; Burgess *et al.*, 1977). Personal air monitoring for CO was performed by the Metropolitan Transportation Authority (MTA) Health and Safety Department and an outside consultant in 2007 with results well below the Occupational Safety and Health Administration (OSHA) and Public Employee Safety and Health (PESH) standards, and the American Conference of Governmental Industrial Hygienists time weighted averages (TWA). Although data are not available for every mobile source-related air contaminant, positive pressure ventilation systems currently in place would be expected to effectively reduce and control employee exposure to other mobile source-related pollutants while in the toll booth.

   <u>Recommendation 1:</u> The MTA and the Port Authority of New York and New Jersey (PANYNJ) should continue to maintain a program to conduct periodic inspection and maintenance on the toll booth positive-pressure HVAC systems to keep them operating in optimal condition, so that exposures continue to be controlled by the HVAC system.

B. Increasing automation of toll collection (*i.e.*, E-Z Pass and boothless plazas) is expected to continue to reduce the exposure of toll booth collectors to air pollutants both by reducing the number of on-site toll collectors and by speeding the flow of traffic through the toll plazas. There is some evidence that implementation of E-Z Pass reduces air pollution levels at toll plazas and in the surrounding communities by decreasing vehicle idling and stop-and-go traffic (Saka, 2000; Lin and Yu, 2008). Although long-term impacts have not been evaluated, minimizing the stop-and-go of traffic at the toll plaza will likely reduce air pollution impacts in the region as well as in the surrounding community.

   <u>Recommendation 2:</u> The MTA and PANYNJ should support efforts to increase the automation of the toll collection process (*i.e.*, E-Z Pass use and boothless plazas) to minimize traffic congestion to the extent practical, while also minimizing congestion at cash only lanes.

C. Health studies of New York City toll plaza workers conducted 15 to 30 years ago reported an increased risk of heart and lung disease. The health status of New York City toll plaza workers, as a group, has not been assessed since that time. However, significant reductions in motor vehicle emissions have occurred over the past 30 years due to changes in gasoline/diesel fuel composition, emission controls, engine efficiency, E-Z Pass, toll plaza traffic pattern design, and positive-pressure HVAC systems in toll booths. These improvements have resulted in a reduction of occupational exposure and health risk from mobile source emissions. The Environmental Protection Agency's (EPA) national emissions control program aims to continue to reduce exposure to mobile source air toxics (MSAT). EPA-projected reductions are expected to reduce MSAT emissions by 57 to 87 percent between 2000 and 2020. Local conditions in terms of vehicle mix and turnover, vehicle miles traveled (VMT), growth rates and local control measures may impact the amount of reduction in different areas. The magnitude of the EPA-projected reductions is, however, so great (even after accounting for VMT growth), that MSAT emissions are expected to decline. The New York State Department of Environmental Conservation (DEC) projects decreases for nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2). In addition, CO levels in ambient air nationwide have decreased by 50 percent since 1990, largely due to emission controls for on-road vehicles. Although exposure of toll plaza workers to motor vehicle emissions has significantly declined over the past 20 years and should continue to decline in the future, their health status, as a group, has not been routinely monitored over that time period. The potential for a National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation should be considered as NIOSH has the expertise, resources and experience to conduct health studies for the MTA and PANYNJ employees for existing and emerging health concerns.

Recommendation 3: Unions and management for the MTA and PANYNJ should engage the New York State Occupational Health Clinic Network and/or NIOSH to assess the need for a program of periodic health screenings for the toll plaza workers. The screenings would include, but not be limited to, pulmonary function and cardiovascular health.

D. The data that were used to characterize pollutant exposures in the environment near toll booths were collected at curbside, adjacent to toll plazas at various sites across the country and internationally. This type of environmental sampling represents the contribution of traffic-related air pollutants to population-level exposures in adjacent neighborhoods based on the proximity to the traffic. The focus in the past on CO in near-booth and in-booth studies was directed at a traffic-related pollutant that presents significant acute health concerns, is amenable to measurement and monitoring, and can be considered a surrogate indicator for other combustion related pollutants. Other transportation-related pollutants do not exhibit all of these attributes, making sampling more challenging. For example, transportation related particulates are present across a relatively wide size distribution, and have different atmospheric residence times, composition and chemical reactivity. These factors need to be considered in designing studies to characterize the potential hazards from particulates around the toll plaza environment. EPA already has studies underway to address transportation-related pollutants near roadways. These studies will provide additional information about criteria pollutants in the near roadway environment that can be compared to levels measured at community-scale monitors.

Recommendation 4: The New York State Department of Health (DOH), DEC and the New York City Department of Health and Mental Hygiene (NYCDOHMH) should monitor the current EPA-funded studies regarding the behavior and concentration of pollutants in the near-roadway environment for their relevance to both occupational exposures and community exposures to traffic-related pollutants near toll plazas. With respect to particulate matter research, New York State should encourage EPA to fund studies that will: better refine the appropriate technologies for sampling; identify the particulate indicators and toxicological endpoints of concern; and incorporate environmental sampling near toll plazas as a high exposure, micro-environment with implications for general ambient air quality. Environmental sampling near toll plazas will help to assess the possible health risks (including those for vulnerable occupational or residential populations) from exposure to mobile source emissions at or near these toll plazas and will provide a benchmark for evaluating control measures to be used in future assessments. If resources are available, the DOH and DEC should consider a pilot project to monitor at and near toll booth plazas to fill data gaps in EPA studies with regard to worker exposures at toll plazas and air quality in adjacent communities. This monitoring could also serve to fulfill federally mandated near-roadway multi-pollutant monitoring.

E. Significant data gaps and scientific challenges remain with respect to assessing exposure to airborne particulates of health concern. Health studies should incorporate real-time and recognized occupational methods (*e.g.*, NIOSH) of monitoring mobile-source related particulates (*e.g.*, elemental carbon). Near-roadway monitoring initiatives at toll plazas could also be used to characterize particulate matter components for a more detailed assessment of human health impacts from traffic-source combustion particulates. Deployment of real-time monitoring instruments for elemental carbon should be evaluated on a pilot basis, and if useful, implemented as an ongoing program.

Recommendation 5: DOH, DEC and NYCDOHMH should monitor EPA's progress in developing a reference analytical method for sub-micron particulates and initiating near-roadway monitoring that incorporates sampling for specific particulate fractions and source attribution to assist in identifying significant particulate sources.

This report fulfills the Task Force's requirements to report to the Governor and Legislature on its findings, conclusions, recommendations and activities already undertaken regarding toll plaza air quality in New York City.

1. CHARGE TO THE TASK FORCE AND SCOPE

On May 27, 2008, Article 12 was added to the Public Health Law, establishing a Task Force on Health Effects of Toll Plaza Air Quality in New York City. The Task Force was created to examine, evaluate and determine the health effects of air quality at toll plazas in New York City including effects on those employed at such toll plazas.

The Task Force was charged to:

- Review the existing literature on air quality at toll plazas and any occupational health studies or case reports on those who work at toll plazas and identify gaps in the scientific literature, as they relate to toll plazas in New York City;
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The Task Force interpreted the law as requesting an assessment of health effects of air quality at toll plazas both for people employed at or around the toll plazas and the community residing or working near toll plazas. The assessment of health effects of air quality would be performed by a review of existing literature and data.

2. ACTIVITIES UNDERTAKEN BY THE TASK FORCE

The Task Force held two in-person meetings in New York City and five conference calls. A secure website was established to share journal articles, data and other pertinent documents between task force members. The two in-person meetings were open to the public and included a time period devoted to taking testimony, although no testimony was provided at either meeting. Notices of all meetings were posted on the New York State Department of Health (DOH) website prior to the meetings.

[2] A 2011 amendment to the Public Health Law extended this date to April 1, 2012.

3. TRAFFIC-RELATED AIR POLLUTION

Mobile sources have long been recognized as major contributors to air pollution in urban settings. Traffic-related air pollution can be classified into two main physical forms: gases and particles. The gases and particles coming out of a tailpipe are referred to as “primary” pollutants, which can undergo chemical transformation in the atmosphere to become “secondary” pollutants. The composition of the vehicle exhaust can be influenced by environmental conditions (hot or cold weather), engine speed, and type of fuel burned (*e.g.*, gasoline, diesel).

Some mobile source-related pollutants, because of health and welfare effects, are regulated in ambient (outdoor) air as criteria pollutants. Under the requirements of the Clean Air Act, last amended in 1990, the United States Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants. These pollutants include both gases and particles emitted from diverse sources that are considered harmful to public health and the environment. Primary standards are set to protect public health, while secondary standards are established to prevent environmental damage including decreased visibility and damage to crops. As mandated by the Clean Air Act, these standards are reviewed and updated periodically in accordance with new findings recorded in the scientific literature. The EPA uses monitoring data to determine whether locations in the United States are in compliance with the standards, a process that results in areas being designated as in “attainment” or in “non-attainment” of specific NAAQS.

Concentrations of criteria air pollutants have decreased markedly over the past forty years based on data from community-, or neighborhood-scale monitoring. However, currently the New York City Metropolitan region remains in non-attainment of the fine particulate matter ($PM_{2.5}$) and ozone NAAQS. When an area is in non-attainment of a NAAQS, the state must develop a State Implementation Plan, or SIP, that will control pollution sources and bring the area into attainment of the standard.

The “Revision to the New York SIP for $PM_{2.5}$ (annual NAAQS): New York Metropolitan Area” dated October 27, 2009 contains the following information for the New York metropolitan non-attainment area which includes New York City, Long Island, northern New Jersey and southern Connecticut. In 2002, 44 percent of nitrogen oxides (NO_x), 25.8 percent of $PM_{2.5}$ and 9.7 percent of sulfur dioxide (SO_2) emissions were attributed to mobile source emissions. In 2011, the New York State Department of Environmental Conservation (DEC) projects that 27.7 percent of NO_x, 12.7 percent of $PM_{2.5}$ and 1.4 percent of SO_2 emissions in the greater New York metropolitan area will come from mobile sources. EPA estimated a 41 percent drop in vehicle NO_x emissions from 1980- 2006 (EPA, 2008). DEC projects a 47.3 percent decrease in NO_x, from mobile sources and a 23.3 percent decrease in all NO_x emissions between 2002 and 2011. For $PM_{2.5}$ the reductions are 55.3 percent (mobile sources) and 9.3 percent (all emissions) and for SO_2 the reductions are 85.7 percent and 3.7 percent respectively.

The reduction of emissions from mobile sources is largely the result of the requirement for ultra low sulfur diesel fuel (15 parts per million (ppm)). Reducing the sulfur content of diesel fuel from 500 to 15 ppm reduces SO_2 emissions, which has made it possible to install exhaust cleaning technology on new and existing diesel engines to remove NO_x and particulates (transition completed in 2006 for on-road diesel (EPA (On-Road Diesel), 2010)). Over 3,000 diesel buses in New York City have been retrofitted with oxidation catalysts and/or particulate traps, reducing the quantity of diesel exhaust emitted by these vehicles. Recognizing that on-road mobile sources are still a source of NO_x emissions, the EPA has incorporated requirements for monitoring near roadways (EPA NO_2, 2010) in the latest NO_x NAAQS revision. Deployment of samplers near toll plazas of major highways as part of federally mandated monitoring for criteria pollutants could provide an opportunity to gather information about levels of criteria pollutants at these locations over time.

Nationally, carbon monoxide (CO) emissions from highway vehicles have decreased. Total CO emissions decreased by 70 percent between 1970 and 2005, while total vehicle miles traveled (VMT) increased by 170 percent during the same period. EPA attributes the 50 percent decline in ambient CO nationwide since 1990 to emission controls for on-road vehicles (EPA Risk and Exposure Analysis (REA) for CO, 2010). The reformulation of gasoline also contributed to reductions in CO emissions. While CO may not be the only indicator of health hazards from the present composition of traffic-related air contaminants (which have dramatically changed since the 1970s), it can serve as a surrogate marker for combustion-related vehicle emissions in some environments.

Our current knowledge of ozone production, transport, and decay does not lead us to believe that toll booth workers are exposed to ozone concentrations markedly different from the general public. Ozone is not directly emitted by vehicles, and NO_x, present in engine exhaust, is an active scavenger of ozone. The New York City metropolitan area is currently in non-attainment of the ozone NAAQS, so exposures of health concern do occur across the region, but ozone exposures would not be expected to be higher at toll plazas.

Mobile sources are also an acknowledged source of toxic airborne organic chemical compounds. The federal mobile source air toxics (MSAT) rule, promulgated in February 2007, identifies 1162 MSATs. Eight of those compounds were highlighted in the regulation as key MSATs (benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, polycyclic organic matter, naphthalene, and diesel exhaust). The Health Effects Institute (HEI) issued Special Report 16 in November 2007 "Mobile Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects" that acknowledges exposure to MSATs also comes from non-vehicular sources and calls for more source attribution work. The HEI report suggests monitoring next to roads and in vehicles and recommends that more research be performed to better characterize the atmospheric transformation of MSATs.

There is confidence that total emissions of regulated pollutants from mobile sources are decreasing, even in the face of increasing vehicle miles traveled (VMT). However, with advances in technology comes the recognition of new pollutants or new forms of pollutants that may raise health concerns. For example, it is currently unclear whether increases in VMT result in increases in ultrafine particulates (UFP, particles with at least one dimension equal to or less than 100 nanometers) in the ambient air. Unlike larger particulates (*e.g.*, fine and coarse) ultrafines contribute very little mass to conventional mass-based methods of particulate sampling and monitoring and do not contribute significantly to particulate measurements that rely on light scattering or extinction. However, as with other particulates, ultrafines can be associated with motor vehicle emissions, and may be generated by the pollution control systems adopted to control the traditional criteria pollutants (Wiseman and Zeirini, 2009). In the 2010 Policy Assessment for particulate matter (PM), EPA suggests that "In order to improve our understanding of the public health impacts of UFPs, consideration should be given to establishing a Federal Reference Method for measuring UFPs in ambient air and establishing a national UFP monitoring network."

Air pollution health effects research is limited by available measurement methods. As is the case with ultrafine particles, lack of adequate measurement techniques for non-mass-based particle properties may bias research that relies on PM mass-based methods, and may not adequately capture all particle-related health effects. Real time measurement techniques for elemental carbon (a surrogate for and fraction of diesel particulate matter) have been successfully deployed in mobile settings in New York City, and offer a research option for measuring particulates. EPA recently funded studies using various particulate indicators and reviewed them in the 2009 Integrated Science Assessment for PM (prepared by EPA for the current PM NAAQS review). These studies include recent developments in measurement techniques for ultrafines and various PM species, including organic and elemental carbon, as well as other traffic-related organic and elemental compounds. Current scientific research seeks to determine which properties of airborne particulates and/or gases are responsible for the health effects (described below) observed with exposure to traffic-related air pollutants.

4. GENERAL HEALTH CONCERNS FROM TRAFFIC-RELATED AIR POLLUTION

The body of scientific evidence evaluating the health effects of traffic-related air pollutants shows associations between pollutants and indicators of both adverse respiratory and cardiovascular health, including mortality from both respiratory and cardiovascular causes. In its evaluation of the latest scientific evidence, The Health Effects Institute (HEI) May 2009 Special Report 17 "Traffic Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure and Health Effects," concludes that the "aggregate evidence with respect to mortality, especially cardiovascular mortality points strongly toward a causative role for traffic-generated pollutants."

For workers at toll plazas, exposure to traffic-related air pollutants is concentrated at the traffic source over the course of an eight (or ten) hour workshift. The exposure pattern of the toll plaza worker population is unique in that these individuals are consistently exposed to air composed of fresh traffic exhaust. Thus far, it is unclear how this concentrated occupational exposure may affect workers' health. The acute health effects from traffic-related air pollution exposure seen in children, the elderly and other susceptible populations in community settings, may not be as easily detected in the toll booth worker population. Although toll booth workers may be exposed to higher concentrations of traffic-related air pollutants during their workshift, these workers may be less susceptible to effects due to biological factors such as age and overall health status – known as the "healthy worker effect." Evaluating the health risk to toll booth workers in terms of chronic health effects is also a research challenge. Studies of chronic effects are inherently dependent on historic exposures, and the composition of air pollutants has changed over time.

Documents such as the recent HEI reports, EPA's Integrated Science Assessments produced for the criteria pollutants, and EPA's Integrated Risk Information System (IRIS) provide comprehensive reviews of the available research and a characterization of the state of the science and knowledge regarding exposures and health effects of mobile source related pollutants. The potential health effects of concern associated with exposure to the major traffic-related air pollutants are discussed below and summarized in Table 1.

Carbon monoxide (CO) is a colorless, odorless gas that can cause cardiovascular and central nervous system effects due to its binding with hemoglobin (the blood component which carries oxygen) in the blood, thereby replacing oxygen and resulting in a hypoxic state. Exposure to CO was historically used to measure overall exposure to traffic exhaust, since acute effects from exposure are easily measured and monitored. New York conducted studies several decades ago with the goal of measuring the exposure of toll booth workers to automobile exhaust (NIOSH, 1991; Stern, 1988). The primary focus in these studies was on CO exposure because it is a traffic-related pollutant that presents significant acute and chronic health concerns, is a distinct chemical entity, is relatively stable atmospherically, and is amenable to measurement and monitoring.

Ozone has been shown to cause respiratory-related health effects. As discussed previously, however, levels of ozone are not expected to be elevated at toll plazas due to its formation as a secondary pollutant downwind from traffic, which is a source of chemical precursors to ozone.

Traffic-related gases are of potential occupational health concern. These include the criteria pollutants (*e.g.*, NO_2, SO_2 and CO), and also volatile organic compounds (VOCs) such as benzene. In its recent reviews of the NO_2 and CO standards, as well as the PM standards, EPA has acknowledged the potential for greater exposure to these compounds near roadways (EPA REA CO, 2010, EPA Policy Assessment (PA), 2010, EPA NO_2 Final Rule 2010). The concern with SO_2 exposure and respiratory effects has been part of the impetus for the present mandate for the use of low-sulfur diesel fuel.

The first federal, mass-based ambient air quality standards for particulates, or particulate matter (PM) were established in 1971. In 1987, they were revised to regulate PM by size fraction -- particulates less than 10 microns (PM_{10}) (inhalable particulates) to protect against respiratory effects. In 1997, a second health-based regulation on a smaller size fraction, particulates less than 2.5 microns ($PM_{2.5}$) or “respirable” particulates, was established. These community-based standards apply to all particles regardless of chemical composition or origin and are set to be protective against respiratory and cardiovascular effects.

Concerns are now being voiced about potential health effects of other PM size fractions, such as UFPs (particulates with at least one dimension equal to or smaller than 100 nanometers). Little is known about the potential health impacts of mobile source related UFPs. Their small size makes them easily transferred from the lungs into the bloodstream and across tissues where they may cause systemic effects. Some of the scientific research to date has found a link between UFPs and cardiovascular markers, which researchers think may be due to oxidative stress (Donaldson, 2001). However, research on the health effects of UFPs is still in the developmental phase. There is not a wealth of clinical or laboratory studies looking at the biological disposition of UFPs, nor are there readily available data to link occupational or community exposures to appropriate health outcome data in an epidemiological study. Ultrafine particulate research is an area of ongoing research.

There is a growing body of scientific literature that attributes particulate-related health effects to diesel exhaust particulates (DEP). DEPs vary in size from ultrafine to above one micron (fine particulate). A significant number of the particulates in DEP are present in the UFP size fraction. In 2002, the EPA released a comprehensive assessment of the health hazards of diesel engine exhaust, acknowledging that short-term exposure to diesel exhaust can cause lung irritation and inflammation, as well as exacerbation of existing allergies and asthma symptoms. EPA also considers DEP a likely human carcinogen, citing evidence of lung cancer risk from long-term exposure (EPA, 2002). Currently, occupational guidelines for DEP (such as using elemental carbon as a marker for DEP) do not exist. However, National Institute for Occupational Safety and Health (NIOSH) method 5040 is a published method for personal sampling for elemental carbon (diesel particulate) in non-mining workplace air. The American Conference of Governmental Industrial Hygienists (ACGIH) has proposed and then withdrawn time weighted averages (TWAs) for diesel exhaust particulate since 1996. A TWA is the exposure limit for an eight-hour workshift. The most recent proposal, a TWA set at 0.02 milligrams per cubic meter (mg/m^3), was withdrawn following the release of EPA's 2002 Diesel Engine Exhaust Health Assessment Document. In 2003, EPA established an inhalation reference concentration for diesel engine exhaust of 5 micrograms/m^3 (elemental and organic carbon and gaseous components combined). An inhalation reference concentration is the concentration in air that if breathed for a lifetime is not expected to produce adverse health effects.

Chemical composition of particulates, with the exception of lead, is not currently regulated at the community level by the NAAQS. The ban on leaded gasoline in the 1970s resulted in a much smaller contribution of lead to the current composition of particulates associated with traffic. Recent studies have found stronger health effect associations with certain chemical components of particle pollution than with measurements of particulate mass (as measured by $PM_{2.5}$ or PM_{10}) (EPA, 2009). While occupational guidelines do exist for some of the components, such as various metals, the guidelines do not take into account the simultaneous presence of assorted chemical constituents, or particulates with adsorbed compounds in various forms.

The category of chemicals referred to as VOCs, is a large, diverse group of chemicals. The types and concentrations of mobile source related VOCs will vary based on factors such as vehicle type, fuel and operation. The potential health effects will vary as well, and include cancer and respiratory effects. Certain VOCs (benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein) have been highlighted for regulation as MSATs because of health concerns and their presence in emissions from mobile and other sources.

5. EXPOSURE TO TRAFFIC-RELATED AIR POLLUTION AT OR NEAR TOLL PLAZAS

In order to assess the exposures of toll plaza workers to transportation-related air pollution, a literature review of previous studies was completed. This review yielded some information regarding toll booth collectors outside of New York State in U.S. cities (Boston, Baltimore, Detroit, Raleigh, Houston, Los Angeles, and Oakland-San Francisco), U.S. states (Texas, Maryland, and Delaware) and international locations (Taipei Taiwan, Rome, Belgium, Korea and Norway). The studies vary regarding exposure model used, personal monitoring and ambient sampling methods, locations and equipment, and contaminants studied. Few recent biological monitoring studies have been undertaken on exposed workers, and more recent studies are more likely to assess the general public's exposures than exposures specific to the toll booth worker population.

Comparisons among the studies are difficult. Research included in the following subsections spans the years 1961 to 2009 and represents a 38-year period during which fuel composition has changed with the removal of lead from gasoline, gasoline reformulations, the addition of new catalysts, and the reduction of the sulfur content of diesel fuel; regulations for both emissions and vehicle equipment have changed; advances in emission controls have been introduced; traffic patterns and volumes have changed with thousands of vehicles per hour presenting increased exposure potentials at rush hour and holidays; laboratory testing equipment, methodologies and portable testing devices have advanced; VMT have risen; acceleration and deceleration are associated with new engine and brake wear emissions; and new traffic controls (E-Z Pass versus toll collectors) have been implemented.

Tables in the following subsections summarize studies assessing toll plaza workers exposure to elevated levels of air pollutants and mobile source air toxics such as benzene, toluene, ethylbenzene, xylene (BTEX), CO, and PM. Workers' exposure to these pollutants is influenced by traffic volume, operating conditions, work shift hours, proximity to passing vehicles, local meteorology, fuel consumption, fleet mix, ventilation systems and respiratory protection. In addition, new pollution constituents may need to be considered; for example catalytic converter components such as platinum, palladium and rhodium (Wiseman and Zereini, 2009). The literature also suggests that additional studies of toll plaza workers' exposures should consider sampling for acrolein, black carbon, and UFP. Currently, personal and ambient air sampling data at toll plazas are limited, and more sophisticated models are needed for more reliable predictions of pollutant concentrations at toll plazas.

Exposed Population at New York City Toll Plazas

The Metropolitan Transportation Authority (MTA) has nine locations where there are currently toll plazas (see Figures 1a and b). These locations include: Throgs Neck, Henry Hudson, Marine Parkway, Bronx Whitestone, Brooklyn Battery, Queens Midtown, Robert F. Kennedy, Cross Bay and the Verrazano Narrows Bridges. There are also toll plazas operated by the Port Authority of New York New Jersey (PANYNJ). These locations include: George Washington, Goethals, and Bayonne Bridges, Outerbridge Crossing and the Lincoln and Holland Tunnels. Three of the PANYNJ locations have toll plazas located on the New York side and include the Bayonne and Goethels Bridges and the Outerbridge Crossing (see Figures 1a and b).

MTA currently has 747 full-time Bridge and Tunnel Officers (BTO's) who work in toll booths and on the plazas. In addition, the MTA has Temporary BTO's who work in the toll booths exclusively and are not represented by a union. The full-time BTO's are represented by two unions, Bridge and Tunnel Officers Benevolent Association, and Superior Officers Benevolent Association. MTA Bridge and Tunnels BTO's work a 40 hour week with two breaks and a lunch each day, not including overtime. The PANYNJ has 220 toll collectors represented by the Transportation Workers Union. We do not know how many of the 220 collectors work at the three locations in New York.

Air Quality Impacts to Workers and Surrounding Communities

Motor vehicle emissions at toll plazas in Metropolitan areas may also impact nearby neighborhoods. Research has shown that PM concentrations decrease exponentially with distance from a roadway, with the higher concentrations of ultrafine and fine particulates closest to the roadway and reaching background levels and a more uniform size distribution by 150 meters from the road (EPA, 2008). Aerial photos of each of the MTA bridges and tunnels show the location of the toll plaza relative to the surrounding neighborhoods (see Figures 2a-i). In most cases, the toll plazas are not located close to residential areas, with few housing units located within 100 meters of toll plazas. In some cases, more housing units are found within 200 meters of toll plazas. However, estimated populations for those areas are also low, making it difficult to conduct epidemiological studies that could associate health outcomes with pollutant concentrations at this geographic scale. While extending the distance to more than 200 meters would likely capture a larger population, at that distance, attributing pollutant concentrations to the toll plazas would be very uncertain. Additionally, availability of health data is limited to disease registries and hospitalization records, potentially limiting the ability to identify all health effects related to vehicle emissions at toll plazas.

Baldauf *et al.* (2009), discuss a consensus developed in recent years that exposure to traffic emissions increases the risk of adverse health effects for populations living, working or going to school near large roadways. The authors point out that large increases in vehicle use have offset per vehicle emission reductions while emissions from some vehicle-associated sources such as brake and tire wear are not regulated and pollutants from these sources may increase with increased vehicle use. One toll plaza study at the Baltimore Harbor Tunnel (Sapkota, 2003) found that traffic volume was a strong determinant for curbside concentrations of 1,3-butadiene, benzene and polycyclic aromatic hydrocarbons (PAH), accounting for 62, 77 and 85 percent, respectively, of the air pollution levels. A summary of the research indicates that air pollution near roads may be mitigated by infrastructure design options and highlights the fact that roadway design options, (that affect pollutant transport and dispersion) such as roadway configuration and the presence of roadside structures, can influence air pollution exposure levels near roadways. These conclusions have policy implications, and suggest regulation of roadway design is an essential part of plans or policies to prevent adverse health impacts from exposure to traffic-related air pollution.

Several studies were performed evaluating contaminants from roadways. These add to the data associated with air quality and the reduction of contaminants from vehicle emissions over the years, which are expected to continue to decline.

Literature Table: Air Quality Impacts (See also Appendix for additional details on studies)

Study Source	Location	Traffic Volume	Pollutant	Exposure Measurement	Main Results/Outcome	Study Applicability
Delaware Department of Transportation (2009)	Delaware (1-95 Newark Toll Plaza)	58,364 vehicles per hour with peak holiday average of 132,297 vehicles per hour	Carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), MSAT's: Benzene, acrolein, formaldehyde, 1,3-butadiene, acetaldehyde, diesel exhaust (gases and particulate matter)	EPA's Mobile 6 emissions model used for re-evaluation of localized air quality impacts based on alternative roadway designs.	All mobile source air toxics (MSATs) (except diesel particulate matter) decrease as speed increases -Widened highways = higher localized MSAT levels - Projected CO levels were 2.8ppm hourly concentration and 2.4ppm 8-hr concentration representing 8% and 26.6% of the current National Ambient Air Quality Standard (NAAQS).	MSAT concentrations will be reduced between 2000 and 2020 due to Environmental Protection Agency (EPA) emission and fuel regulations. Fleet mix and turnover, vehicle miles traveled (VMT), growth rates and local control measures may also influence levels.
Sapkota, A., Buckley T. (2003)	Baltimore, MD Harbor Tunnel Toll Booth	70,000 vehicles per day	1,3-butadiene, benzene and polycyclic aromatic hydrocarbons (PAHs)	Pollutant concentrations were measured over 3-hour intervals on seven weekdays.	Significant association between traffic and curbside concentration of PAHs, 1,3-butadiene and benzene: -2-axle vehicles had an overall contribution between 1-3x -vehicles with 2+ axles emit 60x more PAHs, 32x more 1,3-butadiene and 9x more benzene	-Exposures were exacerbated for residents sitting on porch. - Quantifies the association between outdoor curbside pollutant levels and traffic volume
Destaillats, H., Spaulding, R., Charles, J. (2002)	Oakland-San Francisco Bay Bridge Toll Plaza	250,000 vehicles/day	Acrolein, potentially toxic unsaturated aldehydes and dicarbonyls	Ambient air sampled at the SF Bay Bridge toll plaza during rush hour	Acrolein concentrations lower than U.S. EPA modeling study predictions in 1996 -36 carbonyls and hydroxycarbonyls were identified in the sample extract.	Lower acrolein attributed to reformulation of gasoline, advancement of new catalysts and fleet turnover in 1990

Study Source	Location	Traffic Volume	Pollutant	Exposure Measurement	Main Results/Outcome	Study Applicability
Tsai, P., Lee, C., Chen, M., *et al.* (2002)	Taiwan	6,636 cars ticket, 3743 cars cash and 2840 trucks/buses per shift	Benzene, toluene, ethylbenzene, and xylene (o-, m-, and p-) (BTEX) and methyl tertiary butyl ether (MTBE)	Volatile organic compound (VOC) concentration samples at the breathing zone (150 cm) of attendants in winter during 3 shifts (toll booth types: car lane ticket/cash collecting, bus/truck lane)	-Levels in both car lanes were similar and significantly higher than in the bus/truck lane. -Patterns were consistent for all work shifts -Vehicle flow rate had a significant effect on VOC levels	The development of a model able to predict VOC contents for different types of toll booths is plausible using vehicle flow rate.
Jo, W., Song, K. (2001)	Taegu, Korea (3rd largest city in Korea)	423,342 passenger cars, 17,136 cabs, 35,323 buses and 118,656 trucks registered in the city	BTEX	VOC breath concentrations for parking garage attendants, service station attendants, roadside and underground storekeepers	Pre- and post-work breath concentrations of the workers showed elevated levels compared with a control group - Breath and personal air concentrations for all the target compounds were higher for underground parking garage attendants than for ground-level parking attendants	Mechanical ventilation systems may not have been operating properly. Dispersion assumed to be greater at ground-level parking garages in open areas.

Toll Plaza Technologies that Influence Exposure

E-Z Pass System

The E-Z Pass system was phased in between October 1995 and December 1996. E-Z Pass and Open Road Tolling are put in place to reduce existing traffic congestion. There is no indication in the literature that these toll mechanisms serve to increase VMT. The observed increase in VMTs is seen across road types. However, imposition of new tolls could shift transportation to non-toll roadways (USGAO, 2006). Beginning in January 1996, E-Z Pass was installed throughout the MTA bridges and tunnels. A vehicle with an E-Z Pass tag is able to pass through toll plazas, without stopping to pay a toll. E-Z Pass use helps to reduce congestion, thus reducing toll plaza delays and auto emissions caused by idling engines. All of the MTA bridges and tunnels have E-Z Pass lanes. The annual market share of E-Z Pass for all vehicles has risen from 44 percent in 1997 to 74 percent in 2008. Including truck and bus traffic, the total market share of all paid traffic using E-Z Pass has risen from 42 percent in 1997 to 88 percent in 2008.

Passenger vehicle E-Z Pass share rose from 45 percent in 1997 to 73 percent in 2008 (see Tables 2a-c).

Occupational exposures at the toll plazas and environmental exposures in the surrounding communities are likely to further decrease with the increased use of E-Z Pass, as there is less idling of vehicles waiting to pay tolls. Saka (2000) reported that in the first year of E-Z Pass adoption on the New Jersey Turnpike there were reductions of 11 percent for NO_x and a decrease of more than 40 percent for hydrocarbons and CO. Lin and Yu (2008) also report an expected reduction of 58 percent of the particulate matter from diesel exhaust after implementation of an E-Z Pass system, since much of the diesel particulate emissions occur during the acceleration back to normal travel speed after a vehicle leaves the toll booth. While the continued implementation and use of the E-Z pass auto-pay system is expected to lead to a further reduction in emissions, there is currently no specific information on long-term trends in pollution levels after the implementation of E-Z Pass. Measures to prevent idling due to insufficient cash lanes should also be considered.

All Electronic Tolling (AET) is the system by which cars and trucks can be charged a toll without stopping. Cars and trucks would pass under the AET system and their E-Z Pass tag would automatically be charged for the toll. If the vehicle has no E-Z Pass tag a picture of their license plate would be taken and they would be sent a bill for the toll in the mail.

In January 2011, a two-phase pilot study began on the Henry Hudson Bridge to install AET on the toll plaza. The first phase, which started in January of 2011, has removed the gates on the toll plaza but is still offering cash lanes to pay the toll. This means that there are no BTO's on the toll plaza performing interventions. Beginning in 2012 the cash lanes will be replaced by a full blown AET toll plaza with no gates, no cash lanes, and therefore no BTO's performing interventions or toll collecting on the plaza. The toll plaza will be considered an open road and no individuals would be allowed access without proper procedures, such as working behind an attenuator truck.

Positive-pressure Heating, Ventilation, and Air Conditioning (HVAC) Systems

For toll plaza workers working in the toll booth, occupational exposures have been reduced by the use of ventilation systems installed in the toll plazas. As noted by Sapkota (2005) the actual toll booth provides some protection from air toxics attributable to the pressure control ventilation system present in the toll booth where sampling occurred. Each toll plaza at MTA Bridges and Tunnels is equipped with an HVAC system. These ventilation systems were installed at all facilities in 1972. There was additional upgrading of the HVAC systems completed in 1999. The HVAC system cools each toll booth in the summer and heats it in the winter. The system uses electrostatically charged pleated filters, with a minimum efficiency reporting value (MERV) of 11 on the air intakes. This filter rating is consistent with the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Inc. guidance for filtering automobile emissions with greater than 95 percent efficiency in removing particulates in the 1-3 micrometer size range. MERV ratings have not been established for particulates in the ultrafine (≤100 nanometer size range). Additionally, the systems provide constant positive pressure to the employee in the toll booth throughout the year. The intake for the supplied air to the toll booths are located a number of feet above the toll canopy roofs and to the side to minimize uptake of vehicle exhaust. Positive pressure prevents vehicle exhaust and other ground level pollutants from entering the toll booth. Environmental monitoring has found the HVAC systems to be effective at minimizing exposure of the employees to vehicle exhaust air contaminants. Sapkota (2005) compared the concentration of VOCs and particulate-bound PAHs inside the toll booth to those found curbside in 2001. Levels of VOCs were 2-8 times lower inside the booth. Levels of PAHs were also lower inside the booth (15.4 nanograms/cubic meter (ng/m^3)) compared to curbside (50 ng/m^3).

Two studies (Sapkota *et al.*, 2005 and Rossano *et al.*, 1972) demonstrated effectiveness of positive pressure installed in the toll booths in controlling exposure to PAHs, VOCs and CO inside the toll booths. One study (Burgess *et al.*, 1977) found high levels of CO and lead and recommended the use of an improved ventilation system.

Literature Table: Toll Booth Air Quality and Positive-pressure HVAC Systems (See also Appendix for additional details on studies)

Study Source	Location	Pollutant	Exposure Measurement	Main Results/Outcome	Study Applicability
Sapkota, A., Williams, D., Buckley, T. (2005)	Baltimore Harbor Tunnel Toll Booth	Volatile organic compounds (VOCs) and polyaromatic hydrocarbons (PAHs)	Measurements were taken inside the toll booth and curbside for outside the toll booth approx. 3 feet above ground where the vehicles approach the toll booth in the summer season. Toll booths had positive-pressure ventilation systems.	Morning concentrations of benzene and 1,3-butadiene exceeded afternoon levels with the lowest levels found at night when traffic volume was the lowest. Concentrations in toll booths were found comparable to urban residential setting, which was attributed to the positive-pressure toll booth ventilation system.	-A variation in results was found due to proximity to mobile sources, work shift, traffic volume and time of day. -Chlorinated VOCs found at higher concentrations inside the toll booth attributed to indoor sources (from cleaning products and dry-cleaned uniforms).
Burgess, W., Diberardinis, S., (1977)	Boston tunnel and Massachu-setts Turnpike	Nitrogen dioxide, carbon monoxide (CO), total hydrocarbons, respirable mass particulates, total suspended particulates, sulfur dioxide and lead	Three toll locations (5 miles apart) were monitored four times with two sampling units each of the four sampling periods using aerometric monitoring.	Toll booth collectors had a significant exposure to CO, with mean concentrations ranging from 16-34 parts per million (ppm) during sampling periods. - The total airborne lead concentrations ranged from 8-34 micrograms per meter cubed. - Sulfur dioxide, nitrogen dioxide and airborne particulate matter were also elevated.	-Toll booths should be designed with an adequate supply of air by either an air-purification system or a remote air supply

Study Source	Location	Pollutant	Exposure Measurement	Main Results/Outcome	Study Applicability
Rossano, A., Alsid, H., (1972)	Evergreen Point Bridge toll booth (Washington State)	Carbon monoxide	Continuous monitoring system that sampled at 1-minute intervals from toll operators breathing zone.	Positive-pressure ventilation system in toll booth reduced CO levels from 50-250 ppm to 10-20 ppm (a 30-90% reduction in CO in breathing zone)	

6. HEALTH STUDIES OF TOLL PLAZA WORKERS

<u>Studies of New York City Bridge and Tunnel Traffic Control Officers</u>

Pulmonary Disease

Evans RG, Webb K, Homan S, Ayres SM. 1988. Cross-sectional and Longitudinal Changes in Pulmonary Function Associated with Automobile Pollution Among BTO's. Am J Ind Med.;14(1):25-36.

In the 1970s, New York City BTO underwent longitudinal pulmonary evaluation over an 11 year period, 1970-1981, to determine the pulmonary impact of routine occupational exposure to elevated levels of air pollution (Evans *et al.*, 1988). The study protocol included basic breathing tests (spirometry), CO in blood (carboxyhemoglobin levels as calculated from the concentration of CO in expired air), and a questionnaire addressing respiratory symptoms and smoking status. It was offered on an annual basis to a total of 944 BTO's, and 85 percent participated at least once in the evaluation.

No comparison group (that is, without air pollution exposure) was examined as part of this study, and authors compared tunnel officers with bridge officers. The investigators posited that tunnel workers had higher exposure than bridge workers, so that differences in pulmonary status between the groups might reflect the effects of exposure to higher air pollution levels among the tunnel officers.

Approximately 50 percent (466) of BTO's participated in at least three annual examinations during the 11 year period, and the results for this subset of workers were published (Evans *et al.*, 1988). Average carboxyhemoglobin levels were 10 to 20 percent higher in tunnel officers than in bridge officers and decreased in 1972 when ventilation was introduced into the toll booths. The tunnel BTOs were on average slightly older than the bridge BTO's and worked for Triborough Bridge and Tunnel Authority (TBTA) slightly longer. The carboxyhemoglobin levels rebounded during the following years but decreased again at the end of the study period, 1979-1981. The rebound was thought to be from the BTOs blocking the vents because the air was too cold in the summer and too hot in the winter. In addition, the doors to the toll booths were frequently left open and the ventilation equipment was not always maintained. As expected, smokers had higher carboxyhemoglobin levels than did non-smokers.

Tunnel officers also exhibited, on average, greater evidence of decreased pulmonary function than bridge officers, especially among non-smokers. The decline in pulmonary function over the 11 year study period was greater in tunnel officers than in bridge officers. This occurred both among non-smokers and smokers, though only the former reached statistical significance. These declines were greater than those expected with age.

BTO's (combined) who worked longest had the highest level of decline in pulmonary function after accounting for the effect of age. Officers who had worked, as such, for more than 20 years had poorer pulmonary function than did officers who had worked less than 10 years. Pulmonary function values for officers who had worked 11-20 years were intermediate. All measured pulmonary function declines were statistically significant. The declines were most clearly observed among non-smokers.

Tunnel workers who smoked had higher rates of increased morning phlegm, increased overall phlegm production, and persistent wheezing than did bridge officers who smoked. Tunnel officers (both smokers and non-smokers) had more shortness of breath than did bridge officers. Prevalence of most respiratory symptoms increased dramatically with increasing duration of work as a bridge and/or tunnel officer, especially morning phlegm and cough, shortness of breath and persistent wheezing. This pattern was seen in both smokers and non-smokers.

Evans and colleagues concluded that the disproportionate decrease in pulmonary function experienced by 1) tunnel versus bridge officers and 2) long-term versus short-term BTO's was likely due to occupational exposure to air pollution. CO was not considered the responsible air pollutant but was viewed as a proxy for other more relevant air pollutants. The authors recognized that failing to include retired and disabled workers in the study might have led to an under-estimate of the effects of air pollution (Evans *et al.*, 1988).

Heart Disease Mortality

Stern FB, Halperin WE, Hornung RW, Ringenburg VL, McCammon CS. 1988. Heart Disease Mortality Among Bridge and Tunnel Officers Exposed to Carbon Monoxide. Am J Epidemiol. 128(6):1276-88.

Stern and NIOSH colleagues conducted a retrospective mortality study of 5,529 New York City BTO's who were employed by the Triborough Bridge and Tunnel Authority between January 1952 and February 1981 (Stern *et al.*, 1988). The study population included 4,317 bridge officers and 2,212 tunnel officers. Mortality rates in the general population of New York City were used for comparison. Tunnel officers were considered as having higher exposure to air pollution than bridge officers.

As part of the study, Stern and co-authors summarized existing knowledge about CO levels in the bridge's toll plaza and tunnel in New York City between 1960 and 1981. The available CO measurements included:

- In 1961, mean 24-hour CO levels inside the tunnels were 53 ppm in summer and 49 ppm in winter.
- In 1968, 24-hour average CO levels inside tunnels were 35-40 ppm. CO levels during rush hour traffic in tunnel toll booths were 120-165 ppm in the morning and 65-145 ppm in the evening and in the bridge toll booths were 15-45 ppm in morning and 12-22 ppm in the evening.
- In 1970, 38-day continuous monitoring showed mean 24-hour CO levels of 63 ppm in the tunnel toll booths and 13 ppm in the bridge toll booths.
- In 1981, mean area levels of CO inside tunnels were 38 ppm and outside bridge toll booths were 23 ppm. Personal CO samples taken daily for two weeks showed mean levels of 11 ppm for tunnel officers and 6.2 ppm for bridge officers.

(Note that the current Occupational Safety and Health Administration (OSHA) permissible exposure level is 50 ppm TWA and Public Employees Safety and Health permissible exposure level is 35 ppm TWA. The NIOSH recommends a 35 ppm TWA, and the ACGIH recommends a 25 ppm TWA.)

Study results showed that bridge officers experienced no overall excess in heart disease mortality (89 deaths vs. 104 expected, standardized mortality ratio, SMR = 0.85, (90 percent confidence interval (C.I.) = 0.71-1.02). However, young bridge officers (< 40 years) had an elevated heart disease death risk, SMR = 1.79 (*i.e.*, 79 percent high risk than expected) for arteriosclerotic heart disease (ASHD) mortality (90 percent C.I. = 1.15-3.24). Twelve deaths occurred in this younger group versus six expected. Tunnel officers had excess mortality from ASHD with a SMR= 1.35 (90 percent C.I. = 1.09-1.68). This excess was restricted to tunnel officers with greater than 10 years of employment (SMR = 1.88; 90 percent CI = 1.36-2.56). Like the bridge officers, ASHD mortality risk was highest among younger tunnel officers. The excess occurred among workers less than 60 year old versus greater than or equal to 60 year old.

Of interest is that the increased risk of ASHD mortality among tunnel officers (relative to bridge officers) appeared within one or more months after cessation of work as a tunnel officer, rose for the next four years up to 2- to 5.5-fold, and then moderated, though still at an elevated level, 1.5 to 2.5-fold after five or more years following cessation of work. This temporal pattern of risk suggests that occupational exposures of tunnel officers, whether air pollution or otherwise, are associated with the chronic and long-term expression of heart disease among these workers.

Excess heart disease, whether lethal or not, is unusual in occupational cohorts, because workers are generally healthier than the non-working population. This is a well-known phenomenon labeled “the healthy worker effect.” Thus, working populations usually have lower rates of heart disease than the general population. The finding of excess heart disease mortality among tunnel and younger bridge officers is a striking and highly unusual finding. In addition, excess risk of heart disease is especially important, because it is the most common cause of death in the general population, and any occupational amplification of that risk is likely to affect a sizable number of people.

Heart Disease Incidence

Herbert R, Schechter C, Smith DA, Phillips R, Diamond J, Carroll S, Weiner J, Dahms TE, Landrigan PJ. 2000. Occupational Coronary Heart Disease Among Bridge and Tunnel Officers. Arch Environ Health. 55(3):152-63. Erratum in: Arch Environ Health. 55(4):152-162.

Following the NIOSH study that showed increased heart disease deaths associated with work as a tunnel and/or bridge officer, a cardiovascular screening program was undertaken for BTO’s in the early 1990s by physicians at Mount Sinai School of Medicine (Herbert *et al.*, 2000). Active and retired (1985 and beyond) BTO’s were invited to participate in a multistage screening process. All participants underwent medical, cardiovascular disease, and occupational histories; a special questionnaire (Rose, 1962) for heart disease symptoms; a job strain (Karasek, 1985) questionnaire; physical activity and diet questionnaires; electrocardiogram; physical examination; and determination of serum lipids and triglycerides. Participants who had possible or probable cardiovascular disease based on the examination findings then were offered an exercise stress test and cardiology consultation. Non-smokers were also offered pre- and post-shift carboxyhemoglobin and urine cotinine (biomarkers for carbon monoxide and tobacco smoke exposure) levels.

Possible work-related cardiovascular risk factors evaluated in the study included CO exposure, exposure to other toxic traffic-based air pollutants, job strain, and physical inactivity of the job.

Of 760 BTO's employed by the Triborough Bridge and Tunnel Authority (TBTA) in 1994, 471 (62 percent) participated in the cardiovascular screening, as did 55 additional former BTO's for a total of 526 BTO's in the study. The average age was 44.3 years, and 89 percent of participants were male. Male BTO's had been employed by TBTA for an average of 15.2 years, and females for 8.5 years. One in four BTO's (28 percent) had physician-diagnosed hypertension, and 27 percent smoked cigarettes. Three-quarters of participants reported getting no exercise. Forty-four percent of male BTO's and 55 percent of female BTO's met criteria for experiencing intense job strain.

Twenty-nine male BTO's (5.5 percent) had definite evidence of coronary heart disease, and an additional 87 participants (16.5 percent) had possible coronary heart disease. The risk of coronary heart disease was elevated at odds ratio (a measure of relative risk) = 1.64 for each decade of employment as a BTO, adjusting for non-occupational cardiovascular risk factors. Carboxyhemoglobin levels were low. The authors concluded that two factors contributed to the risk of cardiovascular disease among BTO's; higher levels of exposure to CO among tunnel officers and age. Both factors also act together to produce a significantly elevated risk of cardiovascular disease.

In summary, three comprehensive and complementary studies of New York City BTO's were conducted 15 to 30 plus years ago (Evans *et al.*, 1988; Stern *et al.*, 1988; and Herbert *et al.*, 2000). They show evidence that BTO's were at increased risk of heart and lung disease as a result of occupational exposures experienced as bridge and/or tunnel officers during the testing periods. Limited exposure information and evolving exposures with time preclude the ability to conclusively identify the specific exposures that are responsible for the observed excess risks.

Additional Studies of Health Effects

Studies of tunnel workers in Boston (Larson and Konopinski, 1962; Speizer and Ferris, 1963; Tollerud *et al.*, 1983) and toll booth workers in Taiwan (Yang *et al.*, 2002) found only limited evidence of an association between exposure to motor vehicle emissions and respiratory symptoms.

Larson R. and Konopinski V. 1962. Sumner Tunnel Air Quality. Arch Environ Health. (5):597-608.

Larson and Konopinski reported CO levels at the Sumner Tunnel toll booth locations averaged 70 ppm, often exceeding 200 ppm during peak traffic hours. Airborne lead concentrations averaged 45 micrograms per cubic meter of air (mcg/m$^{3)}$ in tunnel outlet air. These levels were significantly higher than the national primary air quality standard for CO of 9 ppm maximal 8 hour exposure or 35 ppm maximal 1 hour average 1970 standards and the 1.5 ug/m^3 standard for airborne lead adopted by the California Air Resources Board and proposed by EPA in 1978.

Speizer F. and Ferris B. 1963. The Prevalence of Chronic Nonspecific Respiratory Disease in Road Tunnel Employees. Am. Rev. Respiratory Disease. (88):205-212.

A combined air monitoring and medical study was conducted in the Sumner Tunnel, a two-lane automobile conduit under Boston Harbor. Chronic non-specific respiratory disease and chest colds were found to be more prevalent in men who worked for more than 10 years compared to newer employees, but the small sample size (62 workers) did not permit the proper assessment of the effect of age or cigarette smoking on respiratory symptoms in this population.

Tollerud D., Weiss S., Elting E., *et al.* 1983. The Health Effects of Automobile Exhaust. VI. Relationship of Respiratory Symptoms and Pulmonary Function in Tunnel and Turnpike Workers. Arch Environ Health. 38(6):334-340.

The expansion of a second tunnel under Boston Harbor and the extension of the Massachusetts Turnpike expanded the workforce and altered traffic patterns. The authors undertook a study to determine the health effects of automobile emissions on a larger population than the prior Speizer study with 175 tunnel and turnpike workers. This report contains the results of the medical portion of that study, particularly the relationship between automobile exhaust exposure, chronic respiratory symptoms, and pulmonary function. A standard respiratory and illness questionnaire was administered, spirometry was performed, and scalp hair lead and blood lead content were measured as biologic indices of automobile exhaust exposure. Only one person had scalp hair lead levels above the normal range and three had blood lead levels greater than 80 micrograms per deciliter, the acceptable limit for workers at the time of this study in 1972-1975, before OSHA was established in 1979. Alveolar (lower lung) gas samples showed that CO levels were increased in men exposed to higher ambient CO concentrations, but the difference was not statistically significant.

When workers were stratified by smoking status, no significant relationship was found between automobile exhaust exposure and the presence of respiratory symptoms in middle-aged men. The authors noted that any study seeking to determine respiratory effects of environmental agents must allow for the significant health effects of cigarette smoking in the assessment of exposure. In a prospective analysis of 84 of these workers, the observed changes in FEV1.0 and FVC over three years were unrelated to exhaust exposures after controlling for age, height, cigarette consumption and initial level of pulmonary function. The difference between smokers and nonsmokers in this study was approximately 25 percent, a highly significant difference for this study sample size. The authors felt that small differences in symptom prevalence rates between high and low automobile exhaust exposure groups however, could have gone undetected in this study; a minimum sample size of 700 would have been required to detect differences if they were present.

Yang C., Chen Y. and Chuang H. 2002. Respiratory and Irritant Health Effects in Tollbooth Collectors in Taiwan. Journal of Toxicology and Environmental Health, Part A., 2002. (65):237-243.

This was the first epidemiological study of respiratory and irritant health effects in toll workers in Taiwan. The purpose of the study was to assess adverse health outcomes among a group of female toll collectors. Traffic rates were 900,000 vehicles per day, with peak flows in the morning and evening commuting hours. Self- reported chronic respiratory symptoms and acute irritative symptoms were assessed among 363 toll collectors and 147 control group workers. The job as toll collector was associated with a high risk of experiencing acute irritative symptoms;

nose, throat, nausea and headache symptoms were significantly more common among the toll collectors.

Only a few studies have been designed to investigate irritant health effects among subjects occupationally exposed to automobile exhaust. One of these studies was published previously by Strauss *et al.* (1992): health survey of toll booth workers. The results were consistent findings of a higher prevalence of irritation symptoms of nose and throat, nausea and head symptoms among toll booth collectors as compared with controls. The authors concluded that their results were consistent with the limited available evidence through direct irritation and neurotoxic effects and their results were biologically plausible.

The prevalence of respiratory symptoms (coughing, wheezing, dyspnea, *etc.*) found by Yang was high compared to control workers, but the differences were not statistically significant. The authors suspect that there was considerable underestimation of the effects of traffic exhaust on respiratory symptoms. They proposed that short length of employment and symptomatic workers leaving the job of toll booth collector were related to not finding a significant difference. Though these results follow Tollerud *et al.* (1983), who found no relationship between automobile exhaust exposure and respiratory symptoms in exclusively male tunnel and turnpike workers, studies of tunnel workers by Ayres *et al.* (NYC, 1973) and Evans *et al.* (1988) found associations between air pollution and the prevalence of chronic respiratory symptoms and/or impairment of pulmonary function.

7. APPLICABLE STATE AND FEDERAL REGULATIONS

Occupational standards and guidelines are designed to protect workers exposed in an occupational setting. Ambient standards, on the other hand, are designed to protect the general public from disease and may be over protective in the occupational setting since they assume a 24-hours per day, seven day per week continuous exposure, and are designed to include sensitive sub-populations (such as children and the elderly) not generally employed in the workforce.

Occupational Standards and Guidelines (see Table 3)

Federal

As mandated by the Occupational Safety and Health Act of 1970, the U.S. Congress created the OSHA in 1971. The role of OSHA is to establish legally enforceable standards to protect workers from exposure to a variety of hazardous substances, including airborne chemicals, dusts, and physical hazards. To date, OSHA has established approximately 500 Permissible Exposure Limits (PELs), which are the eight-hour regulatory limits of exposure. The NIOSH is the federal agency responsible for providing technical expertise to OSHA. In addition, NIOSH recommends exposure limits through the establishment of its own occupational guidelines - the Recommended Exposure Limits (RELs) for an eight-hour exposure. A third independent national entity, the American Conference of Governmental Industrial Hygienists (ACGIH), a voluntary membership organization, also makes available occupational guidelines for exposure to physical, chemical and biological substances for an eight-hour exposure. The ACGIH's Threshold Limit Values (TLVs) are guided by current health effects research, rather than economic or technical feasibility. Table 3 lists the OSHA regulatory standards and NIOSH/ACGIH RELs for traffic-related air pollutants.

While the majority of the OSHA PELs and the ACGIH TLVs are based on a TWA exposure for an 8-hour work shift, the NIOSH RELs are based on a 10-hour TWA to take into account workers who work more than 8 hours. Some substances also contain multiple guidelines or standards to account for short-term high exposures. These are either Short Term Exposure Limits, which cannot be exceeded for any 15-minute period or Ceiling Limits, which cannot be exceeded at any time during the working exposure.

The OSHA PELs are legally enforceable occupational exposure limits. As many of the PELs were established almost 40 years ago (in 1971), many industrial hygienists and health and safety professionals refer to both NIOSH RELs and ACGIH TLVs in their approach to preventing injury and illness in the workplace. Of the three occupational guidelines or standards discussed for OSHA, NIOSH and ACGIH, the ACGIH (TLV) guideline tends to be the most restrictive since they are more frequently updated based on recent scientific findings.

New York State

States are encouraged to develop and operate their own occupational health and safety programs, which must be reviewed and approved by OSHA. The standards must be at least as stringent as the legally enforceable OSHA standards. In New York State, the Public Employee Safety and Health (PESH) Act established the PESH program in 1980. PESH applies to all public sector employees, including local, county and state public employees. PESH enforces the revised federal OSHA standards adopted in 1987, which OSHA later revoked. PESH exposure limits for airborne contaminants are therefore more stringent than many of OSHA's current standards, which reflect the original 1971 standards. The PELs enforced by PESH are included in Table 3.

There are no federal or state occupational standards or guidelines for exposure to diesel exhaust particulates. The most recent attempt at setting a diesel guideline was proposed for the 2002 Notice of Intended Changes (NIC) to the ACGIH TLVs. The proposed TLV of 0.02 mg/m^3 was based on elemental carbon measurements. The ACGIH TLV committee later withdrew the diesel guideline from the 2002 NIC citing insufficient scientific evidence (ACGIH, 2008). The withdrawal occurred after substantial comments from outside parties. Difficulty in establishing a satisfactory measurement method for diesel exhaust particulates and inconsistent toxicological findings may play a role in the present lack of a diesel exposure guideline.

Ultrafine particulate matter also presents a regulatory challenge because of the difficulty in establishing a satisfactory measurement method, and the limited number of studies of UFP health impacts. Currently, no exposure guidelines exist for UFP.

National and New York State Ambient Air Quality Standards (Table 3)

Under the requirements of the Clean Air Act, last amended in 1990, the EPA established NAAQS for six criteria air pollutants. These widespread pollutants include gases and particulates emitted from diverse sources that are considered harmful to public health and the environment. Primary standards are set to protect public health, while secondary standards are established to prevent environmental damage including decreased visibility and damage to crops. As mandated by the Clean Air Act, these standards are reviewed and updated periodically in accordance with new findings recorded in the scientific literature.

Prior to the Clean Air Act and the promulgation of NAAQS, New York State established statewide air quality objectives as early as 1964. State and federal ambient air quality standards apply to community-level exposures, which include sensitive sub-populations such as children, the elderly, and those with chronic respiratory disease, and consider that exposures may be for 24-hours, seven days per week. The current NAAQS along with New York State's ambient air standards can be found in Table 3. Ambient air quality standards have not been established specifically for diesel particulates or UFP or most of the MSATs.

8. CONCLUSIONS AND RECOMMENDATIONS

A. Positive pressure heating ventilation and air conditioning (HVAC) systems have been shown to reduce toll collectors' exposure to mobile source-related air pollutants in several studies of toll booth workers in areas outside of New York City. Despite high levels of volatile organic compounds (VOCs) and particulate-bound polycyclic aromatic hydrocarbons (PAHs) in outdoor air, the levels measured inside toll booths with positive pressure HVAC systems at the Baltimore Harbor tunnel were comparable to those found in urban residential indoor environments (Sapkota *et al.*, 2005). Similarly, sampling showed that carbon monoxide (CO) levels were reduced to levels well below acceptable exposure levels as documented in occupational standards and guidelines (Rossano *et al.*, 1972; Burgess *et al.*, 1977). Personal air monitoring for CO was performed by the Metropolitan Transportation Authority (MTA) Health and Safety Department and an outside consultant in 2007 with results well below the Occupational Safety and Health Administration (OSHA) and Public Employee Safety and Health (PESH) standards, and the American Conference of Governmental Industrial Hygienists' (ACGIH) time weighted averages (TWA). Although data are not available for every mobile source-related air contaminant, positive pressure ventilation systems currently in place would be expected to effectively reduce and control employee exposure to other mobile source-related pollutants while in the toll booth.

   <u>Recommendation 1:</u> The MTA and the Port Authority of New York and New Jersey (PANYNJ) should continue to maintain a program to conduct periodic inspection and maintenance on the toll booth positive-pressure HVAC systems to keep them operating in optimal condition, so that exposures continue to be controlled by the HVAC system.

B. Increasing automation of toll collection (*i.e.*, E-Z Pass and boothless plazas) is expected to continue to reduce the exposure of toll booth collectors to air pollutants both by reducing the number of on-site toll collectors and by speeding the flow of traffic through the toll plazas. There is some evidence that implementation of E-Z Pass reduces air pollution levels at toll plazas and in the surrounding communities by decreasing vehicle idling and stop and go traffic (Saka, 2000; Lin and Yu, 2008). Although long-term impacts have not been evaluated, minimizing the stop-and-go of traffic at the toll plaza will likely reduce air pollution impacts in the region as well as in the surrounding community.

   <u>Recommendation 2:</u> The MTA and PANYNJ should support efforts to increase the automation of the toll collection process (*i.e.*, E-Z Pass use and boothless plazas) to minimize traffic congestion to the extent practical, while also minimizing congestion at cash only lanes.

C. Health studies of New York City toll plaza workers conducted 15 to 30 years ago reported an increased risk of heart and lung disease. The health status of New York City toll plaza workers, as a group, has not been assessed since that time. However, significant reductions in motor vehicle emissions have occurred over the past 30 years due to changes in gasoline/diesel fuel composition, emission controls, engine efficiency, E-Z Pass, toll plaza traffic pattern design, and positive-pressure HVAC systems in toll booths. These improvements have resulted in a reduction of occupational exposure and health risk from mobile source emissions. The Environmental Protection Agency's (EPA) national emissions control program aims to continue to reduce exposure to mobile source air toxics (MSAT). EPA-projected reductions are expected to reduce MSAT emissions by 57 to 87 percent between 2000 and 2020. Local conditions in terms of vehicle mix and turnover, vehicle miles traveled (VMT), growth rates and local control measures may impact the amount of reduction in different areas. The magnitude of the EPA-projected reductions is, however, so great (even after accounting for VMT growth), that MSAT emissions are expected to decline. The New York State Department of Environmental Conservation (DEC) projects decreases for nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2). In addition, CO levels in ambient air nationwide have decreased by 50 percent since 1990, largely due to emission controls for on-road vehicles. Although exposure of toll plaza workers to motor vehicle emissions has significantly declined over the past 20 years and should continue to decline in the future, their health status, as a group, has not been routinely monitored over that time period. The potential for a National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation should be considered, as NIOSH has the expertise, resources and experience to conduct health studies for the MTA and PANYNJ employees for existing and emerging health concerns.

Recommendation 3: Unions and management for the MTA and PANYNJ should engage the New York State Occupational Health Clinic Network and/or NIOSH to assess the need for a program of periodic health screenings for the toll plaza workers. The screenings would include, but not be limited to, pulmonary function and cardiovascular health.

D. The data that were used to characterize pollutant exposures in the environment near toll booths were collected at curbside, adjacent to toll plazas at various sites across the country and internationally. This type of environmental sampling represents the contribution of traffic-related air pollutants to population-level exposures in adjacent neighborhoods based on the proximity to the traffic. The focus in the past on CO in near-booth and in-booth studies was directed at a traffic-related pollutant that presents significant acute health concerns, is amenable to measurement and monitoring, and can be considered a surrogate indicator for other combustion related pollutants. Other transportation-related pollutants do not exhibit all of these attributes, making sampling more challenging. For example, transportation related particulates are present across a relatively wide size distribution, and have different atmospheric residence times, composition and chemical reactivity. These factors need to be considered in designing studies to characterize the potential hazards from particulates around the toll plaza environment. EPA already has studies underway to address transportation-related pollutants near roadways. These studies will provide additional information about criteria pollutants in the near roadway environment that can be compared to levels measured at community-scale monitors.

Recommendation 4: The New York State Department of Health (DOH), DEC and the New York City Department of Health and Mental Hygiene (NYCDOHMH) should monitor the current EPA-funded studies regarding the behavior and concentration of pollutants in the near-roadway environment for their relevance to both occupational exposures and community exposures to traffic-related pollutants near toll plazas. With respect to particulate matter research, New York State should encourage EPA to fund studies that will: better refine the appropriate technologies for sampling; identify the particulate indicators and toxicological endpoints of concern; and incorporate environmental sampling near toll plazas as a high exposure, micro-environment with implications for general ambient air quality. Environmental sampling near toll plazas will help to assess the possible health risks (including those for vulnerable occupational or residential populations) from exposure to mobile source emissions at or near these toll plazas and will provide a benchmark for evaluating control measures to be used in future assessments. If resources are available, the DOH and DEC should consider a pilot project to monitor at and near toll booth plazas to fill data gaps in EPA studies with regard to worker exposures at toll plazas and air quality in adjacent communities. This monitoring could also serve to fulfill federally mandated near-roadway multi-pollutant monitoring.

E. Significant data gaps and scientific challenges remain with respect to assessing exposure to airborne particulates of health concern. Health studies should incorporate real-time and recognized occupational methods (*e.g.*, NIOSH) of monitoring mobile-source related particulates (*e.g.*, elemental carbon). Near-roadway monitoring initiatives at toll plazas could also be used to characterize particulate matter components for a more detailed assessment of human health impacts from traffic-source combustion particulates. Deployment of real-time monitoring instruments for elemental carbon should be evaluated on a pilot basis and, if useful, implemented as an ongoing program.

Recommendation 5: DOH, DEC and NYCDOHMH should monitor EPA's progress in developing a reference analytical method for sub-micron particulates and in initiating near-roadway monitoring that incorporates sampling for specific particulate fractions and source attribution to assist in identifying significant particulate sources.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological profile for Benzene. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Draft Toxicological profile for Benzene. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2009. Draft Toxicological profile for 1,3-Butadiene. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2011. ToxFAQS Accessed online January 27, 2011 via http://www.atsdr.cdc.gov/az/a.html.

American Conference of Governmental Industrial Hygienists. 2008. https://www.acgih.org/faqs.htm accessed 2/19/10.

Air Quality Reevaluation, I-95 Newark Toll Plaza. 2009. Delaware Department of Transportation.

Ayres S, Evans R, Licht D, Griesback J, *et al.* 1973. Health effects of exposure to high concentrations of automotive emissions. Studies in bridge and tunnel workers in New York City Arch. Environmental Health. (27):168-178.

Baldauf R, Cahil T, Bailer C, *et al.* 2009. Can Roadway Design Be Used to Mitigate Air Quality Impacts from Traffic. Air and Waste Management Association, August, 2009.

Burgess W, Diberardinis S. 1977. Health Effects of Exposure to Automobile Exhaust - V. Exposure of Toll Booth Operators to Automobile Exhaust. American Industrial Hygiene Association Journal. (38):184-191.

Destaillats H, Spaulding R, Charles J. 2002. Ambient Air measurement of Acrolein and Other Carbonyls at the Oakland-San Francisco Bay Bridge Toll Plaza. Environ. Sci Technol. 36(10):2227-2235.

Donaldson K, Stone V, Seaton A, MacNee W. Ambient particle inhalation and the cardiovascular system: potential mechanisms. Environ Health Perspective (2001) 109(4):523-527.

Evans RG, Webb K, Homan S, Ayres SM. 1988. Cross-sectional and longitudinal changes in pulmonary function associated with automobile pollution among bridge and tunnel officers. Am J Ind Med.; 14(1): 25-36.

Hazardous Substances Databank (HSDB). 2011. Accessed January 27, 2011 via http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

Herbert R, Schechter C, Smith DA, Phillips R, Diamond J, Carroll S, Weiner J, Dahms TE, Landrigan PJ. 2000. Occupational coronary heart disease among bridge and tunnel officers. Arch Environ Health. May-Jun; 55(3):152-63. Erratum in: Arch Environ Health. Jul-Aug; 55(4):152-162.

Jo W, Song K. 2001. Exposure to volatile organic compounds for individuals with occupations associated with potential exposure to motor vehicle exhaust and/or gasoline vapor emissions. The Science of the Total Environment. (269):25-37.

Karasek R, Pieper C, Schwartz J. 1985. Job Content Instrument Questionnaire and User's Guide. Revision 1.1. New York: Columbia University Job/Heart Project.

Larson R, Konopinski V. 1962. Sumner Tunnel Air Quality. Archives of Environmental Health. (5):597-608.

Lin J, Yu D. 2008. Traffic-related Air Quality Assessment for Open Road Tolling Highway Facility. Journal of Environmental Management. (88):962-969.

National Institute for Occupational Safety and Health. 1991. Toll Collectors and Tunnel Officers (Carbon Monoxide). http://www.cdc.gov/niosh/pgms/worknotify/carbonmonox.html.

Revision to the NYS Implementation Plan for $PM_{2.5}$, October 27, 2009. National Ambient Air Quality Standard.

Rose G. 1962. The Diagnosis of Ischaemic Heart Pain and Intermittent Claudication in Field Surveys. Bull WHO. (27):645-58.

Rossano A, Alsid H. 1972. Evergreen Point Bridge Toll Booth Ventilation Study. Air Resource Program University of Washington. September 1972.

Saka A, Agboh D, Ndiritu S, Glassco R. 2000. An estimation of mobile emissions reduction from using electronic toll collection in the Baltimore metropolitan area: a case study of the Fort McHenry tunnel toll Plaza. National Transportation Center, Morgan State University.

Sapkota A, Buckley T. 2003. The Mobile Source Effect on Curbside 1,3-Butadiene, Benzene, and Particle-Bound Polycyclic Aromatic Hydroxarbons Assessed at a Tollbooth. Journal of the Air and Waste Management Association. June 2003, (53):740-748.

Sapkota A, Williams D, Buckley T. 2005. Tollbooth Workers and mobile Source-Related Hazardous Air Pollutants: How Protective Is the Indoor Environment: Environ. Sci. Technol. 39(9):2936-2943.

Speizer R, Ferris B. 1963. The Prevalence of Chronic Nonspecific Respiratory Disease in Road Tunnel Employees. Am. Rev. Respiratory Disease. (88):205-212.

Strauss P, Orris P, and Buckley L. 1992. A health survey of toll booth workers. American Journal of Ind. Med. (22):379-384.

Stern FB, Halperin WE, Hornung RW, Ringenburg VL, McCammon CS. 1988. Heart disease mortality among bridge and tunnel officers exposed to carbon monoxide. Am J Epidemiol. Dec; 128(6):1276-88.

The Health Effects Institute Special Report 16. November 2007. "Mobile Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects.

The Health Effects Institute Special Report 17, January 2010. Traffic Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure and Health Effects.

Tollerud D, Weiss S, Elting E, *et al.* 1983. The Health Effects of Automobile Exhaust. VI. Relationship of Respiratory Symptoms and Pulmonary Function in Tunnel and Turnpike Workers. Archives of Environmental Health. 38(6):334-340.

Tsai P, Lee C, Chen M, *et al.* 2002. Predicting the contents of BTEX and MTBE for the three types of tollbooth at a highway toll station via the direct and indirect approaches. Atmospheric Environment. (36):5961-5969.

U.S. Environmental Protection Agency. 2002. Health Assessment Document for Diesel Engine Exhaust (HAD). U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC, EPA/600/8-90/057F.

U.S. Environmental Protection Agency. 2006. Air Quality Criteria for Lead. Final Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/144aF-bF, 2006.

U.S. Environmental Protection Agency. 2008. Risk and Exposure Assessment to Support the Review of the NO2 national Ambient Air Quality Standard (REA). Office of Air Quality Planning and Standards. EPA-452/R-08-008a.

U.S. Environmental Protection Agency. 2008. National Ambient Air Quality Standards for Ozone (Ozone); Final Rule 40 CFR Parts 50 and 58.

U.S. Environmental Protection Agency. 2009. Integrated Science Assessment for Particulate Matter (ISA). Center for Environmental Assessment - RTP Division, Office of Research and Development. /600/R-08/139F.

U.S. Environmental Protection Agency. 2009. Integrated Science Assessment for Sulfur Oxides –Health Criteria (SO_2). National Center for Environmental Assessment- RTP Division, Office of Research and Development. EPA/600/R-08/047F.

U.S. Environmental Protection Agency. 2010. Policy Assessment for the Review of the Particulate Matter National Ambient Air Quality Standards First External Review Draft (PA). Air and Radiation Office of Air Quality Planning and Standards. EPA 452/P-10-003.

U.S. Environmental Protection Agency. 2010. Regulatory Announcement: Direct Final Rule and Notice of Proposed Rulemaking: Revisions to Motor Vehicle Diesel Fuel Sulfur Transition Provisions and Technical Amendments to the Highway Diesel, Nonroad Diesel, and Tier 2 Gasoline Programs (On Road Diesel). http://www.epa.gov/oms/regs/fuels/diesel/420f05051.htm accessed 7/2010.

U.S. Environmental Protection Agency. 2010. National Ambient Air Quality Standard for Nitrogen Dioxide (NO_2); Final CFR Parts 50 and 58.

U.S. Environmental Protection Agency. 2010. Risk and Exposure Assessment to Support the Review of the Carbon Monoxide Primary National Ambient Air Quality Standards: Second External Review Draft (REA CO). Office of Air Quality Planning and Standards, Health and Environmental Impacts Division EPA-452/P-10-004.

U.S. Environmental Protection Agency. 2010. Policy Assessment for the Review of the Particulate Matter National Ambient Air Quality Standards; Second External Review Draft.

U.S. Environmental Protection Agency. 2011. Integrated Risk Information system accessed online January 26, 2011 via http://www.epa.gov/iris/index.html.

United States Government Accountability Office (USGAO). 2006. Report to Congressional Requesters Highway Finance, States' Expanding Use of Tolling Illustrates Diverse Challenges and Strategies GAO-06-554.

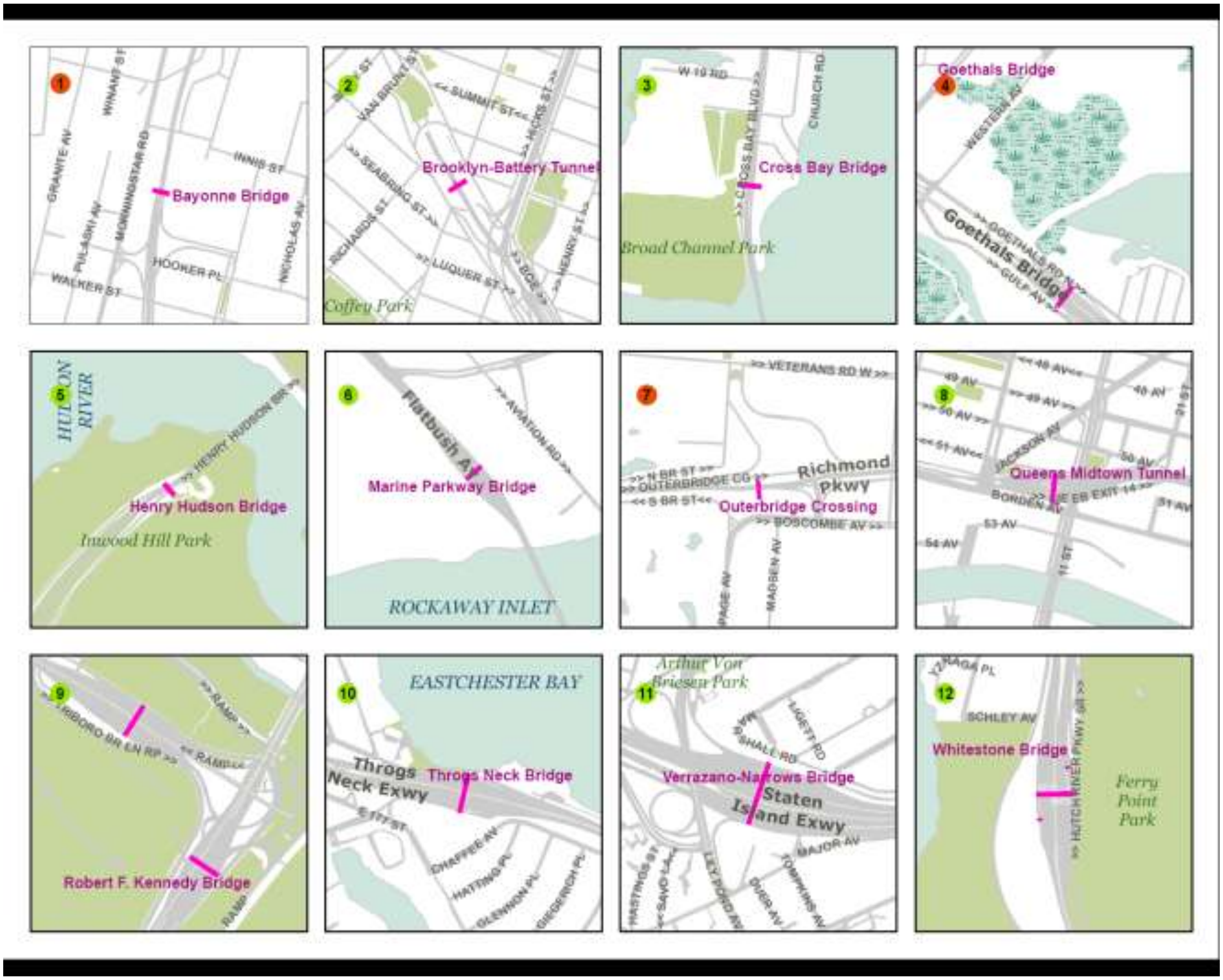
Wiseman CLS, Zereini F. 2009. Airborne particulate matter, platinum group elements and human health. Sci. Tot Environ. Apr;407(8):2493-2500.

Yang C, Chen Y, Chuang H. 2002. Respiratory and Irritant Health Effects in Tollbooth Collectors in Taiwan. Journal of Toxicology and Environmental Health, Part A., 2002. (65): 237-243.

FIGURES

Figure 1a. Map of MTA and Port Authority Toll Plaza Locations in New York City.

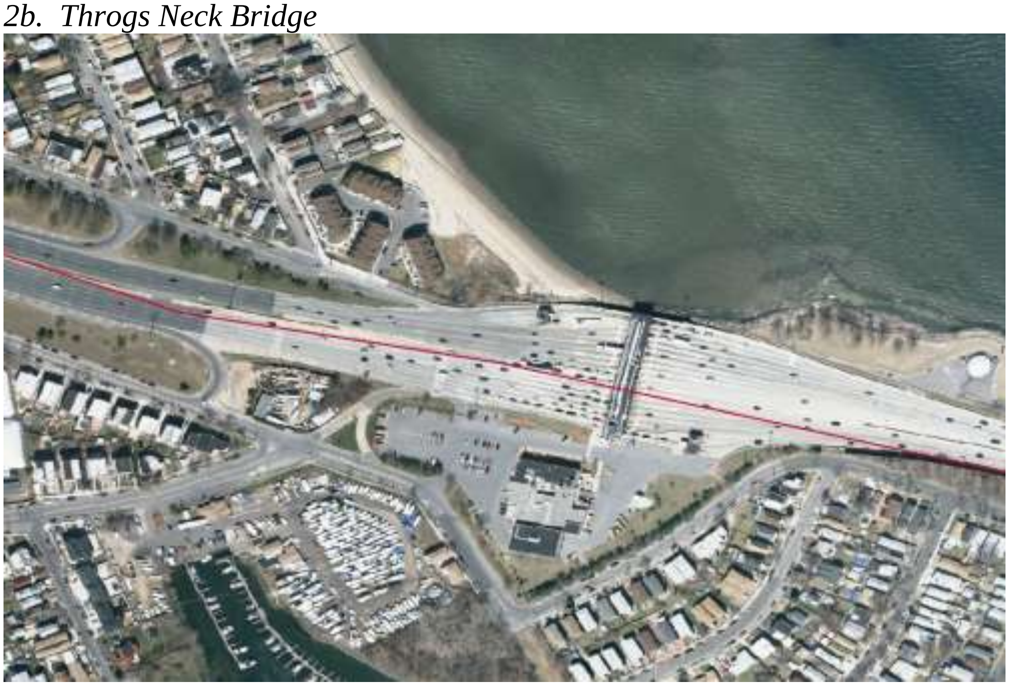
Figure 1b. Map of Metropolitan Transportation Authority and Port Authority Individual Toll Plaza Locations in New York City.



Figures 2a-i. Metropolitan Transportation Authority Toll Plazas in New York City.

2a. Queens Midtown Tunnel

2b. Throgs Neck Bridge



2c. Bronx Whitestone Bridge

2d. Verrazano Narrows Bridge

2e. Brooklyn Battery Tunnel

2f. Henry Hudson Bridge Toll Plaza

2g. Robert F. Kennedy Bridge

2h. Marine Parkway- Gil Hodges Memorial Bridge

e

2i. Cross Bay Veterans Memorial Bridge Toll Plaza

Figures 3a-c. Port Authority Toll Plazas in New York City.

3a. Bayonne Bridge

3b. Goethals Bridge

3c. Outerbridge Crossing

TABLES

Table 1: Traffic-Related Air Pollutants, Sources, and Health Effects.

Pollutant	Formation and Sources	Health Effects
Carbon Monoxide	85–95 percent of CO emissions are from motor vehicle exhaust in urban areas. Catalytic converters, introduced in 1975, have led to significant reductions in CO levels. CO levels at toll booths in New York City have significantly declined since the 1970s and 1980s.	Cardiovascular disease or pulmonary impairment in susceptible individuals and workers in environments involving exertion, heat stress, or other stressful conditions. Possible central nervous system effects and effects on birth outcomes (EPA REA CO, 2010)
Nitrogen Dioxide	NO_2 is a marker for a group of highly reactive nitrogen oxide gases (NO_x) that also play a role in ground-level ozone formation. Implementation of more stringent emissions controls for light and heavy-duty motor vehicles should contribute to a future reduction in vehicle-related NO_2 emissions, currently a major source of NO_2.	Increased airway responsiveness and respiratory symptoms, increased risk of emphysema (EPA NO_2 Final Rule 2010)
Ozone	Ground-level ozone is a secondary pollutant formed chemically from NO_x and volatile organic compounds (VOCs) in the presence of sunlight. Levels are highest during warmer months and near mid-day. Areas downwind of primary pollution sources, such as heavy traffic, have higher levels. Concentrations of ozone at toll booth plazas would therefore be expected to be low.	Pulmonary function decline from repeated intermittent exposures or from single short-term exposures. Possible cardiovascular effects from short-term exposures (EPA Ozone Final Rule 2008)
Sulfur Dioxide	Sulfur dioxide (SO_2) is a chemical marker for the group of highly reactive gases (oxides of sulfur (SO_x). Emissions from vehicles using sulfur-containing fuel contribute to SO_2 levels in urban areas. Since 2007, highway vehicles with heavy-duty engines are regulated to use low-sulfur diesel fuel, with the goal of further reductions in traffic-related SO_2 concentrations.	Respiratory irritation, coughing, increased sputum production, and broncho-constriction in workers. Accelerated loss of pulmonary function (EPA ISA, 2009).
Benzene	Benzene is a volatile organic compound (VOC) found and low concentrations in ambient air. Industrial emissions, gas stations and motor vehicle exhaust are important sources of benzene to outdoor air.	Increased risk of Leukemia, changes in blood components (anemia), central nervous system effects. EPA has classified benzene as a Category A carcinogen (known human carcinogen) (ATSDR, 2007).

Pollutant	Formation and Sources	Health Effects
Particulates (as measured by total particulate mass)	Particulate Matter (PM) air pollution is composed of small solid particles and liquid droplets, which can be composed of a variety of chemical compounds including nitrates, sulfates, organic chemicals, metals, and compounds found in soil. The combustion engine produces large amounts of particulates in the smaller size range, which are thought to have greater health impacts. Inert or nuisance dust is regulated occupationally for particulates of non-specified compositions.	Reduced visibility, deposits in the eyes, ears and nasal passages, throat and eye irritation, upper-respiratory-tract problems, skin injury, and other forms of physical irritation. Smaller particulates associated with cardiovascular and respiratory symptoms and mortality (EPA ISA, 2009).
Lead	Prior to the ban on leaded gasoline in the 1970s, motor vehicle exhaust was a primary source of lead particles in the air. Since then, levels of lead in the air have greatly declined, and most atmospheric lead is found near lead smelters. Currently, motor vehicles may contribute to airborne lead concentrations in urban areas by re-suspending dust on roadways.	Effects on heme synthesis in the blood, and neurological effects. (EPA Lead Final Report, 2006).
Diesel Exhaust Particulates	Diesel exhaust is a mixture of both particulates and gases. Diesel Exhaust Particulates (DEP) consists of an elemental carbon core with adsorbed organic compounds and small amounts of other compounds such as sulfate, nitrate and metals. Fresh diesel exhaust is mostly composed of extremely small ultrafine particulates less than 0.1 um in size.	Short-term exposure can cause lung irritation and inflammation, and exacerbation of existing allergies and asthma symptoms. Considered a likely human carcinogen by EPA due to lung cancer risk from long-term exposure (EPA HAD, 2002).
Ultrafine Particulates	Ultrafine particulates are defined as particles less than 0.1 um in diameter. They result from combustion, biological processes or chemical reactions in air or water, and single particulates tend to group together over time forming larger (but still sub-micron) particulates, making particle number and size measurements difficult.	Small size allows for transfer from the lungs into the bloodstream and across tissues. Linked with chemical markers of cardiovascular damage. Health effects from ultrafine particulates may differ from effects seen with larger particulates having the same chemical composition (EPA PM PA, 2010)

Pollutant	Formation and Sources	Health Effects
1,3-Butadiene	A colorless gas produced from petroleum processing, waste, wood and tobacco burning. Commercially, it is used to make plastics and synthetic rubber that is used for tires (ATSDR, 2011).	Increased incidence of blood cell cancers observed in polymer production workers. Animal studies (mice) found reproductive and developmental effects following chronic inhalation exposure. (EPA IRIS, 2011)
Formaldehyde	Formaldehyde is a colorless gas produced by human activities and natural sources (ATSDR, 2011).	Increased incidence of respiratory tumors in workers occupationally exposed during resin formation. Animal studies found malignant nasal tumors following chronic inhalation exposure (in rats and mice, EPA IRIS, 2011).
Acetaldehyde	Acetaldehyde is a colorless liquid that readily becomes a vapor. It is present in vehicle exhaust, and is produced when wood, tobacco, gas, fuel oil and coal are burned (HSDB, 2011).	Animal studies found degeneration of cells lining the nasal passages and respiratory tumors in rats following chronic inhalation exposure (EPA IRIS, 2011).
Acrolein	Acrolein is a colorless or yellow liquid that quickly changes to a vapor when heated. Small amounts of acrolein are produced when wood, tobacco, gasoline, and oil are burned. It is also produced commercially to make other chemicals (ATSDR, 2011).	Animal studies (rats) found increased incidence of nasal lesions following sub-chronic inhalation exposure (EPA IRIS, 2011).

Tables 2a-c. Annual E-Z Pass Market Share 1997 to 2008.

Table 2a. Total Traffic - Annual E-Z Pass Market Share*

Year	Total Paid Traffic	E-Z Pass Traffic	E-Z Pass Market Share
1997	266,519,564	117,367,239	44%
1998	279,463,396	160,098,000	57%
1999	289,106,717	172,421,003	60%
2000	296,632,531	188,990,499	64%
2001	293,219,838	197,696,514	67%
2002	299,994,683	205,353,133	69%
2003	297,465,352	207,559,889	70%
2004	302,995,482	212,290,700	70%
2005	300,385,193	214,676,195	72%
2006	302,058,593	219,287,588	73%
2007	304,364,216	223,583,491	74%
2008	295,679,638	218,773,027	74%

*Data provided by MTA Health and Safety

Table 2b. Trucks/Buses - Annual E-Z Pass Market Share.*

Year	Total Paid Truck/Bus	E-Z Pass Truck/Bus Traffic	E-Z Pass Market Share
1997	13,332,429	5,596,654	42%
1998	15,423,365	9,931,338	64%
1999	16,678,273	11,561,503	69%
2000	17,758,602	12,982,012	73%
2001	18,572,851	14,250,005	77%
2002	19,399,467	15,142,105	78%
2003	19,415,434	15,542,015	80%
2004	19,772,948	16,182,472	82%
2005	20,119,208	16,841,911	84%
2006	20,724,992	17,651,174	85%
2007	21,167,687	18,238,250	86%
2008	21,035,521	18,400,336	88%

*Data provided by MTA Health and Safety

Table 2c. Passenger Vehicles - Annual E-Z Pass Market Share.*

Year	Total Paid Passenger Traffic	E-Z Pass Passenger Traffic	E-Z Pass Market Share
1997	253,187,135	111,770,585	45%
1998	264,040,031	150,166,662	57%
1999	272,428,444	160,859,500	59%
2000	278,873,929	176,008,487	63%
2001	274,646,987	183,446,509	67%
2002	280,595,216	190,211,028	68%
2003	278,049,918	192,017,874	70%
2004	283,222,534	196,108,227	69%
2005	280,265,985	197,834,284	71%
2006	281,333,601	201,636,414	72%
2007	283,196,529	205,345,241	73%
2008	274,644,117	200,372,691	73%

*Data provided by MTA Health and Safety

Table 3: Traffic-Related Ambient Standards and Occupational Standards and Guidelines.

		Ambient Air Standards			Occupational Standards and Guidelines			
Pollutant	**Averaging Time**	**EPA Primary[1] Standard**	**EPA Secondary[2] Standard**	**NYS Standard**	**OSHA PEL**	**PESH PEL[3]**	**NIOSH REL**	**ACGIH TLV[4]**
GASES								
Ozone	1 hr[5]	0.12 ppm	Same as primary	0.12 ppm				
	8 hr	0.075 ppm	Same as primary	0.08 ppm	0.1 ppm (TWA[6])	0.1 ppm (TWA)		Heavy work: 0.05 ppm Moderate work: 0.08 ppm Light work: 0.10 ppm <2 hrs:0.20 ppm(TWA)
	Max					0.3 ppm (Ceiling limit)	0.1 ppm (Ceiling limit)	
CO	1 hr	35 ppm	None	35 ppm				
	8 hr	9 ppm	None	9 ppm	50 ppm (TWA)	35 ppm (TWA)		25 ppm (TWA)
	10 hr						35 ppm (TWA)	
	Max					200 ppm (Ceiling limit)		
NO_2	1 hr	0.100 ppm						
	8 hr							3 ppm (TWA)
	Max				5 ppm (Ceiling limit)	1 ppm (STEL: 15 min TWA)	1 ppm (STEL[7]: 15 min TWA)	5 ppm (STEL: 15 min TWA)

1 Standard set for protection of human health
2 Standard set for protection of property and the environment
3 The New York State occupational and safety program Public Employee Safety and Health (PESH) implements all OSHA standards for public employees. PESH implements all standards from 1987 that were later rescinded by OSHA.
4 2009 Threshold Limit Values
5 This standard has been revoked by EPA, but some areas have continuing obligations to prevent "backsliding"
6 Time-Weighted Average
7 Short-Term Exposure Limit

Pollutant	Averaging Time	Ambient Air Standards: EPA Primary[1] Standard	EPA Secondary[2] Standard	NYS Standard	Occupational Standards and Guidelines: OSHA PEL	PESH PEL[3]	NIOSH REL	ACGIH TLV[4]
	Annual (Arithmetic Mean)	0.053 ppm	Same as primary	0.05 ppm				
SO_2	1 hr	0.075 ppm		0.075 ppm		5 ppm (STEL: 15 min TWA)	5 ppm (STEL: 15 min TWA)	0.25 ppm (STEL:15 min TWA)
	3 hr		0.5 ppm	0.5 ppm				
	8 hr				5 ppm (TWA)	2 ppm (TWA)		
	10 hr						2 ppm (TWA)	
	24 hr	0.14 ppm		0.14 ppm				
	Annual			0.03 ppm				
Benzene	8 hr				1 ppm (TWA)[8]	1 ppm (TWA)	0.1 ppm (TWA)	0.5 ppm (TWA)
	Max				5 ppm (STEL: 15 min TWA)	5 ppm (STEL: 15 min TWA)	1 ppm (STEL: 15 min TWA)	2.5 ppm (STEL: 15 min TWA)
1,3-Butadiene			None					2 ppm (TWA)
Formaldehyde			None					0.3 ppm (Ceiling limit)
Acetaldehyde			None					25 ppm (Ceiling limit)
Acrolein			None					0.1 ppm (Ceiling limit)
PARTICULATES*								
Total Suspended Particulates	24 hr			250 mcg/m^3				
	Annual			75 mcg/m^3				
PM_{10}	1 hr			380 mcg/m^3				
	24 hr	150 mcg/m^3	Same as primary					

8 Except for some industries, where the PEL remains at 1971 standards: 10 ppm (8-hr TWA) 25 ppm (STEL)

Pollutant	Averaging Time	Ambient Air Standards: EPA Primary[1] Standard	EPA Secondary[2] Standard	NYS Standard	Occupational Standards and Guidelines: OSHA PEL	PESH PEL[3]	NIOSH REL	ACGIH TLV[4]
	Annual (Arithmetic Mean)							
$PM_{2.5}$	1 hr			88 mcg/m^3				
	24 hr	35 mcg/m^3	Same as primary					
	Annual (Arithmetic Mean)	15 mcg/m^3	Same as primary					
Inert or Nuisance Dust (Respirable Fraction)	8 hr				5 mg/m^3 (TWA)	5 mg/m^3 (TWA)		3 mg/m^3 (as PNOS[9])
Inert or Nuisance Dust (Total Dust)	8 hr				15 mg/m^3 (TWA)	15 mg/m^3 (TWA)		10 mg/m^3 (as PNOS) (inhalable fraction)
Lead	8 hr				50 mcg/m^3 (TWA)	50 mcg/m^3 (TWA)		0.05 mg/m^3
	10 hr						50 mcg/m^3 (TWA)	
	30-day Avg							
	Rolling 3-Month Avg	0.15 mcg/m^3	Same as primary					
	Quarterly	1.5 mcg/m^3	Same as primary					
Diesel Exhaust Particulates	24 hr	See PM_{10} $PM_{2.5}$			NONE	NONE	NONE	NONE[10]
Ultrafine Particulates	Annual				NONE	NONE	NONE	NONE

9 Particulates Not Otherwise Specified: particulates without an applicable TLV that are insoluble or poorly soluble in water, and have low toxicity (*i.e.,* do not cause toxic effects other than by inflammation or the mechanism of lung overload).

10 Diesel guideline proposed for the 2002 Notice of Intended Changes (NIC) to the ACGIH TLVs was 0.02 mg/m^3 (as Elemental Carbon), but it was later withdrawn from the NIC.

		Ambient Air Standards			Occupational Standards and Guidelines			
Pollutant	**Averaging Time**	**EPA Primary[1] Standard**	**EPA Secondary[2] Standard**	**NYS Standard**	**OSHA PEL**	**PESH PEL[3]**	**NIOSH REL**	**ACGIH TLV[4]**
OTHER								
Non-methane hydrocarbons	3 hr (6-9 am)			0.24 ppm				
Noise	Duration per day (hours)				Sound level dB(A) slow response	Sound level dB(A) slow response		Sound level dB(A)
	8				90	90	85 dB(A)	85
	6				92	92		
	4				95	95		88
	3				97	97		
	2				100	100		91
	1½				102	102		
	1				105	105		94
	½				110	110		
	¼ or less				115	115		
	max				140 dB (Ceiling limit)	140 dB (Ceiling limit)		145 dB(C) (Ceiling limit)

APPENDIX

Toll Booth Air Quality and Positive-pressure HVAC Systems

Two studies (Sapkota *et al.*, 2005; Rossano *et al.*; Alsid, 1972) demonstrated effectiveness of positive pressure installed in the toll booths in controlling exposure to polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and carbon monoxide (CO) inside the toll booths. One study (Burgess and Diberardinis, 1977) found high levels of CO and lead and recommended the use of an improved ventilation system.

Sapkota A., Williams D. and Buckley T. 2005. Tollbooth Workers and Mobile Source-Related Hazardous Air Pollutants: How Protective Is the Indoor Environment: Environ. Sci. Technol**.** 39(9):2936-2943.

This study of Baltimore Harbor Tunnel Toll Booth workers measured the concentrations of air toxins including VOCs and PAHs inside and outside of the toll booths during the summer season. A variation in results was found due to proximity to mobile sources, work shift, traffic volume and time of day. Observed 8-hour time weighted average (TWA) 1,3-butadiene and benzene levels were below the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLV) and the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL). The mean outdoor benzene and 1,3-butadiene concentrations varied by shift; mornings exceeded afternoon levels with the lowest levels found at night when traffic volume was the lowest. The 1,3-butadiene and benzene measurements track with bimodal traffic pattern peaks in the morning and afternoon rush hour traffic. The toll booth's heating, ventilation and air conditioning (HVAC) system included air filtration and maintenance of positive pressure within the booth. The air filtration system had a maximum efficiency reporting value (MERV) 13 rating, which reflects a >98 percent efficiency of removal for 0.3-1.0 micrometer particles. The extent of exposure was largely influenced by the protection provided by the indoor environment, where two to eight-fold lower levels of benzene and 1,3-butadiene were observed inside toll booths for all three shifts with the results lacking distinct bimodal patterns. Levels of PAHs were similarly reduced. Exposure reductions inside toll booths were attributed by the authors to positive pressure control ventilation, representative of 55 percent of Maryland toll booth designs. The authors also noted that this was a "best case scenario" for pressure control ventilation since the job tasks of toll booth collectors also involved leaning outside the booth for toll collection. Chlorinated VOCs found at higher concentrations inside the toll booth, were attributed to indoor sources (the use of cleaning products in the booth and dry-cleaned uniforms of the collectors). In summary, the authors concluded that despite high levels of mobile source-related VOCs and PAHs in outdoor air, the levels inside the toll booth were comparable to the urban residential setting, demonstrating the protection offered by a positive-pressure toll booth ventilation system.

Rossano A. and Alsid H. 1972. Evergreen Point Bridge Toll Booth Ventilation Study. Air Resource Program University of Washington. September 1972.

The Evergreen Point Bridge toll booth ventilation study in Washington State resulted in the development of a prototype toll booth with a positive pressure ventilation system that reduced measured CO levels of 50-250 ppm to an acceptable range of 10-20 ppm. The ventilation system showed a 30-90 percent reduction in CO entering the operator's breathing zone in the toll booth.

Burgess W. and Diberardinis S. 1977. Health Effects of Exposure to Automobile Exhaust - V. Exposure of Toll Booth Operators to Automobile Exhaust. American Industrial Hygiene Association Journal. (38):184-191.

Using Boston tunnel and Massachusetts Turnpike workers, Burgess and Diberardinis measured pollutant levels in the air to which the workers were exposed. The findings indicated that toll booth collectors had a significant exposure to CO, with mean concentrations ranging from 16-34 ppm during sampling periods. Daily mean concentrations as high as 94 ppm were recorded. The total airborne lead concentrations ranged from eight to 34 micrograms per meter cubed and sulfur dioxide (SO_2), nitrogen dioxide and airborne particulate concentrations were elevated to a lesser degree. The study concluded that toll booths should be designed with an adequate supply of air by either an air-purification system or a remote air supply.

General Air Quality Impacts

Air Quality Reevaluation, I-95 Newark Toll Plaza, 2009 Delaware Department of Transportation**.**

This project updated CO, mobile source air toxics (MSAT), and fine particulate matter ($PM_{2.5}$) analyses as a result of updated air quality rules and design changes on a toll plaza redesign. The actual project was the installation of a highway speed toll collection system using a gantry so maintenance can be done from above without closing lanes. Average daily traffic in 2009 was 58,364 vehicles per hour with peak holiday average of 132,297 vehicles per hour. This assessment was required for localized air quality impacts of federally funded or approved transportation projects in PM_{10} and $PM_{2.5}$ non-attainment and maintenance areas deemed to be projects of air quality concern. Using the Environmental Protection Agency (EPA) Mobile 6 emissions model 6.2.03, the projection for CO concentrations for 2030 was a 1-hour concentrations of 2.8 ppm and an 8-hour concentration of 2.4 ppm, which represent 8 and 26.6 percent respectively of the National Ambient Air Quality Standards (NAAQS) (35.0 ppm for 1 hour and 9.0 ppm for 8 hour). EPA has designated six prioritized MSATs, which are known or probable carcinogens or can cause chronic respiratory effects: benzene, acrolein, formaldehyde, 1,3-butadiene, acetaldehyde, and diesel exhaust (gases and particulate matter). The MOBILE 6 emissions model projects that emissions of all priority MSATs, except diesel PM, decrease as speed increases. The authors' discussion of MSATs identified technical shortcomings of emissions and dispersion models and an uncertain science with respect to exposure modeling and health effects, preventing meaningful or reliable estimates of MSAT emissions and health impacts. The authors present a qualitative model to assess the levels of future MSAT emissions, providing a basis for identifying and comparing MSAT emissions for alternative roadway designs. For example when a highway is widened, the localized level for MSAT emissions could be higher, but this could be offset due to increases in speeds and reductions in congestion, associated with lower MSAT emissions. MSATs will be lower in locations where traffic shifts away from the toll plazas. The study concluded that MSAT concentrations will decrease in future years due to EPA's vehicle emission and fuel regulations, which are projected to reduce MSAT emissions by 57 to 87 percent between 2000 and 2020. Local conditions in terms of fleet mix and turnover, vehicle miles traveled, growth rates and local control measures may also influence levels.

Sapkota A. and Buckley T. 2003. The Mobile Source Effect on Curbside 1,3-Butadiene, Benzene, and Particle-Bound Polycyclic Aromatic Hydrocarbons Assessed at a Tollbooth. Journal of the Air and Waste Management Association. June, (53):740-748.

This study of the Baltimore Harbor Tunnel Toll Booth workers provided a model for estimating the relevancy of curbside pollution levels of 1,3-butadiene, benzene and PAHs associated with traffic, as relevant to exposures in the urban environment. Mobile source emissions present a unique public health threat because of the exposure potential resulting from their proximity and integration into U.S. urban communities. Using multivariate regression, a significant association between traffic and curbside concentration was observed. Much of the pollutant variability was explained by traffic volume (70,000 vehicles per day), class and meteorology, providing a real-world basis by which to validate models and estimate exposure. Results suggest that vehicles with more than 2- axles emit 60, 32 and nine times more PAH, 1,3-butadiene and benzene respectively, compared to vehicles with two axles. However, because there are 29 times more vehicles with two axles on the highway than vehicles with more than two axles, the overall contribution to total pollutant levels are within a factor of 1-3. The findings of high pollutant concentrations measured in close proximity to roadways and during times of high traffic, may be relevant to the exposure potential along commuting arterials that transect some urban communities. In cities such as Baltimore, housing stock has been constructed very close (6-10 feet) to the heavily trafficked roadways. Exposures can be further exacerbated by the residents sitting outside on their stairs or porch and socializing, typical in urban communities. Depending on time-activity patterns of urban residents (*e.g.*, frequency, duration and time of day at home) their exposure may be underestimated relative to estimates given by ambient central-site monitoring or modeling. This assessment defines an experimental approach and estimate of the mobile source effect on the curbside pollutant concentration under real-world meteorological conditions. The resulting model may be useful for evaluating ambient exposure, risk and control strategies. Previous estimates had largely relied on dynamometer emissions testing and estimates of vehicle miles driven. This new model represents some of the first time-resolved measurements quantifying the association between outdoor curbside pollutant levels and traffic volume.

Destaillats H., Spaulding R. and Charles J. 2002. Ambient Air Measurement of Acrolein and Other Carbonyls at the Oakland-San Francisco Bay Bridge Toll Plaza. Environ. Sci Technol. 36(10):2227-2235.

This study of the Oakland-San Francisco Bay Bridge Toll Plaza, assesses the busiest commuter traffic in northern California at an average of 250,000 vehicles/day. Ambient air measurements of acrolein and other chemicals were collected at a toll plaza during rush hour traffic. These compounds either exist in motor vehicle emissions or can arise from the photo-oxidation of other hydrocarbons emitted from mobile sources such as 1,3-butadiene. Acrolein is a severe lung irritant that, at high acute exposures, can induce oxidative stress and delayed-onset lung injury including asthma, congestion, and decreased pulmonary function. Thirty-six carbonyls and hydroxycarbonyls were identified in the sample. The results of the acrolein analyses were lower than the U.S. EPA modeling study predictions using 1996 data, which was attributed to the reformulation of gasoline and the advancement of new catalysts and fleet turnover in the 1990s.

Tsai P., Lee C., Chen M., *et al.* 2002. Predicting the Contents of benzene, toluene, ethylbenzene and xylene (BTEX) and methyl tertiary butyl ether (MTBE) for the Three Types of Tollbooth at a Highway Toll Station Via the Direct and Indirect Approaches. Atmospheric Environment. (36):5961-5969.

These toll booth studies measured indoor concentrations of BTEX and MTBE at the breathing zone of the attendants during the winter. MTBE is a fuel additive for reducing emissions of CO and hydrocarbons from motor vehicles. None of the toll booths had control ventilation or heating system; the window was closed. Three types of toll booths (car ticketing, car cash and bus/truck lane) were assessed.

	Car Ticket	**Car Cash**	**Bus/Truck**	**TLV-TWA**
Benzene	6.23 ppb*	5.98 ppb	3.13 ppb	0.5 ppm**
Toluene	21.93 ppb	21.71 ppb	13.91 ppb	100 ppm
Ethylbenzene	3.24 ppb	3.25 ppb	2.05 ppb	50 ppm
Xylene	8.56 ppb	8.59 ppb	4.52 ppb	100 ppm
MTBE	5.63 ppb	6.04 ppb	2.70 ppb	None

* ppb=parts per billion

**ppm=parts per million

conversion factors: (Benzene 1 ppm = 3.26 mg/m^3) (Toluene1 ppm = 3.75 mg/m^3) (Ethylbenzene 1 ppm = 4.35 mg/m^3) (Xylene 1 ppm = 4.34 mg/m^3)
(MTBE 1 ppm = 3.61 mg/m^3)

Levels in both car lanes (tickets and cash) were similar and higher than in the bus/truck lane. Patterns were consistent for all work shifts. The authors noted that VOC content in different types of toll booths at a highway toll station had never been assessed before. They performed direct sampling to characterize their VOC content, but since field testing is costly and labor consuming their specific aim was to develop a model for predicting VOC contents.

The authors also performed an indirect approach method conducting multivariate regression analyses to predict VOC contents for any type of toll booth using four independent variables, including vehicle flow rate, wind speed, relative humidity and air temperature. Only vehicle flow rate had a significant effect on VOC levels, although its effects on different types of toll booths were not consistent. The authors concluded that a model to predict VOC contents for different types of toll booths could be theoretically plausible. They advised using caution with their results as fleet age for cars, buses and trucks (7.47, 7.74 and 9.58 years, respectively) may be different in other countries. Also, truck/bus traffic was much lower in volume than the two car toll plaza traffic (6636 cars ticket, 3743 cars cash and 2840 trucks/buses per shift) and the results should be used with caution.

Jo W. and Song K. 2001. Exposure to Volatile Organic Compounds for Individuals with Occupations Associated with Potential Exposure to Motor Vehicle Exhaust and/or Gasoline Vapor Emissions. The Science of the Total Environment. (269):25-37.

This study evaluated work-time exposures to six VOCs from motor vehicle exhausts and/or gasoline vapor emissions. These six were benzene, toluene, ethylbenzene, and xylene (ortho, meta, and para) (BTEX). The study was conducted in Taegu, the third largest city in Korea. Though they did not measure exposures of toll collectors, they did measure exposures to parking garage attendants and other occupations. In this study, the body burden was represented by breath concentrations. For nearly all target VOCs, the post-work breath concentrations of the workers were slightly or significantly higher than the pre-work breath concentrations. Both pre- and post-work breath concentrations of the workers showed elevated levels compared with a control group. The post-work breath concentrations were significantly correlated with the measured personal air concentrations. The breath and personal air concentrations for all the target compounds were both higher for underground parking garage attendants than for ground-level parking attendants, explained by the authors as due to ventilation differences between the two types of parking garages. Though mechanical ventilation systems were operating during work time in all the underground parking garages, the authors assumed that these systems were not sufficient to prevent a build-up of the target pollutants emitted from vehicles driving in and out. Further, since the ground- level parking garages were all located in open areas, the target pollutants emitted from vehicles driving in and out were more readily dispersed, resulting in decreased concentrations. The study also took smoking status into consideration in the analyses.