Path To Healthier Air:

Toronto Air Pollution Burden of Illness Update

April 2014

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Authors:

Stephanie Gower, Ronald Macfarlane, Marco Belmont, Kate Bassil, and Monica Campbell

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Phone: 416-338-7600
TTY: 416-392-0658
email: publichealth@toronto.ca

This document was updated May 2016 to correct errors in the numbers of hospitalizations shown in Figure 2 and in associated text referencing the percent of hospitalizations attributable to O_3, $PM_{2.5}$, and NO_2

Executive Summary

Toronto is on a path to healthier air. Policies and programs implemented at all levels of government over the past decade to reduce emissions have led to downward trends in pollutant emissions, ambient air pollution levels, and related health impacts. However, there is still much work to be done to reduce emissions that are harmful to health. A continued commitment to cleaner air that builds on the successes of the past decade is a way to move further along the path towards healthier air for all of Toronto's residents.

In 2004, Toronto Public Health reported that air pollution contributed to 1,700 premature deaths and 6,000 hospitalizations each year in Toronto. Ten years later, air pollution still has a serious impact on the health of Toronto's residents, despite improvements in air quality. Air pollution is currently estimated to give rise to 1,300 premature deaths and 3,550 hospitalizations each year in the City.

Over half of Toronto's air pollution is emitted within the City's boundaries, with the biggest local source being traffic including all types of on-road vehicles such as personal vehicles and freight trucks. On average, these sources account for about 280 deaths and 1,090 hospitalizations in the City each year or about 42% of premature deaths and 55% of hospitalizations due to air pollution emitted in Toronto. These values represent decreases as compared with 2007 estimates that air pollution from vehicles gave rise to about 440 deaths and 1,700 hospitalizations each year, but still represent an important health impact.

A renewed focus on reducing emissions from traffic is required to achieve continued improvements to air quality for the City. Such emissions reductions may be attained by achieving mode shift to healthier alternatives, ensuring that potential impacts of major transportation corridors are mitigated, and improving efficiency of goods movement in the City. Ongoing efforts to reduce industrial and small business emissions and reduce natural gas consumption through energy conservation efforts also remain key pillars of an approach to achieve cleaner air in Toronto. Supporting collection of data through air quality modelling and monitoring will further aid the City and local communities and organizations in identifying additional pollution prevention strategies.

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Air Quality and Health: Then & Now

In 2004, Toronto Public Health (TPH) reported on an extensive body of scientific evidence that air pollution adversely affects the health of children and adults. The report described the link between five key air pollutants and increased incidence and duration of respiratory symptoms, reduced lung function, acute and chronic bronchitis, asthma attacks, emergency room visits, increased hospitalizations for respiratory and cardiac causes, elevated mortality rates, and reduced life expectancy (TPH, 2004). The "common air contaminants" that were the focus of the report are sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), and ozone (O_3).

Based on 1999 data (the best available at the time), TPH reported that air quality in the City contributed to 1,700 premature deaths and 6,000 hospitalizations each year.

Since then, evidence has continued to accumulate showing that these common air contaminants are associated with adverse health impacts. A recent review of the health risks of air pollution by the World Health Organization (WHO, 2013) found:

- additional support for the effects of both short-and long-term exposure to $PM_{2.5}$ on both mortality and morbidity, especially for cardiovascular effects; evidence linking long-term exposure to $PM_{2.5}$ with atherosclerosis, adverse birth outcomes and childhood respiratory disease; and emerging evidence for links between long-term $PM_{2.5}$ exposure and neurodevelopment, cognitive function, and chronic disease conditions such as diabetes;
- new evidence for effects of long-term exposure to ozone on respiratory and cardiorespiratory mortality, asthma incidence, asthma severity, hospital care for asthma and lung function growth, and strengthened evidence for the short-term effects of ozone on a range of pulmonary and vascular health-relevant end-points. New data suggest ozone exposure may affect cognitive development and reproductive health, including preterm birth;
- new evidence of associations between short- and long-term exposure to NO_2 and both morbidity and mortality, mainly for respiratory outcomes;
- additional evidence that exposure to SO_2 may contribute to cardiovascular and respiratory mortality and morbidity as well as asthma symptoms in children, and new evidence suggesting that exposure to SO_2 contributes to adverse birth outcomes.

More generally, the WHO concluded that air pollution, and $PM_{2.5}$ specifically, should be classified as carcinogens. The finding applies to all parts of the world, even though the specific composition of air pollution can be different in different places. The WHO characterized air pollution as the “most widespread environmental carcinogen” (IARC, 2013).

A new report further underscores that exposure to air pollution has significant health implications: according to the WHO, air pollution is linked to 1 in 8 deaths worldwide (United Nations, 2014). They estimate that in 2012 alone 7 million people died globally as a result of air pollution, making it the world’s largest single environmental health risk.

Updated Burden of Illness Estimates

Approach

To update the estimates of premature deaths and hospitalizations attributable to air pollution in Toronto, TPH followed the same methodological approach that was used in 2004 (Pengelly and Sommerfreund 2004). Briefly, the approach relies on knowing

1. for each pollutant, concentration response functions that quantify the percent change in a particular health outcome per unit change in ambient concentration of that air pollutant;
2. the prevalence of each health outcome of interest in Toronto;
3. the ambient concentration of each pollutant;
4. the number of people at risk (eg., the population of Toronto).

The burden of illness is then calculated for each pollutant by multiplying the concentration response function (in the format of percent change in a particular outcome per unit of exposure) with the concentration of the associated pollutant in Toronto, and then by the prevalence of that outcome in Toronto with and the population at risk. The total burden is calculated as the sum of all individual pollutant-related burdens.

To complete an updated estimate of burden of illness from air pollution in Toronto, each data input must be updated. In order to reflect new findings from published research over the last decade, a literature review was conducted to update the concentration response functions used to calculate the burden of illness from mortality, cardiovascular hospitalization, and respiratory hospitalization. Mortality and hospital discharge data for the City of Toronto was extracted from the IntelliHEALTH database for the most recent year available (2009 data). The air quality data was updated by extracting "matching" 2009 data for air pollution levels in Toronto from the Ontario Ministry of the Environment's annual *Air Quality in Ontario* reports.

In addition, TPH was able to broadly characterize which sources have the greatest impact on premature deaths and hospitalizations attributable to air pollution. This was accomplished by building on a recent study that used sophisticated modelling to identify the proportion of ambient pollution levels arising from traffic, non-road mobile (such as rail and airport), industrial, and residential/commercial sources (Toronto Environment Office, 2011). That report also identified how much of Toronto's air pollution originates from outside the City, whether from other parts of Ontario, or from the U.S. By combining this information with recent ambient monitoring data and applying the burden of illness calculations, it is possible to estimate how much of the overall burden of illness arises from each source type.

Findings

Based on the most current information available, TPH estimates that air pollution in Toronto from all sources currently gives rise to 1,300 premature deaths and 3,550 hospitalizations annually (see Table 1). These estimates include the impact of pollution originating in other parts of Ontario and the United States and represent a decrease of 23% in premature deaths and 41% in hospitalizations as compared with 2004 estimates.

Air pollution in Toronto comes mainly from traffic, industrial sources, residential and commercial sources, and off-road mobile sources such as rail, air, and marine sources. Of these sources, traffic has the greatest impact on health, contributing to about 280 premature deaths and 1,090 hospitalizations each year, or about 20% of all premature deaths and 30% of all hospitalizations due to air pollution. When only pollutants emitted within Toronto's boundaries are considered, the

proportions of premature deaths and hospitalizations attributable to traffic are 42% and 55%, respectively. These values represent decreases as compared with 2007 estimates that air pollution from vehicles gave rise to about 440 deaths and 1,700 hospitalizations each year, but still represent an important health impact (see Table 1).

Table 1: Burden of illness attributable to air pollution from sources inside and outside Toronto

Air Pollution Source		Health Outcome	
		Premature Deaths	Hospitalizations
All Sources Combined[1]		***1,300***	***3,550***
Sources in Toronto	Traffic (Cars and trucks)	280	1090
	Mobile off-road (eg.,rail, air, marine sources)	80	280
	Industrial	120	200
	Residential/Commercial	190	400
Sources outside Toronto	Transboundary from United States	390	870
	Transboundary from Ontario	270	740

[1] Totals may not appear to sum correctly as a result of rounding

While these findings reflect improvements in Toronto's air quality over the past decade, they also show the serious health impact that air pollution continues to have in the City.

Toronto Public Health estimates that air pollution in Toronto currently contributes to 1,300 premature deaths and 3,550 hospitalizations annually. This represents a decrease of 23% in premature deaths and 41% in hospitalizations as compared with 2004

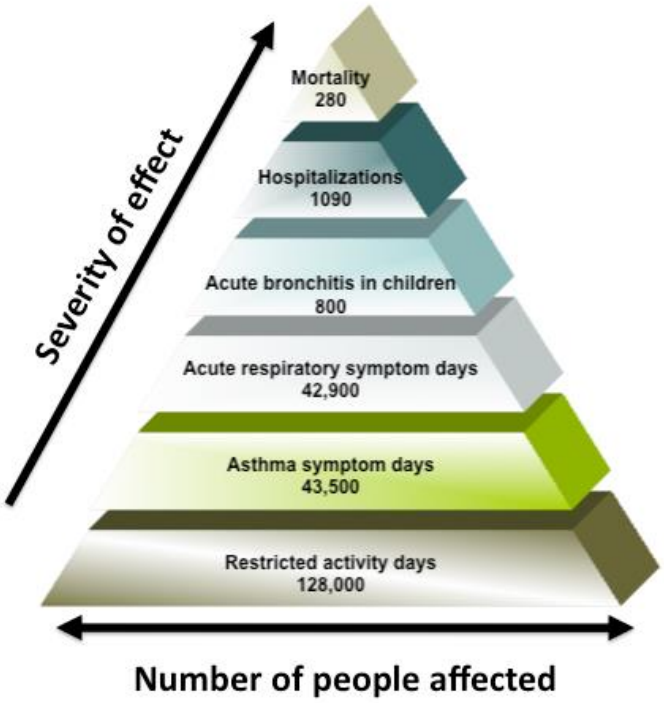
The updated burden of illness findings focus on premature deaths and hospitalizations. However, the impacts of air pollution on health are broader than this and include moderate and less severe effects such as chronic bronchitis and asthma symptom days, visits to physicians, and school and work absences. Researchers have long recognized that these less severe outcomes are more common, affecting a greater number of people. This effect is often conceptualized using a 'pyramid' of health effects, with the least common but most serious health outcomes appearing at the peak of the pyramid, and the less serious but more numerous health outcomes appearing in progressive levels below that peak (See Figure 1).

While this study did not directly calculate the number of health outcomes for these more common events, it is safe to assume that the numbers are high. To provide a sense of the magnitude of these other health impacts it may be useful to scale up from previous estimates in a 2007 report estimating the burden of illness from air pollution related to traffic in the City (TPH, 2007). A comparison of the estimates of 440 premature deaths and 1,700 hospitalizations attributable to air pollution from traffic to the current estimates of 280 premature deaths and 1,090 hospitalizations from traffic sources suggests that a scaling factor of 0.64 could be applied to the other health outcomes to derive an estimate of their magnitude. This approach assumes that the concentration

response functions for these other health outcomes are well-represented by research that was available in 2007 and that the growth in Toronto's child population is well-represented by growth in the population overall.

This estimation method is a reasonable way to characterize the overall magnitude of these impacts. The results are that air pollution in Toronto from traffic likely contributes to 800 episodes of acute bronchitis among children, 42,900 asthma symptom days (also mostly among children), 43,500 days where respiratory symptoms such as chest discomfort, wheeze, or sore throat would be reported, and 128,000 days when people would stay in bed or otherwise cut back on normal activities as a result of air pollution (See Figure 1).

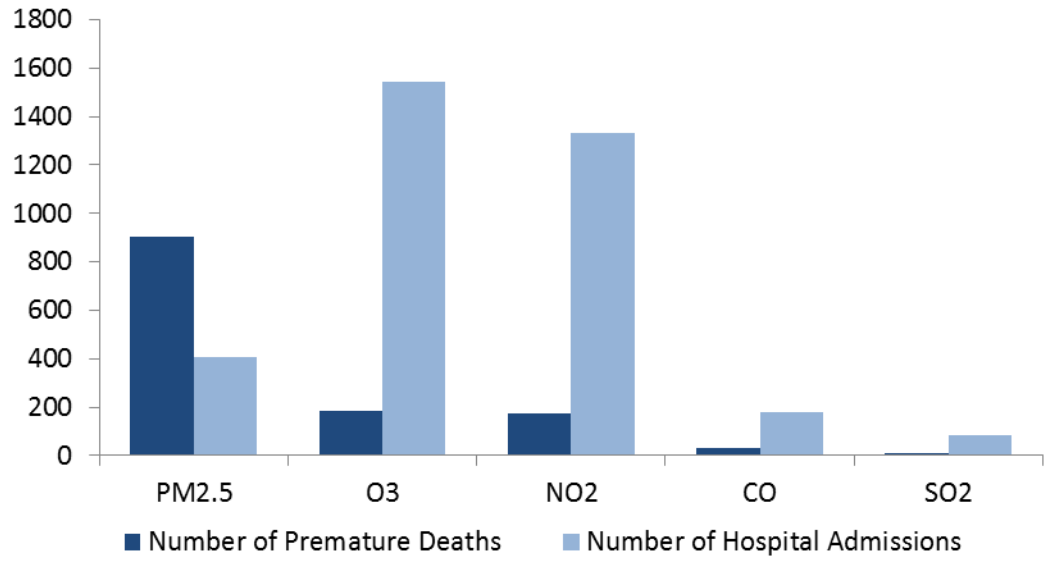
Figure 1: Pyramid of Health Effects from Traffic-Related Air Pollution



Pollutants Associated With the Greatest Health Impacts

Five air pollutants were considered in the calculation of the burden of illness from air pollution in Toronto. Figure 2 shows the estimated numbers of premature deaths and hospitalizations attributable to each of the five common air contaminants. When the proportion of the burden attributable to each individual pollutant is considered, $PM_{2.5}$, O_3, and NO_2, contribute the most to cardiovascular and respiratory ill health. They account for about 69%, 13%, and 14% of premature mortality and about 11%, 44%, and 38% of hospitalizations, respectively. Carbon Monoxide and SO2 contribute relatively little to the overall burden of illness, with CO accounting for 3% of deaths and 5% of hospitalizations, and SO2 accounting for 1% of deaths and 2% of hospitalizations.

Figure 2: Pollutant Contributions to Air Quality Burden of Illness, Toronto, 2009



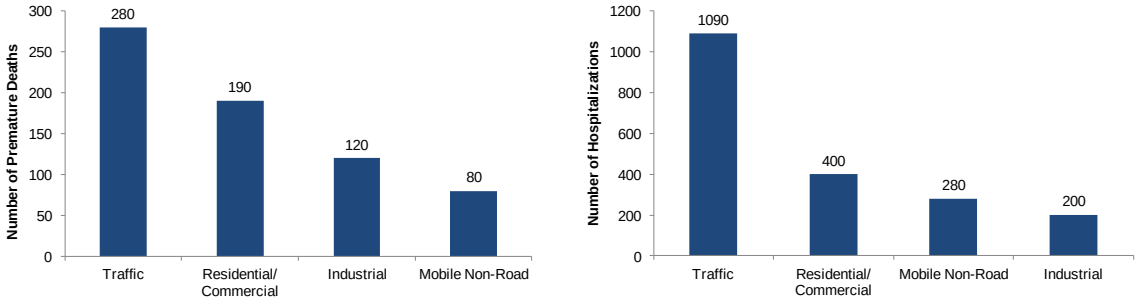
Prepared by: Toronto Public Health

Source Types Associated with the Greatest Health Impacts

Figure 3 shows the distribution of premature deaths and hospitalizations arising from air pollution emitted within the City's boundaries by source. The biggest local source is traffic, which accounts for about 280 premature deaths and 1090 hospitalizations each year in Toronto, which translates to 42% of deaths and 55% of hospitalizations arising from air pollution emitted within Toronto's boundaries. Traffic sources include all types of on-road vehicles such as personal vehicles and freight trucks.

Residential and commercial sectors are the next most important local contributors to health impacts from air pollution, accounting for about 190 premature deaths and 400 hospitalizations (or 28% of deaths and 20% of hospitalizations arising from pollution emitted in Toronto). The main source of emissions from residential and commercial properties is combustion of natural gas to heat homes and buildings, as well as heating water.

Figure 3: Estimated Number of Premature Deaths and Hospitalizations Attributable to Air Pollution Emitted in Toronto by Source, Toronto, 2009



Based on emissions reported to the National Pollutant Release Inventory (NPRI), industrial sources account for about 120 premature deaths and 200 hospitalizations (or 18% of deaths and 10% of hospitalizations arising from pollution emitted in Toronto). Finally, mobile non-road sources such as emissions arising from rail and air traffic contribute about 80 premature deaths and 280 hospitalizations (or 12% of deaths and 14% of hospitalizations due to pollution emitted in Toronto).

Next Steps to Achieve Healthier Air

The transportation sector remains a key contributor to emissions that cause harmful health impacts. Reducing emissions from this sector means tackling issues such as vehicle dependence, the impacts of highways and truck traffic, and vehicle performance. Working towards healthier air also means continued efforts to reduce air pollution arising from the residential, commercial, and industrial sectors.

Traffic

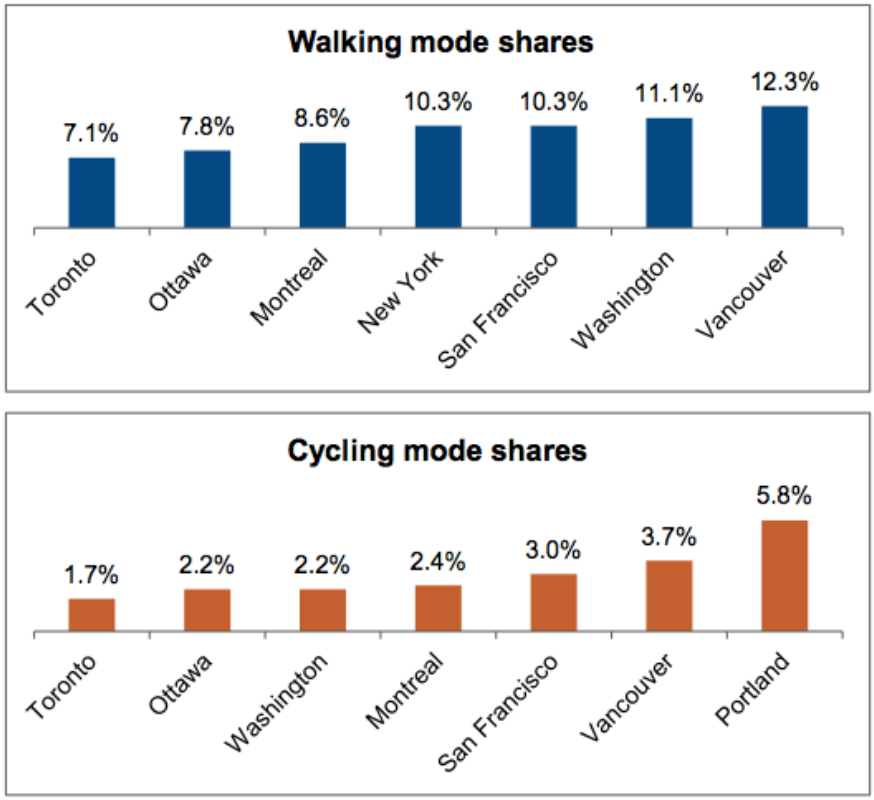
Traffic is the biggest local contributor to the overall burden of illness from air pollution in Toronto. Of the health impacts that are related to pollution originating within Toronto's borders, cars and trucks account for 42% of premature deaths and 55% of hospitalizations. Evidence shows that traffic-related air pollution is linked to a broad range of respiratory and cardiovascular outcomes, cancer, and hormonal and reproductive effects. While most of these hospitalizations involve the elderly, traffic-related pollution also has significant adverse effects on children, particularly with respect to acute bronchitis and asthma (TPH, 2007; TPH, 2010).

Reducing Vehicle Dependence

One way of reducing emissions from traffic is to create more opportunities for people to use alternate modes of transportation, including walking, cycling, and taking transit. When people walk or cycle instead of drive, they reduce the number of cars on the road, directly reducing emissions. They may also indirectly reduce emissions by relieving congestion: when traffic flow is improved, vehicles also spend less time on the road adding to air pollution. People who choose to walk or cycle also gain significant health benefits from the added physical activity, including significantly reducing their risk of all-cause mortality, cardiovascular disease, obesity, type II diabetes, and certain types of cancer.

Achieving a mode shift from vehicles to more active forms of transportation such as walking and cycling is very feasible. About 55% of all trips in Toronto are less than 7 km, and are therefore very conducive to cycling. Over 20% of all trips are under 2 km and therefore very walkable. Despite this, the proportion of people using walking and cycling as transportation in Toronto lags behind other major cities (See Figure 4) (TPH, 2012a).

Figure 4: Active commuting mode shares of North American cities



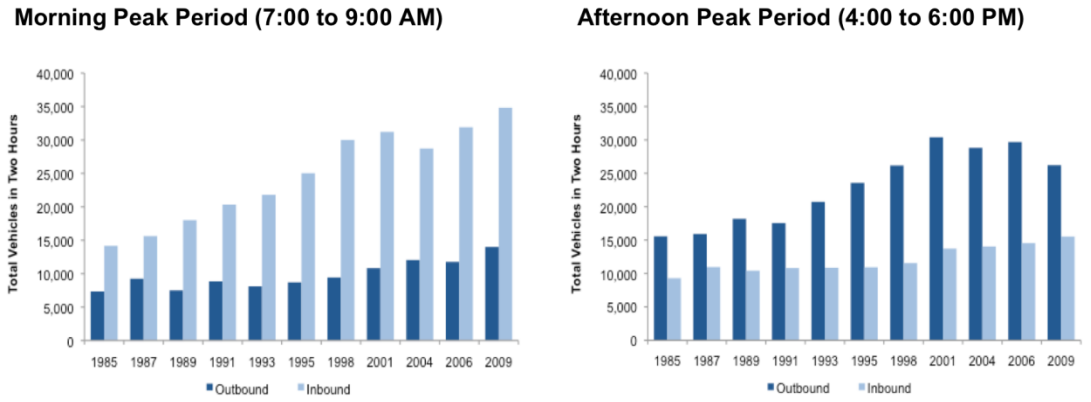
Source: Toronto Public Health, 2012a

Targeted efforts must be made to increase safety for pedestrians and cyclists and make walking and cycling more attractive and accessible to Toronto residents. It is critical to invest in safe, connected infrastructure that supports walking and cycling in the city. This means adding or improving facilities such as sidewalks, bike lanes, and pedestrian and bike paths that enable pedestrians and cyclists to be adequately separated from traffic. It can also include strategies to achieve speed reduction, traffic signal retiming to improve flow of all modes, and designing intersections with pedestrians and cyclists in mind (TPH, 2012a). In addition, cyclists and pedestrians should be considered at all phases of planning and construction involving new or existing road or transit-ways. City Planning and Transportation Services are jointly developing "Complete Streets Guidelines" for the City of Toronto, which will help ensure that all users are considered when roads are newly built or reconstructed.

There is local evidence that implementing such infrastructure can have multiple benefits. Toronto residents who live in more walkable neighbourhoods demonstrate healthier lifestyles than those who live in less walkable neighbourhoods in many respects - they walk more often, use transit more often, drive less often, and drive fewer kilometres each week. They also have lower body weights (TPH, 2012b). In addition, there evidence that Toronto residents would like to see more of this type of infrastructure: three quarters of Toronto residents surveyed expressed a strong preference for a walkable neighbourhood, while only 6% expressed a strong preference for an auto-oriented neighbourhood (TPH, 2012b). A recent poll found that 81% of Torontonians believe that more people would ride bikes if there was more and better cycling infrastructure such as protected bike lanes and paved shoulders (STRCC, 2013).

Efforts must also be made to improve transit, so that those making longer trips have a viable alternative to driving. As shown in Figure 5, the numbers of vehicles entering the City each morning and leaving the city each evening continues to increase steadily. This suggests that many commuters from the outer parts of the Greater Toronto Area drive into the city each morning to get to work, and then leave in the evening. There are many fewer people driving in the opposite directions, meaning that there are more vehicles coming into the city than leaving and that the numbers coming in are increasing each year. The figure represents total vehicles travelling in the east-west direction on all major roads crossing the boundary between the City of Toronto and the Regional Municipality of Durham. Similar trends are observed in the West end of the City, along the border with Peel Region (DMG, 2011).

Figure 5: Total Vehicles Crossing the Toronto-Durham Border in the Morning and Afternoon, 1985-2009



Source: 2011 Greater Toronto Area Cordon Count Summary

Prepared by: Toronto Public Health

Efficient transit is one way to provide an alternative to driving for people who commute over longer distances. Metrolinx, an agency of the provincial government, has a mandate is to implement "The Big Move", a regional transportation plan that has been approved by the provincial government and regional governments across the Greater Toronto and Hamilton area. The plan calls for $50 billion in investment over 25 years. Sixteen billion of The Big Move initiatives are currently funded through senior government commitments, while the remaining $34 billion in transportation improvements remains unfunded.

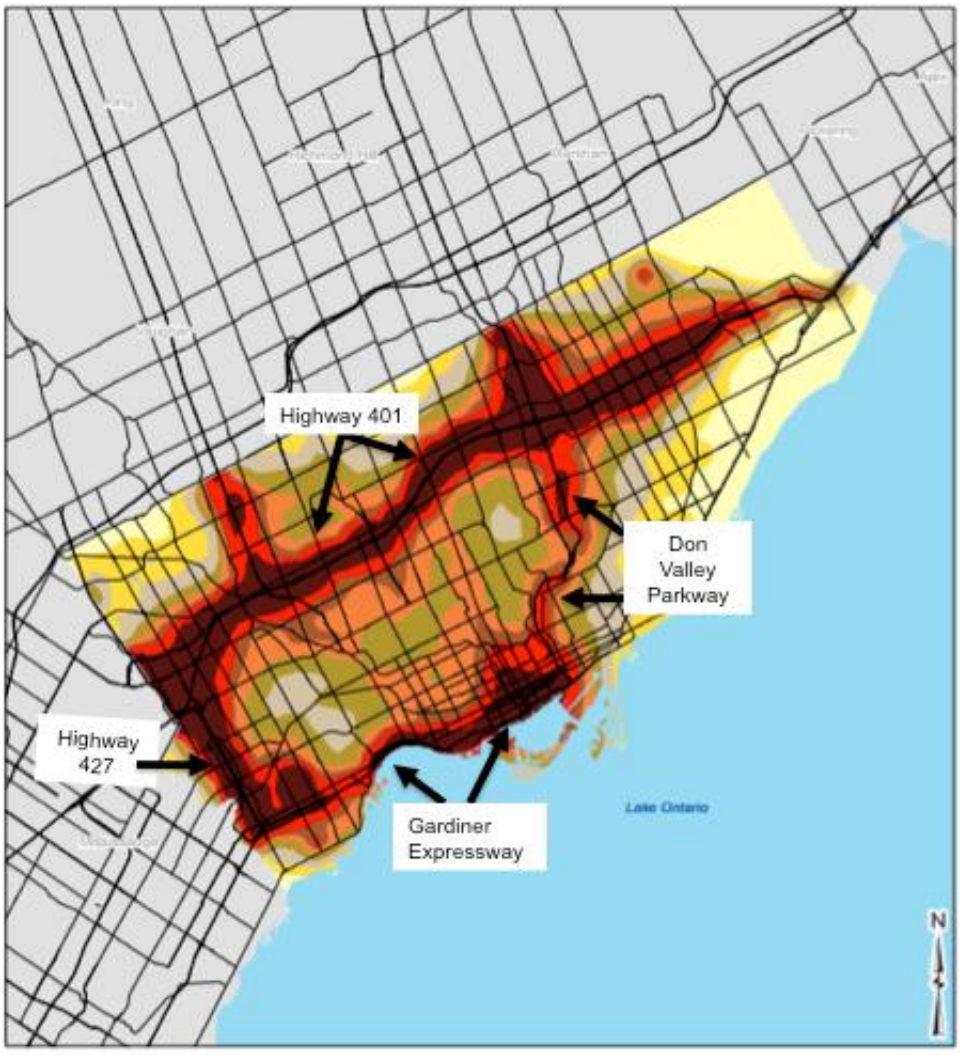
With sufficient funding, the range of projects included in The Big Move may offer opportunities to re-engineer the way people travel around the region, encouraging not only transit use, but also active transportation. Currently, 25% of the funding is set aside for local transportation initiatives. To ensure that active transportation is adequately funded, a significant portion of this funding should be dedicated to local walking and cycling projects. This will support more connected, efficient, safe, healthier travel that does not require use of a car.

In addition, active transportation considerations should be integrated into all aspects of planning, funding, and design for each of the Big Move projects, to ensure that they become models of multi-modal, healthy transportation networks that truly reduce congestion, emissions, and travel times as well as health and economic costs.

Highways

Some of the highest levels of air pollution in the City of Toronto occur along the major highways where many vehicles travel together along a concentrated route, all releasing emissions. One of the main emissions from cars and trucks is $NO_{x,}$ which transforms in the air to NO_2, one of the common pollutants consistently linked to health impacts. Figure 6 shows the relatively high concentrations of NO_x that occur along the City's major highways including Highway 427, Highway 401, Highway 400, the Don Valley Parkway, and the Gardiner Expressway. In this figure, the darker colours represent higher concentrations of NOx. While the figure is based on older (2006) data, the overall patterns in emissions are expected to be the same today. Recent studies conducted in two Toronto neighbourhoods examined both ambient air pollution and related health risks arising from local levels of air pollution - and found both to be highest near major highways.

Figure 6: NO_x levels across the City of Toronto, 2006



Source: Adapted from Golder Associates, 2011

These findings are is consistent with a 2010 synthesis of the best available evidence on traffic and health impacts, which concluded that traffic-related impacts of air pollution are of health concern and warrant further attention. The report identified an exposure zone within a range of up to 300 to 500 m from a highway or a major road as the area most highly affected by traffic emissions, and estimated that 30% to 45% of people living in large North American cities live within such zones (HEI, 2010).

The rapid increase in the number of cars on the roads and increasing dependence on motor vehicles have resulted in an increase in the proportion of people living and working close to busy roads and highways around the world, and there are concerns that these trends are counteracting the benefits of regulations and technologies intended to reduce pollution (HEI, 2010).

In some jurisdictions, efforts have been made to establish separation distances between sensitive land uses (e.g., residences, schools, hospitals) and busy highways. For example, a guidance document created by the California Air Resources Board suggests a separation distance of 150 metres from urban roads carrying more than 100,000 vehicles per day, and British Columbia recommends a minimum setback of 150 metres from roads carrying more than 15,000 vehicles per day (Halton region, 2009). In Halton, draft land use compatibility guidelines require that an assessment be completed if a sensitive use falls within 150 metres of a major highway or within 30 metres of a major arterial. Development proponents must demonstrate mitigation measures in their application that adequately address land use compatibility issues (Halton, 2012).

In Toronto, high-density residential developments are increasingly being built close to high-volume highways, with some new builds along the Gardiner within metres of the highway. Efforts to increase density and accommodate new residents coming to Toronto may mean that even more buildings will be planned for areas near busy highways. Many of these buildings are residential, meaning that people may spend a great deal of time there, and thus be exposed to pollution from the highways every day over many years.

There is some evidence that strategies exist to mitigate impacts of air pollution from busy highways. These may include building design and placement that ensures adequate airflow around tall buildings (eg., Ng, 2009), locating the most sensitive uses in mixed-use developments away from the roadside, ensuring that the closest buildings to the highways "face" away from highways, and designing buildings such that the “exposed” side might include places such as hallways and washrooms rather than more sensitive indoor spaces such as bedrooms and living rooms (Halton, 2012). Additional strategies could include ensuring that air intakes are away from pollution sources and that ventilation systems adequately filter pollutants before distributing air inside buildings.

As new developments are planned for Toronto, it may be useful to explore opportunities to identify design alternatives that could minimize the impacts of air pollution from highways on the people who use nearby buildings.

Performance Standards for Vehicles

Emissions standards for vehicles have been strengthened over the past decades. Most recently, new greenhouse gas emissions standards were announced for heavy-duty vehicles (Environment Canada, 2013). However, these regulations do not target the common air contaminants that are the focus of this report. In June 2013, Canada announced its intention to align its transportation-related air pollution emission standards with the more stringent United States proposed Tier 3 standards. However, this has yet to be implemented. Since then, the United States Environmental

Protection Agency announced that it would strengthen its Tier 3 standards for sulphur in fuels and vehicle emissions by harmonizing them with the more stringent standards adopted by the California Air Resources Board (Environmental New Service, 2014). Canada's position on adopting these new strengthened standards is not clear.

TPH has previously suggested that Canada strengthen its vehicle emissions regulations. A recent report to Toronto's Parks and Environment Committee (City of Toronto, 2014) again suggested that Toronto should advocate for adoption of significant and timely improvements in vehicle fuels and engines. Additional gains may also be achieved with a focus on clean vehicle technologies such as hybrids and electric vehicles. Such advocacy may be more effective if undertaken in partnership with other major urban centres and stakeholders across North America.

Relying on emissions standards alone may not yield the emissions reductions needed. Improved vehicle performance must be complemented by reduced fuel use so that gains in efficiency are not eroded by a large number of vehicles travelling longer distances or spending more time stuck in traffic. In particular, additional measures are required for heavy vehicles, which tend to have long lifetimes, meaning that vehicles with older, polluting technologies remain on the road for long periods of time, even as standards are phased in for newer vehicles (Environment Canada, 2013).

Truck Traffic

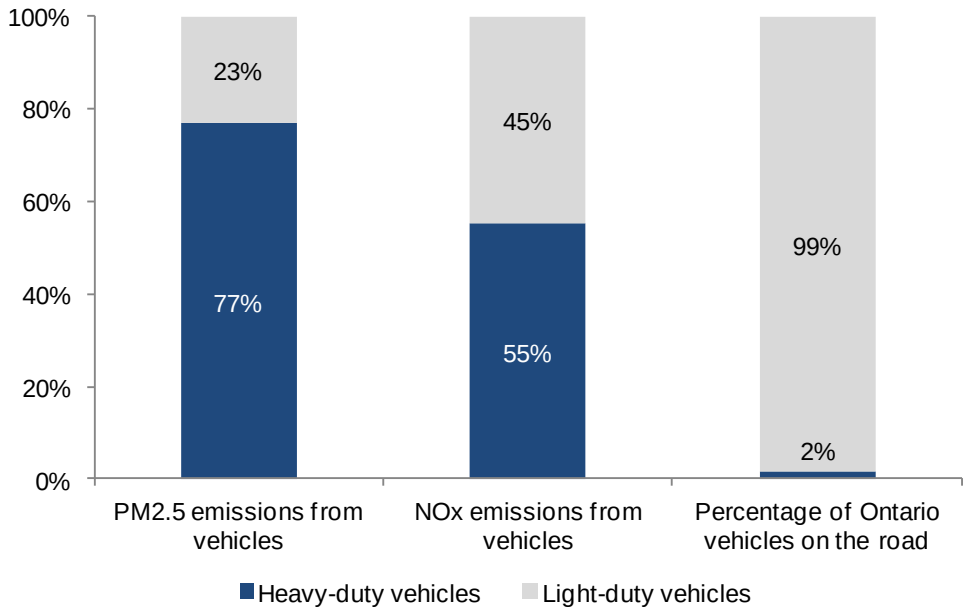
A large proportion of the traffic on highways is truck traffic, and heavy trucks have a disproportionate impact on air quality. In 2009, heavy vehicles made up just 1.5% of Canada's vehicle fleet (Natural Resources Canada, 2009), but according to data from Environment Canada, heavy-duty vehicles including trucks were responsible for almost 80% of $PM_{2.5}$ emissions and over half of NO_x emissions from vehicles in Ontario (Environment Canada, 2014) (See Figure 7).

In 2009, heavy-duty vehicles made up just 1.5% of Canada's vehicle fleet, but were responsible for almost 80% of $PM_{2.5}$ emissions and over half of NO_x emissions from vehicles in Ontario

Most heavy trucks are diesel vehicles. Diesel emissions in particular are a concern, as diesel engines tend to emit more PM and NO_x than gasoline engines. As well, based on mounting evidence for a link between diesel emissions and cancer, the International Agency for Research on Cancer (IARC) reclassified diesel exhaust from "probable carcinogen" to "carcinogenic to humans" (IARC, 2012).

The Pembina Institute recently released a set of recommendations aimed at moving goods more efficiently and with less pollution in the City of Toronto (Grond & Angen, 2014). The report outlines that trucks are an important contributor to the region's economy, accounting for 90% of urban freight operations in the GTHA. However, efficiency in goods movement is diminished by traffic congestion in the City and a lack of co-ordination across local clients receiving goods that results in multiple, overlapping deliveries within the same neighbourhood or building. As well, efficiency is limited by a lack of collaboration among truck operators: Pembina reports that empty trucks represented a full 37% of trips surveyed.

Figure 7: Emissions of $PM_{2.5}$ and NO_x from On-Road Vehicles, Ontario, 2009



Source: Data for vehicle emissions extracted from Environment Canada NPRI database for Ontario; fleet mix data from (Natural Resources Canada, 2009)

Prepared by: Toronto Public Health

Pembina recommends several strategies to improve the efficiency of goods movement in Toronto and reduce emissions of both air pollutants and greenhouse gases. For example, an urban freight strategy may improve the efficiency of deliveries in the city. Such a strategy could consider ideas such as off-peak deliveries, better on-street parking for truck loading, and use of advanced technologies that combine on-road data with mapping systems to improve delivery efficiency. Pembina also describes how neighbourhood freight forums may bring together fragmented and independent businesses and clients to review and potentially co-ordinate their transportation practices. This may be especially useful for planning consolidated and off-peak deliveries in areas where congestion, road space management, and air quality issues are of concern. Finally, Pembina outlines additional research needed to help build the case for clean vehicle incentive programs and emissions fees policies.

These ideas warrant further exploration. If supported by appropriate partnership between the City of Toronto and other agencies, they have the potential to lead to cleaner air, fewer greenhouse gas emissions, and less congestion in the City.

Residential and Commercial Sources

The emissions attributed to residential and commercial sectors arise almost entirely from combustion of natural gas. Natural gas is a cleaner energy source than coal or oil, emitting fewer air pollutants (mainly NO_x) and greenhouse gases overall. However, as emissions related to natural gas combustion are related to about 28% of premature deaths and 20% of hospitalizations arising from air pollution emitted with Toronto's borders, it is clear that burning natural gas still contributes harmful emissions to Toronto’s air pollution.

Energy conservation is a primary method for reducing natural gas use. There is evidence that efforts to reduce natural gas use are having a positive impact: the Environmental Commissioner of Ontario (ECO) concluded that Enbridge Gas and Union Gas achieved commendable natural gas savings in 2012 (ECO, 2013) and the City of Toronto reported a 3.5% decrease in natural gas consumption in 2011 compared with 1990 levels. However, these reductions may not be translating directly into air quality improvements in more recent years: the City also reported that NO_x emissions attributable to natural gas have remained relatively stable between 2004 and 2011 (City of Toronto, 2013). The report suggests that this may be a result of increased reliance on natural gas as an energy source since the closure of Ontario's coal-fired power plants.

Energy conservation efforts have been ongoing in the City over the past decade through a host of programs and activities that target various building types and energy users. The Toronto Green Standard applies higher energy efficiency requirements for new construction beyond the Ontario Building Code. Other City programs that target building energy conservation and provide financial assistance include: Tower Renewal efforts, Home Energy Assistance Toronto, the Better Building Partnership, Eco-Roof promotion, Enwave Energy Corporation's Deep Lake Water Cooling, Toronto Solar Neighbourhoods, Live Green Toronto, and a number of Toronto Hydro energy efficiency programs and projects supported by the Toronto Atmospheric Fund. Continued implementation of energy efficiency programs should yield additional benefits into the future.

In addition, programs such as Leadership in Energy and Environmental Design (LEED) and ecoENERGY may be encouraging adoption of measures that decrease energy requirements in building and homes across Toronto. LEED is a green building rating system, administered by the Canada Green Building Council. In particular, the LEED program for existing buildings (called LEED EB:OM) enables buildings to identify ways to reduce energy use – and at the same time encourages adoption of sustainable modes of travel. In the past, Natural Resources Canada's ecoENERGY programs included guidance and funding to help homeowners reduce their energy consumption.

The ECO suggested that there may be some saturation of residential energy conservation initiatives. However, the report indicated that there is still potential to improve energy efficiency in larger commercial buildings where costs may be a keen motivator to reduce consumption. As well, the ECO suggested that there is room to improve the technical standards for Ontario building code by restricting the use of trade-offs that reduce the level of energy performance of the building envelope (ECO, 2013).

Industrial Sources

While emissions of SO_2 and NO_2 reported to the National Pollutant Release Inventory (NPRI) have decreased by decreased 30% and 17% respectively across Canada between 2008 and 2012, air pollution from large industries still contributes to 18% of premature deaths and 10% of hospitalizations from air pollution emitted within Toronto. NPRI attributes the reductions in reported emissions to decreases from base metal smelters and other manufacturing facilities, and coal-fired electricity generating stations. The reasons include process efficiencies, facility closures and production decreases in some cases (Environment Canada, 2014).

The NPRI collects information from large emitters across Canada, such as factories, electricity generation facilities and wastewater treatment plants. Small and medium-sized facilities such as dry cleaners, auto repair shops, and printing companies, which represent the majority of facilities in Toronto, are not required to report to the NPRI. From this perspective, the proportion of the burden of illness attributed to industrial processes may currently be underestimated.

To supplement this information TPH led the development of an Environmental Reporting and Disclosure Bylaw that requires local businesses to track and report on the manufacture, process, use and release of 25 priority substances. The associated program, ChemTRAC, is now fully phased in and provides information that will support emissions reduction from smaller businesses across the City.

ChemTRAC is helping to identify the substances of concern as well as the locations of sources, which can in turn inform and support pollution prevention programs for specific substances, geographic areas, source types or industrial processes. The program also provides new data on industrial and commercial sources of pollutants and will be used to support future local air quality modelling studies. As well, tracking and reporting to the ChemTRAC program helps businesses identify the major sources of chemicals in their facility. With the major sources identified, businesses can develop plans to reduce the use and release of these substances in their facilities. TPH is assisting businesses on this by providing them with supports to green their operations through pollution prevention and innovation.

Air Toxics

While the common air contaminants are the focus of this report, there is another class of air pollutants that may affect the health of Toronto residents: air toxics. These are substances for which exposure over a long time is associated with the development of cancer, reproductive effects or birth defects. Examples of air toxics include benzene, tetrachloroethylene, and lead. While the overall burden of illness from air toxics is unknown, reviews of local data suggest that some air toxics are likely to be present in Toronto's air at levels that pose a risk to health.

Many actions that may be taken to reduce emissions of the common air pollutants may have co-benefits for reducing air toxics. ChemTRAC is a prime example of a program that addresses both the common air contaminants and air toxics, as it requires reporting on twenty-five substances that span pollutants with a range of potential health impacts. For example, emissions from vehicles are a complex mix of all kinds of air pollutants, so actions to reduce vehicle use will reduce emissions of many different substances. Similarly, emissions from industrial sources are often a mix of substances. Moving to greener alternatives may result in reductions of both common air contaminants and air toxics. Similar to the common air pollutants, emissions of air toxics from large industrial emitters appear to be decreasing over time: total reported releases of toxics included in the NPRI decreased 23% between 2008-2012 (Environment Canada, 2014).

Communicating About Health Risks from Air Pollution

The Air Quality Health Index (AQHI) was developed by Health Canada and Environment Canada in collaboration with provincial, municipal and NGO representatives. The purpose of the AQHI is to help people protect themselves from air pollution by telling them when the best times are to be active outdoors or when they should reduce or reschedule activities. The AQHI measures air quality in relation to health on a scale from 1 to 10. The higher the number, the greater the health risk associated with the air quality. Five categories are used to describe the level of health risk associated with the index reading (e.g. Low (1-3), Moderate (4-6), High (7-10) and Very High (10+)). The AQHI provides a special set of messages for people most sensitive to air pollution (i.e. people with heart and lung conditions, children, the elderly, etc.). The AQHI provides readings every hour and provides maximum forecast values for the day, night and following day.

A 2013 analysis by Public Health Ontario (PHO) found that while there were a number of high risk days during the first few years that the AQHI was implemented, these occur less frequently in recent years. This is likely a reflection of overall improvements in air quality during this time.

Although air quality has improved since the AQHI was piloted in 2007, there are still days and times when pollution presents a health risk. PHO's analysis found that each unit increase in AQHI is equivalent to a roughly 1% increase in daily mortality across Ontario, meaning that even at lower AQHI values any increase in exposure to air pollution increases the risk of premature death. This is particularly true in people with underlying respiratory or cardiac problems. As well, PHO concluded that the AQHI is most often in the moderate risk category. In this category, excess daily mortality risk ranged from 2.6% to 6.8%, meaning that exposure to air pollution increases the chance of dying by 2.6 to 6.8 % compared with normal rates of death. It is important that the AQHI continue to be promoted alongside messaging that reminds people of the potential health impacts of poor air quality. This enables all residents, and especially those at risk, to pay attention to their own symptoms and reduce exposure during times when health risks may be elevated.

What is Monitoring?

Specialized equipment is used to measure actual concentrations of pollutants. Depending on the equipment, measurement may be continuous, or may occur at specified time intervals. In Toronto, measurements for some pollutants are taken all the time. For others, the levels are only measured once every six days. Most monitors measure air quality at one location only. In “mobile monitors”, equipment is mounted in a vehicle that can drive to different locations. However, mobile equipment is not often available for use in Toronto.

What is Modelling?

In Air Quality Modelling, information about known sources, typical emissions rates, the weather, and geography is used to predict the concentrations of pollutants for a place of interest. Air quality models are estimates based on complex mathematics done by computers. In Toronto, air quality modelling supports a series of local air quality studies.

Addressing Local Air Quality Health Concerns

It is important to recognize that the burden of illness numbers represent averages for the City as a whole. While some sources of pollution such as transboundary contributions add a relatively constant background level of air pollution (and therefore risk) across the City, local sources are likely to create areas of elevated health risk nearby.

Because there is considerable local variation in air pollution concentrations across the city, tracking the emissions and concentrations of air pollution is important in helping to understand the health implications of local decisions and activities, and in setting priorities for pollution prevention. Ideally, this could be done through a combination of air quality modelling and monitoring.

Air quality modelling results can create a continuous “picture” showing expected air quality everywhere in a community. Models can be used to see what might happen to air quality if a new source is added to the community, or if an existing source is eliminated. Models can provide estimates about where the pollution is coming from: for example, how much is from cars, and how much is from industry. Modelling is much cheaper than monitoring. However, modelling requires a lot of detailed data about air pollution sources and weather patterns, and modelling predictions are only

as good as the data that is used as input. If there are problems with the data, or data is not available this can affect the model's accuracy.

The local air quality studies carried out by the Environment and Energy Division in collaboration with TPH are modelling studies that tackle the spatial distribution of health risk. These studies support identification of localized issues. As more of them roll out across the City, they will also help shape Toronto's future air quality agenda, as patterns in emissions or risk emerge. For example, the two studies already completed suggest a consistent impact from the high-volume highways. To help local residents, community groups, business, and industry in these areas tackle specific air quality concerns identified through these studies, the Environment and Energy Division is arranging for community facilitators to identify and undertake actions to improve air quality and create a more sustainable community.

Air quality monitoring is useful because it provides information about actual concentrations in a specific location, and also allows investigation of trends in air quality over time. As well, it is used as input for the Air Quality Health Index (AQHI). On the other hand, monitoring equipment is expensive to purchase, and must be maintained regularly. As well, most air quality monitors are stationary – they measure air quality at only one location. In Toronto, there are four monitoring stations that measure the most common air pollutants. They cannot provide information about air pollution concentrations at other locations, or about where the air pollution is coming from.

Modelling and monitoring together are a powerful combination: Air quality monitors in the area being modelled can be used to check air quality model results. If the models are good at predicting what happened in the past and what is happening now at the monitor's location, they should be good at predicting what is happening at other places in the neighbourhood. Air quality models are becoming very reliable and sophisticated, and they enable analyses that monitors cannot. For example they can help to identify which sources are responsible for most of the pollution in a community. They also allow prediction of what would happen to local air quality if air pollution emissions changed for some reason.

Recent advances in air monitoring research suggest that an inexpensive air-quality monitor may be available within a few years (Lorinc, 2013). The technology, which is under development at the University of Toronto could be deployed on utility poles and would measure pollutants such as fine particulate, NOx, VOCs and CO. Once this technology becomes available, it may offer community organizations more opportunities to conduct their own monitoring to gather evidence in support of local health and environmental concerns. At the same time, it would be useful for TPH to have access to such equipment, to help in investigating local concerns and complaints, track changes in air quality associated with various projects and pollution prevention efforts, and to validate modelled estimates such as those being produced by the local air quality studies, as well as any measurements that may be collected by the community.

In the meantime, there is great interest in accessing monitoring equipment among jurisdictions in and around the GTA (pers. comm. Gaby Kalapos, 2014), including TPH. Because monitoring can be expensive, and because the cheaper monitoring units under development may also be limited in terms of the types of air toxics they can measure, it would be useful to explore the idea of sharing costs and use of a more sophisticated mobile monitor among area health units, municipalities, Public Health Ontario, and the OMOE.

On the Path to Healthier Air

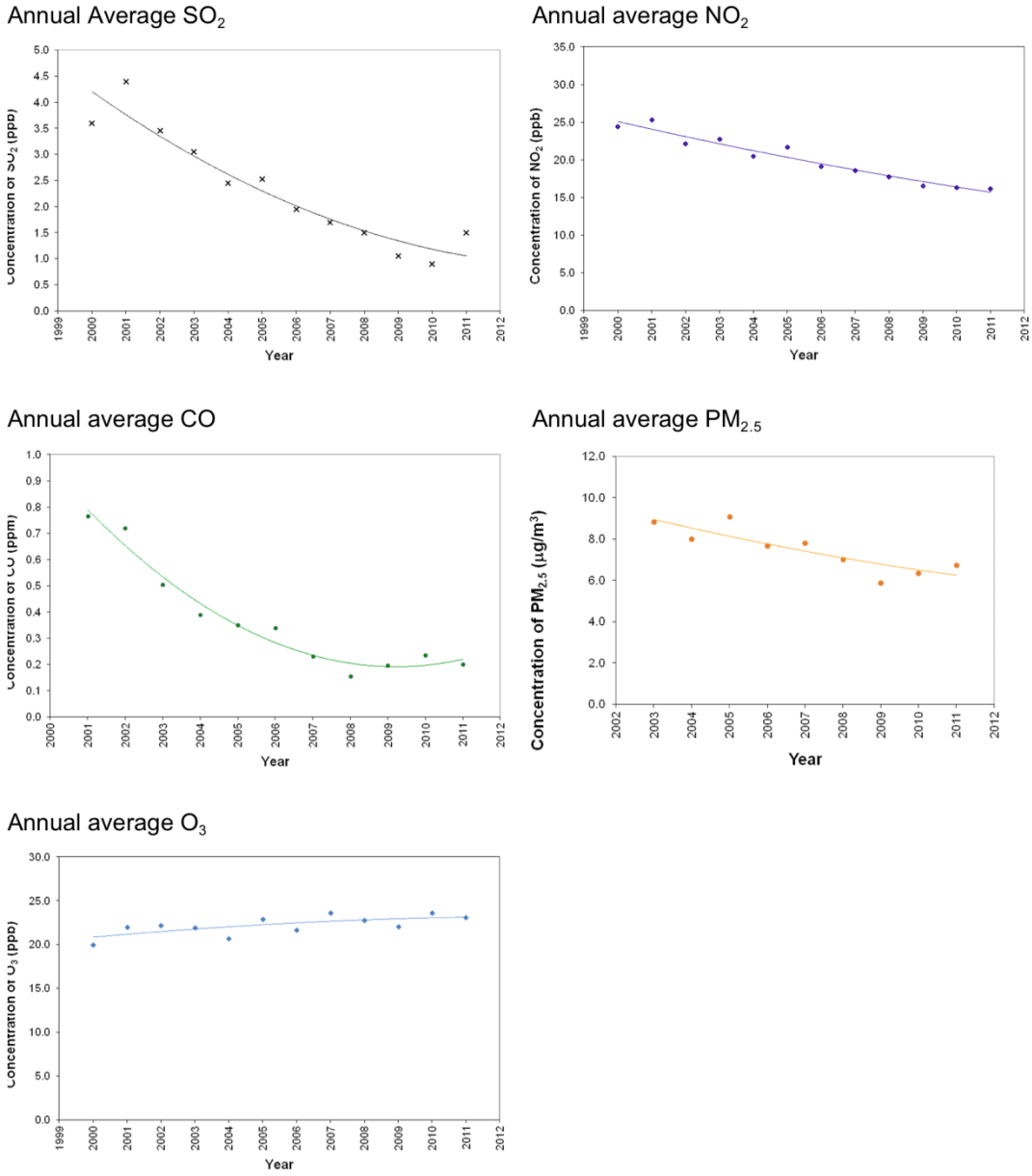
The updated estimates of 1,300 premature deaths and 3,550 hospitalizations attributable to air pollution in Toronto each year represent decreases of 23% and 41% compared to 2004 estimates. These decreases in adverse health outcomes arising from air pollution are directly related to improvements in air quality that have been achieved for key pollutants in Toronto since 2000. Average levels of four out of five pollutants have decreased substantially in Toronto in the decade that followed. Between 2000-2011, ambient levels of SO_2 decreased by 79% and levels of NO_2 decreased by 36%. Between 2001-2011[2], levels of CO decreased by 78%, and between 2003 (the first year $PM_{2.5}$ was monitored) - 2011, ambient levels of $PM_{2.5}$ dropped by 30%.

In contrast, levels of O_3 increased by 10% between 2000 and 2011. There are several reasons that levels of O_3 might be on the rise. Ozone is a secondary pollutant, meaning that unlike the other four pollutants, it is not emitted directly from a specific source. Instead, it is formed as a result of photochemical reactions that occur in the air between pollutants such as NOx and VOCs in the presence of sunlight. Because of the complex chemistry between NO_x and O3, actions to reduce NO_x may result in localized increases in O_3 levels, since there is less NO_2 available to react with and destroy the ozone. On a more regional scale, the warmer, sunnier conditions expected with climate change also promote the formation of ozone. Indeed, temperature data from Pearson International airport shows an upward trend from 2001 to 2012. Finally, there is also new evidence that ozone may be transported over long distances from China to North America in amounts sufficient to adversely affect air quality. Lin et al. found that the contribution from Chinese pollution was sufficient to result in one extra day or more of noncompliance with the US ozone standard in 2006 for some regions in the United States (2014).

Figure 8 shows recent trends in ambient levels of the five common air contaminants. This figure suggests that while significant gains have been achieved in air quality, especially for NO_x and CO, progress may now be slowing. For several of the pollutants including SO_2, $PM_{2.5}$, and CO, levels measured in 2010 and 2011 are suggestive of a possible flattening or upward trend. Continued tracking of this data into the future will be required to assess whether this is a new trend, or just a result of year-to year variability.

[2] 2000 was excluded from this estimate because levels of CO were unusually high that year

Figure 8: Trends in ambient air pollution levels for five common air pollutants in Toronto 2000-2011.



Source: Based on annual Air Quality in Ontario reports from the Ontario Ministry of the Environment.
Prepared by: Toronto Public Health

Achievements in Improving Air Quality

Key sources of common air contaminants in Toronto over the past decade include transportation sources, industrial sources, and energy use. The improvements in air quality are likely a result of a combination of policy and program successes achieved across these source types over the past decade. Some of these successes are illustrated in Table 2.

Table 2: A selection of air quality initiatives with positive impacts in Toronto

Date	Initiative
1999	City Council adopts the Environmentally Responsible Procurement Policy
1999	City of Toronto adopts low-sulphur fuel purchasing practises
1999	The Government of Ontario introduces the Drive Clean Program, a program that reduces nitrogen oxides and volatile organic compounds through emissions testing of vehicles and enforcement
2000	Federal Government signs the Canada-Wide Standards for $PM_{2.5}$ and Ozone. In 2013 standards become more stringent
2001	Toronto City Council adopts the Bike Plan
2001	City of Toronto is a key partner in launching the Black Creek Regional Transportation Management Association. It was the first of its kind in Ontario and the precursor to Smart Commute, which now exists as a network of 13 Smart Commute programs across the GTHA
2002	Federal regulations come into force that reduce the limit for sulphur in gasoline fuels In 2005 the limit becomes more stringent
2003	City of Toronto Clean Roads to Clean Air program introduces new street sweepers that entrain less particulate matter
2004	City of Toronto implements Green Fleet Plan to choose more environmentally sustainable vehicles, fuels and practices for City vehicles and operations. In 2008 Phase II is implemented
2005	Closure of Lakeview coal-fired power plant
2005	Ontario Regulations are adopted to set air quality standards for toxic substances to protect local communities
2006	Federal regulations come into force that reduce the limit for sulphur in diesel fuels for on-road applications. In 2010, limits come into force for off-road applications, and in 2012, limits come into force for rail and marine applications
2006	Ontario Regulations establishing industry sector emission caps for NO_x and SO_x come into force, with milestones in 2007, 2011, 2015
2007	A new, health-based index called the Air Quality Health Index (AQHI) is promoted in Toronto
2007	Settlement announced in a lawsuit filed by USEPA against American Electric Power claiming the large utility had violated the requirements of the Clean Air Act. The settlement required major reductions in NO_x and SO_x emissions
2007	City Council Adopts a Climate Change Action Plan which includes actions and targets to reduce locally-generated air pollution emissions by 20%, from 2004 levels by 2012 for the Toronto urban area
2008	Toronto City Council Adopts the Toronto Walking Strategy
2009	Ontario's *Green Energy Act* was introduced into the Legislature
2010	The Chemtrac program comes into effect, requiring local facilities to annually track and report on the use and release of priority air pollutants
2010	Idling Control Bylaw updated, limiting idling to one minute
2010	The Toronto Green Standard is implemented, creating a two-tier set of performance measures with supporting guidelines related to sustainable site and building design for new private and public development. In 2014 The Toronto Green Standard Version 2.0 is in effect with increased energy performance targets
2013	Ontario has now shut down 17 of 19 coal-fired units, with all to be shut down by the end of 2014

A few specific examples illustrate the range of initiatives undertaken to improve Toronto's air quality. For example, in 2001, the City of Toronto became involved in an American court case filed by the U.S. Environmental Protection Agency against American Electric Power – one of the biggest utilities in the United States. After gaining "Friend of the Court" status, the City and the

Medical Officer of Health submitted information about the harmful impact of transboundary air pollution from U.S. coal-fired power plants on health in Toronto. The settlement announced in 2007 required the utility to reduce emissions from its sixteen coal-fired power plants – which resulted in better air quality in Toronto.

Over the years, Toronto has also played an important role advocating for improved federal and provincial air quality policy. For example, as early as 1999, the City advocated for adoption of low-sulphur fuels regulations Canada-wide while also adopting low-sulphur fuels purchasing practices locally. These practices, which included buying on-road low-sulphur diesel for off-road uses allowed the City to reduce SO_2 emissions from its corporate fleet from about 29.5 tonnes per year in 1999 to about 6 tonnes per year in 2003 (OPHA, 2003). Federal regulations followed several years later, requiring low sulphur fuels on-road in 2006, and off-road in 2010.

A key initiative that improved air quality in the Toronto region is the closure of Ontario's coal-fired power plants. As early as 2000, TPH identified three coal-fired power plants that contributed to poor air quality in southern Ontario – the Nanticoke, Lambton and Lakeview Generating Stations. On at least four separate occasions, Toronto's Board of Health recommended conversion of coal-fired power plants to natural gas because of the health and environmental benefits associated with such a shift. In 2005, Lakeview Power Generating Station was closed. In 2007, the province of Ontario committed to phasing out all coal-fired power plants, and has now shut down 17 of the 19 units. The remaining plants are expected to be closed by the end of 2014.

The City has shown leadership in improving air quality here in Toronto. In 2007, City Council unanimously adopted a Climate Change, Clean Air, and Sustainable Energy Action Plan, which included ambitious targets to reduce locally-generated pollutants by 20% from 2004 levels by 2012 for the Toronto urban area. The Plan, along with a 2009 Sustainable Energy Strategy, have also driven many successful initiatives to improve energy efficiency, such as a new program for improvements to private residential properties called the Home Energy Loan Program.

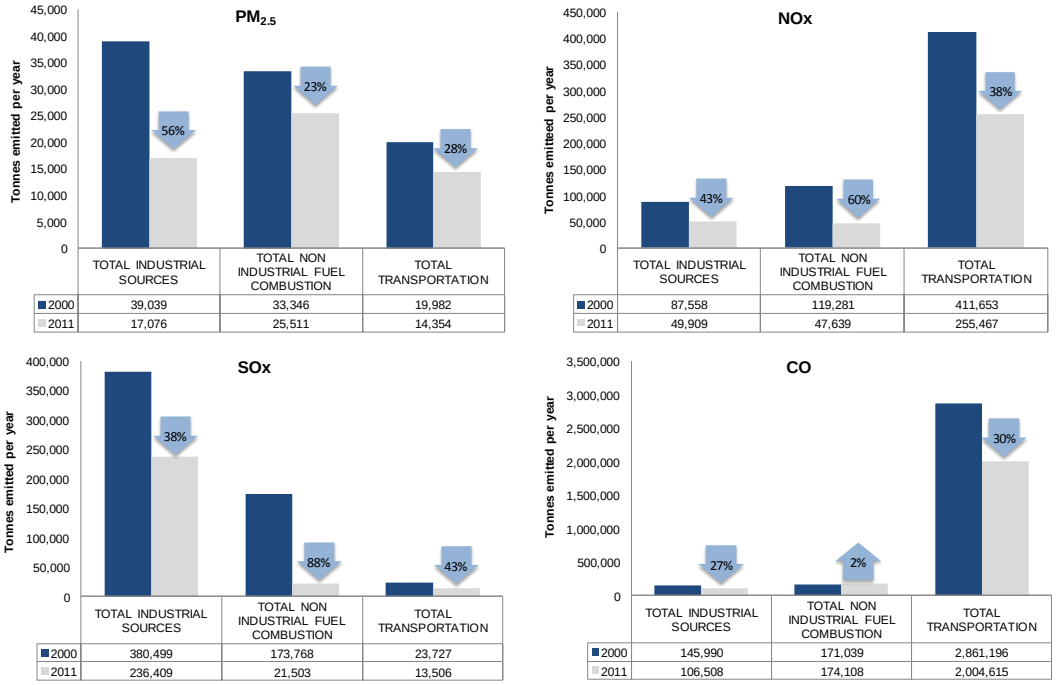
As well, TPH led development of a bylaw requiring local facilities to annually track and report on the use and release of priority air pollutants. The associated program, ChemTRAC, came into effect in 2010. That same year, TPH led the development of an updated Idling Control Bylaw which reduced the allowable idling time down from three minutes to one minute.

In addition to promoting actions to improve air quality, TPH has also been active in finding ways to help people protect themselves from the adverse health impacts of air pollution. TPH was a key advocate and partner in the development of the Air Quality Health Index (AQHI) and its associated communications materials. This health-based index provides information to the public about how to protect themselves from the adverse impacts of air pollution. Toronto piloted the index in 2007, and it is now available in municipalities and regions across Canada.

Encouraging Trends in Reported Emissions

The various actions described above have resulted in measurable decreases in emissions. Figure 9 provides an overview of decreases in emissions for three key source types province-wide between 2000-2011. The figure indicates that for SO_x, the greatest drop is related to emissions from fuel combustion, while for NO_x and CO, the greatest improvements are from reductions in transportation-related emissions. For $PM_{2.5}$, the successes appear to arise mainly from reductions in industrial emissions.

Figure 9: Percent Change in Ontario-wide Air Pollution Emissions for Three Key Source Types, Ontario, 2000 and 2011



Source: Data courtesy of Environment Canada

Prepared by: Toronto Public Health

Other sectors that reported emissions in Ontario (and not shown in Figure 9) include open sources, incineration, and "miscellaneous". Emissions reported under the categories of incineration and "miscellaneous" are negligible relative to those from transportation, industry and fuel use, and are therefore not discussed further in this report. Open sources are a major contributor to Ontario emissions of $PM_{2.5}$, and include agricultural sources, dust from unpaved roads, and mine tailings, which hold little relevance to Toronto. Dust from construction and paved roads is also included under "open sources" and likely contributes to levels of $PM_{2.5}$ in the city. These sources may be partly addressed through the City's Clean Roads to Clean Air program which used street sweepers that entrain less on-road dust.

Conclusions

Air quality in Toronto is improving, and as a result, the adverse health impacts are declining. However, with air pollution still contributing to an estimated 1,300 premature deaths and 3,550 hospitalizations, there is more work to do to achieve cleaner air. The successes of the past 15 years show that with concerted action across emission sources, improvements can indeed be achieved. While many of Toronto's next steps will require continued efforts to reduce the air quality impacts from transportation, there are also still opportunities to reduce emissions from residential, commercial, and industrial sources.

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