UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

SOCAAR
southern ontario centre for atmospheric aerosol research

Near-Road Air Pollution Pilot Study

SUMMARY REPORT
FALL 2019

CONTEXT

The Southern Ontario Centre for Atmospheric Aerosol Research (SOCAAR) at the University of Toronto, in collaboration with Environment and Climate Change Canada, the Ontario Ministry of the Environment, Conservation and Parks, and Metro Vancouver conducted a two-year (2015–2017) study into traffic-related pollutant concentrations near major roadways to evaluate the potential impacts on Canadians.

The Near-road Air Pollution Pilot Study establishes methodologies for ongoing monitoring of pollution levels across Canada and has identified four areas of significant concern for Canadian health: trucks in cities, wind and winter, local urban traffic, and the hidden pollution of brake and tire wear.

Exposure to traffic emissions has been associated with a wide range of adverse health outcomes, including increased risk of respiratory diseases such as asthma, birth and developmental concerns, cancer, and cardiovascular and respiratory mortality. While some individual pollutants in traffic exhaust are toxic, it is the combination of the many pollutants present in emissions that is of concern.

There are three major factors that are driving the need for increased attention to air quality near roads:

1. Many Canadians live close to roadways.
2. Vehicle emissions are changing.
3. Exposure varies a lot across cities.

MANY CANADIANS LIVE NEAR MAJOR ROADS

Near-road air quality studies have long confirmed that elevated concentrations of pollutants can be found within 50 metres of a road, but more recent studies have shown that vehicle emissions can reach up to 250 metres from a road. More attention is needed in this area, as Canada's urban areas and populations continue to grow. Nearly **one-third of Canadians live within 250 metres of a major road and are thus exposed to traffic emissions** (Figure 1). The highest percentages live in Ontario and British Columbia, which were the focus of this study.

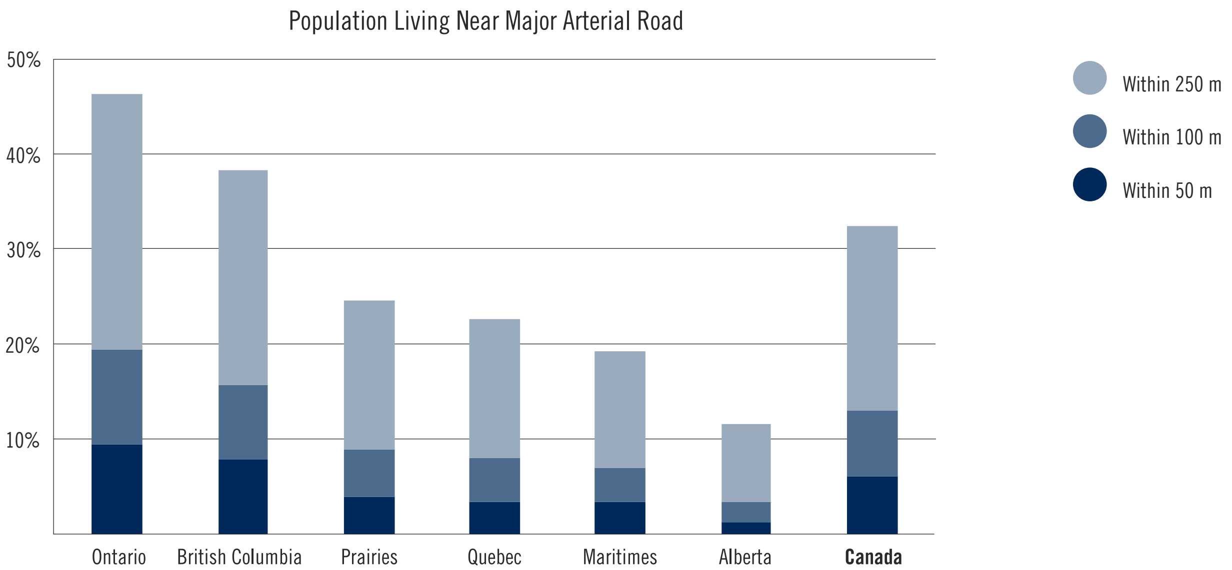

Figure 1. Percentage of provincial or national populations living within 50 metres, 100 metres or 250 metres from a major arterial road based on 2006 Census data. One third of Canadians live near enough to a major road to be affected by the vehicle emissions.

CANADA'S VEHICLE EMISSIONS ARE CHANGING

Significant progress has been made in reducing vehicle emissions over past decades. Compared to 1970 models, new vehicles are roughly 99% cleaner for common pollutants. Fuels are now much cleaner: lead has been eliminated, and sulfur levels are more than 90% lower than they were prior to regulation.

The use of the catalytic converter, fuel injection, and on-board diagnostics means that cars have become increasingly cleaner and durable. However, **the number of vehicles increases every year**, with almost 25 million cars and trucks on Canadian roads in 2017. **The number of people commuting into cities by car has also increased** by 28% in the past two decades.

The types of vehicles are changing as well, as **Canadians are buying trucks at a much higher rate** than passenger cars. In the past decade, truck sales have risen 20%. Heavier vehicles mean more wear and tear on road surfaces, on tires, and brakes, all of which contribute to airborne particles—often metals—in the air.

While there have been impressive strides in pollution management over the years by both manufacturers and government, they have been offset to some degree by the increased number of vehicles, the increased number of kilometers driven, and the increased use of heavier vehicles in urban settings.

Our study brings into focus the current state of near-road pollution in Canada through observations at six monitoring sites in Vancouver, British Columbia and Toronto, Ontario (Figure 2). Three sites were located beside major roads, representing a trucking route, downtown road and highway. Measurements were also made at three nearby background sites, which were located well away from traffic.

The findings not only reveal the impact of local traffic but also identify specific pollutants that should be monitored going forward. This study also establishes the foundations for a much-needed national near-road pollution monitoring network to advise policymakers and help create guidelines and laws to protect the health of Canadians.

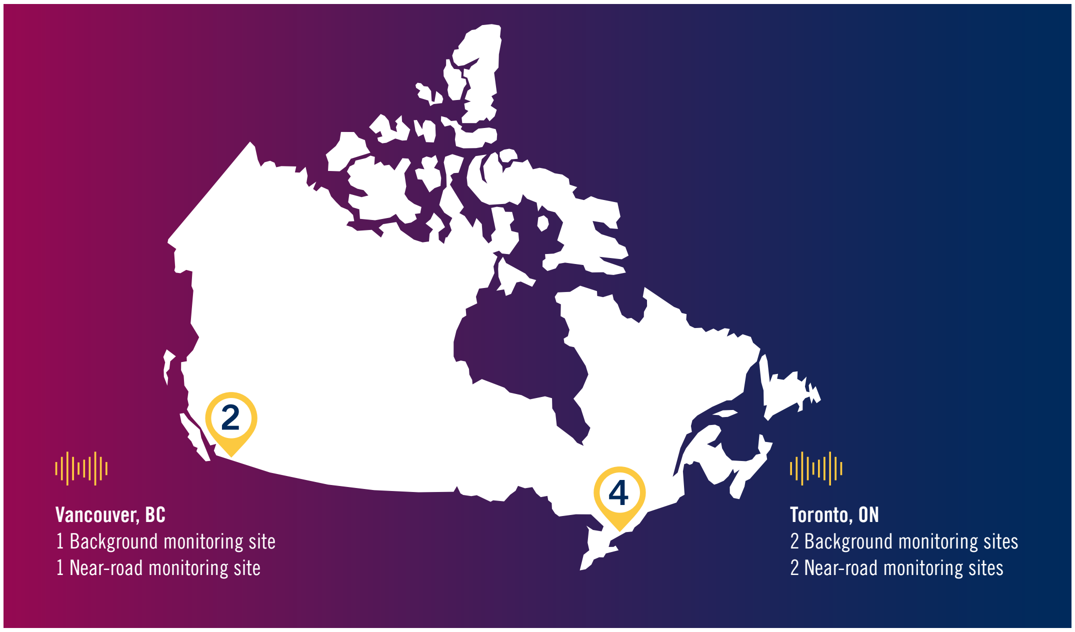

Figure 2. A total of six monitoring stations were used in this study. The Vancouvuer sites were located on Clark Drive and Sunny Hill Children's Hospital in the city's east side. The Toronto sites were more geographically dispersed, covering highway, downtown, and non-urban conditions. Average daily traffic counts across the three near-road sites ranged from 17,000 to 411,600 vehicles.

FINDINGS

Vehicles emit a complex mixture of air pollutants that can reach wide areas around busy roads. The area impacted is affected by traffic type and density, urban design, and wind speed and its direction. Our study compared pollution beside major roads and at background sites located away from major roads.

Over the course of two years working in two provinces and with millions of data, the study identified four areas of concern. These are areas that policymakers and researchers should be focused on, as they raise important questions about the health of Canadians living in urban environments:

TRAFFIC IN CITIES

How much is traffic increasing air pollution concentrations near roads?

LARGE TRUCKS

How do diesel vehicles impact urban areas?

WIND AND WINTER

How do wind and seasons affect pollution levels?

BRAKE AND TIRE WEAR

How do non-tailpipe emissions affect air quality?

TRAFFIC IN CITIES

Air pollution comes from various sources: industrial, agricultural, and natural, such as wildfires. In cities, traffic is a dominant source creating higher concentrations of many air pollutants near busy roads.

Vehicle emissions are the dominant roadside polluter.

Our study found that the concentrations of traffic pollutants were highest on weekdays during morning rush hour. Concentrations were lower in the morning on weekends, consistent with lower weekend morning traffic. Surprisingly midday concentrations on weekends were also lower than on weekdays, even though car traffic was similar.

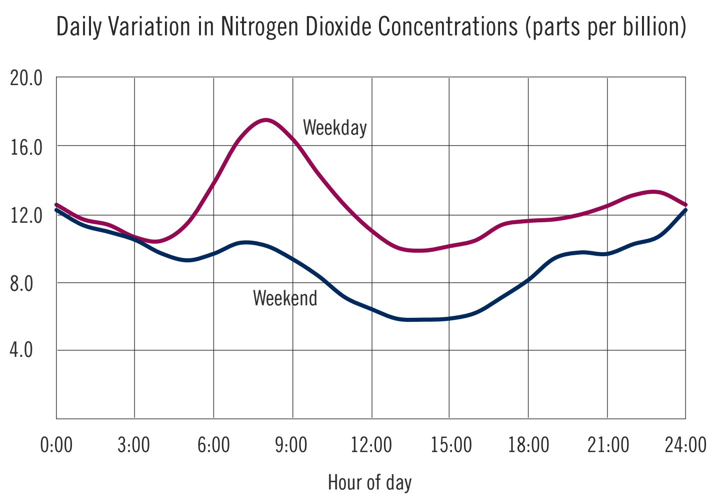

Figure 3. The average daily variation in nitrogen dioxide (NO_2) concentrations were highest during morning rush hour on weekdays at the downtown site. NO_2 was lower on weekends, even midday when the car traffic was similar to that on weekdays.

Nitrogen oxides (NO_x) such as nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are emitted in vehicle exhaust and are a good indicator of traffic pollution. Figure 3 shows the daily pattern of nitrogen dioxide. Catalytic converters have substantially reduced the emission of nitrogen oxides from gasoline powered cars so that in Canada, most of the vehicle-related emissions of nitrogen oxides now come from diesel vehicles.

We determined how much vehicles on nearby roads were contributing to air pollution by comparing the concentrations at the near-road sites to those at background sites well away from traffic. This comparison showed a substantial "excess" of traffic related pollutants near busy roads. For example, Figure 4 compares the concentrations of ultrafine particles at the highway site to a nearby background site. These microscopic particles, with diameters less than 100 nanometres, are the smallest airborne particles emitted by vehicles. They are much smaller than a blood cell and once inhaled can travel through the body more easily than larger particles.

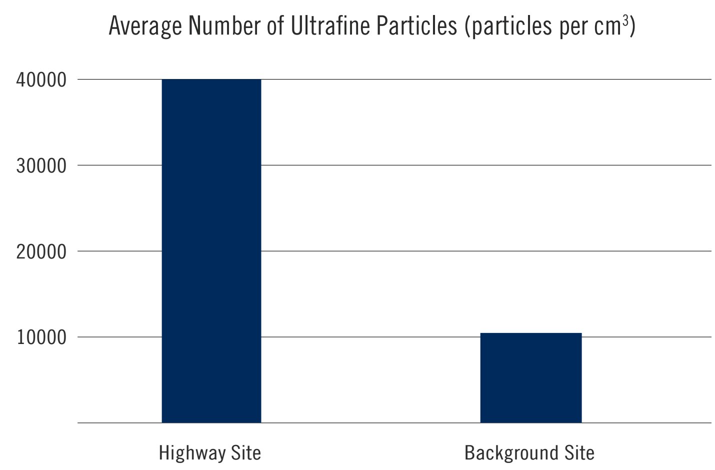

Figure 4. The average concentrations of ultrafine particles at the highway site was four times higher than at a background site away from traffic based on 2015–2017 measurements.

Figure 4 shows that at the highway site, 40,000 ultrafine particles are present in each cubic centimetre of air; **this corresponds to inhaling approximately 20 million of these particles in each breath taken at this site.** Further, an excess of 30,000 ultrafine particles per cubic centimetre was present

TRAFFIC IN CITIES

at the highway site vs. the background, representing a factor of four difference between these sites.

Comparison with the background sites also allowed us to estimate what portion of the pollutants were due to the local traffic. For example, 75% of the ultrafine particles at the highway site were due to the local traffic and only 25% were from the other sources, as measured at the background site.

Figure 5 shows that over 80% of the nitrogen monoxide and 60% of the black carbon (BC) also came from nearby traffic at this highway site. The percentages were lower at the truck route and downtown sites but still approximately half of the traffic pollutants came from local traffic. Thus, local traffic can detract substantially from air quality near major roads, creating pollutant concentrations that vary on average by factors of two to five across cities.

The pollutants in Figure 5 are associated with vehicle emissions—diesel vehicle emissions in particular—and were much higher beside roads. In contrast, only a small portion of the carbon dioxide was coming from these nearby vehicles. Certainly, vehicles contribute substantially to the carbon dioxide emitted to the atmosphere. However, carbon dioxide is also produced by many natural processes and molecules spend about 40 years in the atmosphere after being emitted. As a result, there is a lot of carbon dioxide already built up in the atmosphere from past emissions and the carbon dioxide due to local vehicle emissions near roads represents only a small percentage of this high background.

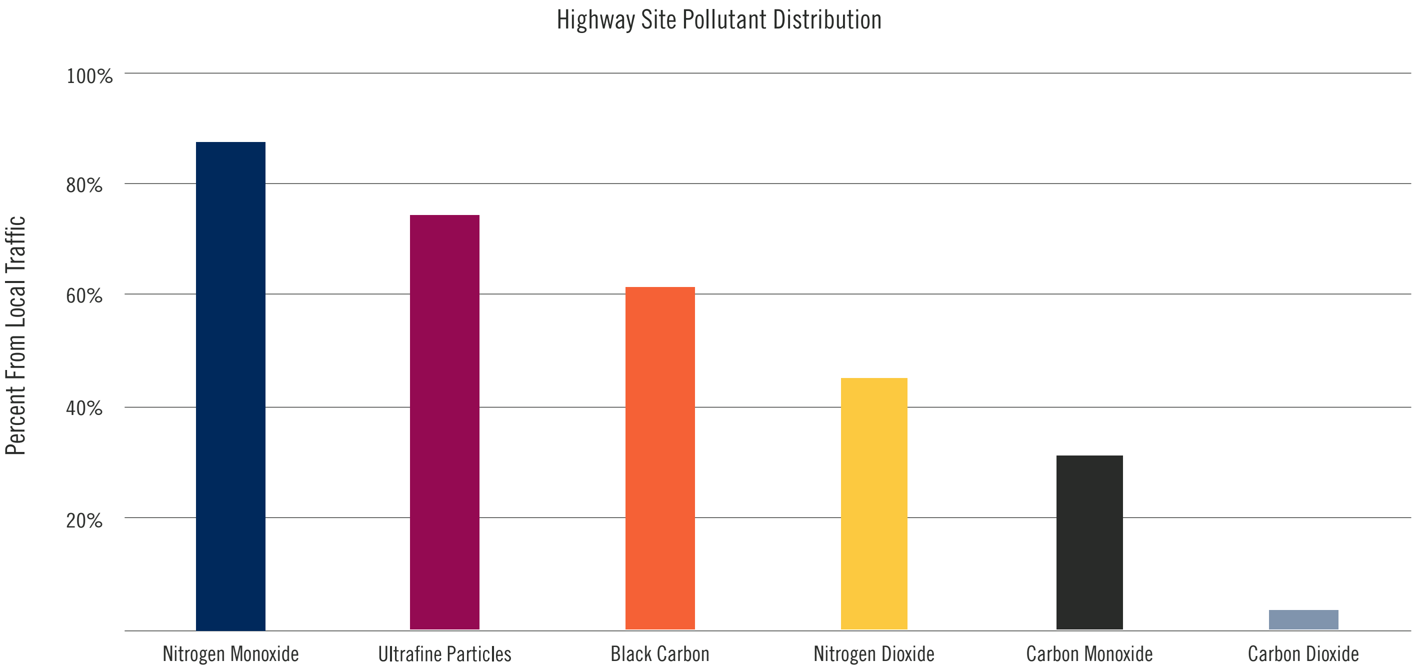

Figure 5. The majority of the pollutants such as nitrogen oxides, ultrafine particles, and black carbon are due to local traffic at the highway site, based on two years of measurements (2015-2017).

LARGE TRUCKS

Large trucks contribute disproportionally to emissions.

The highway site was located alongside one of the busiest in the world, carrying over 400,000 vehicles per day. The truck route and downtown sites had ten times less traffic. Figure 6 shows that **the "excess" pollution due to traffic at the truck route and highway sites were very similar**, particularly for pollutants like nitrogen oxides and black carbon that are produced more by trucks than cars. This similarity was because approximately 8% of the vehicles are large trucks at both locations as compared to 2% at the downtown site. Concentrations at these sites depended much more on the proportion of large trucks in the fleet than the total traffic volume. An emission factor is the amount of a single pollutant released into the air by a vehicle for every kilogram of fuel that it burns. We calculated emission factors using over 400 days of measurements, consolidating the emissions from 200 million vehicles. Analysis of these emission factors also showed that variability at and across the three sites depended more on the proportion of large trucks in the fleet than the total traffic volume.

Emission factors also allowed the portion of the emissions from trucks to be estimated. For example, emissions at the highway site were higher on weekdays than weekends due to the higher portion of trucks (Weekdays: 10%, Saturday: 6%, Sunday: 1%). Figure 7 shows that the trucks emitted more of the black carbon than cars at the highway site, except on Sunday when trucks only represented 1% of the vehicles.

The dangers of diesel exhaust

Diesel exhaust is a recognised human carcinogen. It contains a large number of chemical compounds both as gases and within particles. Some of these compounds, such as black carbon[1] and nitrogen oxides are commonly used as markers to estimate exposure to diesel exhaust.

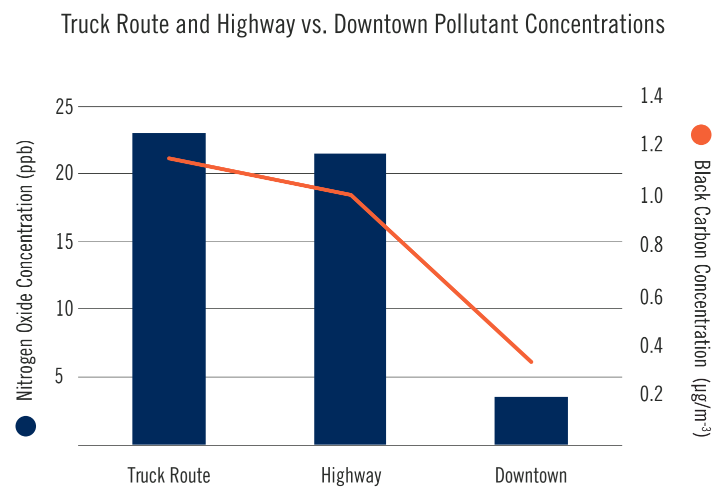

Figure 6. Average excess black carbon and nitrogen oxide concentrations are similar at the truck route and highway sites despite a factor of ten difference in traffic. Concentrations are lower at the downtown site, which has similar car traffic to the truck route but much lower truck traffic.

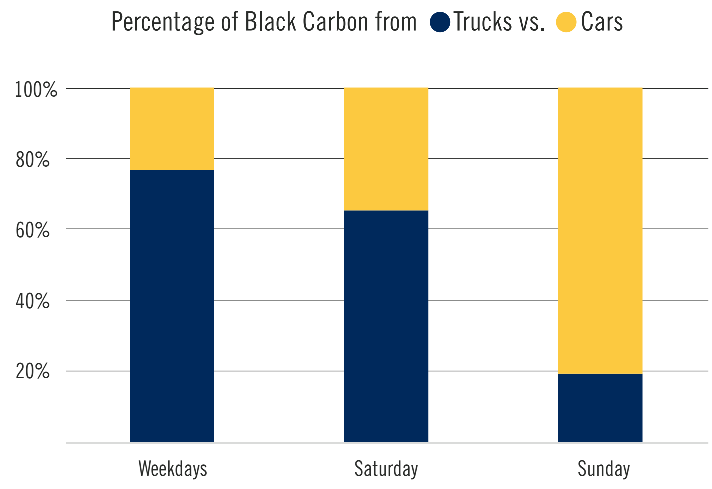

Figure 7. The majority of black carbon emissions are due to diesel trucks at the highway site, except on Sundays, when trucks represent only 1% of the vehicles.

[1] Exposure to diesel exhaust in workplaces is measured in terms of elemental carbon (EC). Elemental carbon is very similar to black carbon except that different measurement methods are used such that 1 $\mu g/m^{-3}$ of EC = 1.4 $\mu g/m^{-3}$ of black carbon. Details on the differences between the elemental and black carbon we measured are described in Appendix A of the full report available at www.socaar.ca.

LARGE TRUCKS

We found elevated levels of nitrogen oxides at both the truck route and highways sites, but not the downtown site. As shown in Figure 8, the **NO_2 concentrations exceeded the 2020 annual Canada Ambient Air Quality Standard** (CAAQS) of 17 ppb at both locations. Moreover, NO is abundant close to the road; NO will become NO_2 as it is carried away from the road. As a result, even 150 metres from the highway, the concentration of NO_2 still exceeded 17 ppb, as more of the nitrogen oxides were converted to the form of NO_2, balancing the reduction in concentration due to dilution. Thus, significant exposure to diesel emissions can occur and **reductions in emissions will be needed in order to achieve the 2020 annual CAAQS for NO_2** near roads, especially with substantial diesel traffic.

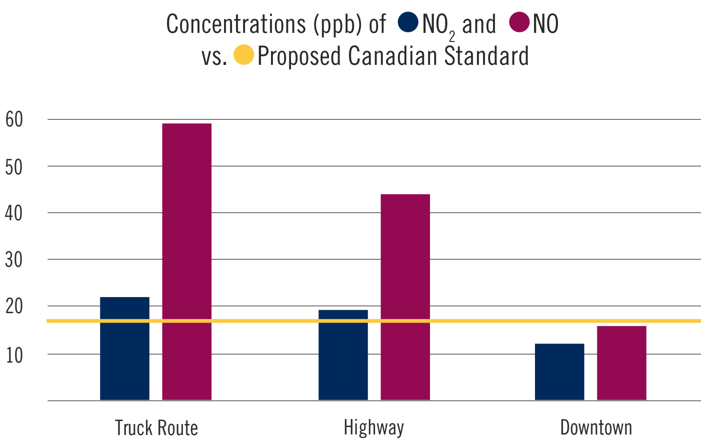

Figure 8. The hourly averaged nitrogen oxide data for 2015–2017 indicates that excessive exposure to diesel exhaust is occurring at some sites. Reductions in emissions will be required to achieve the 2020 Canadian ambient air quality standard for NO_2 of 17 ppb, indicated by the yellow line.

Black carbon is a second indicator of exposure to diesel exhaust. Black carbon particles are produced by the incomplete combustion of fossil fuels and diesel engines create much more than cars due to the design of the engines. Our data shows that there is significant black carbon released into the air from large trucks producing excessive exposure to diesel exhaust near roads with high truck traffic.

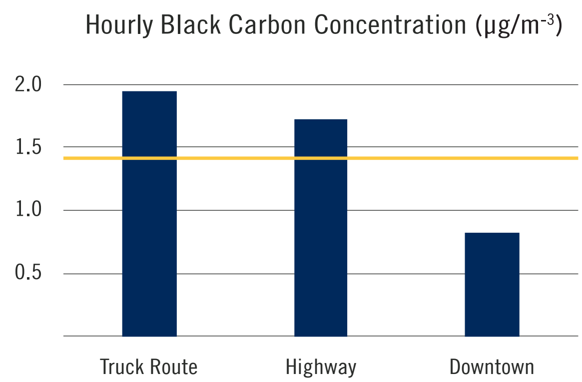

Figure 9. The hourly average black carbon concentration for 2015–2017 indicates that excessive exposure to diesel exhaust is occurring at some sites. Comparison with a standard of 1.4 $\mu g/m^{-3}$ (yellow line) proposed in the Netherlands indicates that reductions in diesel emissions are required as the resulting risk of lung cancer is well above the normally accepted limit.

There is no standard or guideline to govern exposure of the public to black carbon. The Netherlands has proposed an exposure standard for workers. This standard corresponds to a lifetime risk of lung cancer 400 cases in 100,000 people, much higher than the 1 in 100,000 risk-factor often used to establish allowable exposure in industry. Moreover, standards for public exposure are generally much lower than those for workers as some members of the public are more vulnerable. The average concentrations of black carbon at the highway and truck route sites exceeded this standard, as shown in Figure 9. These results show that excessive exposure to black carbon can occur near roads with significant proportions of large trucks and that **Canada should take further steps to assess and reduce this exposure**. Given its high traffic volume, the highway site had a representative mix of highly polluting trucks, and newer low emitting trucks with properly functioning emission treatment systems. A majority of these emissions are believed to originate from the minority of the trucks; these highly polluting trucks should be identified and repaired, retrofitted, removed or relocated away from populated areas. Stronger consideration should also be given when siting future facilities for our more vulnerable citizens, such as daycares, schools and retirement homes, away from roads carrying high proportions of heavy trucks.

WIND AND WINTER

Collecting data at multiple sites over two years allowed air quality to be measured under a large variety of conditions. By comparing these data, two additional variables emerged that significantly affected pollution levels: wind and winter.

Wind conditions affect concentrations.

Overall, our data showed how strongly wind affects air pollution levels. Wind blows the pollutants away from the road and higher wind speed dilutes them more quickly reducing the concentrations. As a result, concentrations are higher on the downwind side of roads, decreasing with increasing distance from the road. In contrast, on days with little to no wind the pollutants build up in a wide region that extends on both sides of the road. The dispersion of pollutants can be restricted by the local urban topography as features that block the wind, such as buildings and hills, can prevent the spread of pollution but also trap pollutants increasing the near-road concentrations. More specifically we found that:

- Pollutant concentrations were up to six times higher when the monitoring site was directly downwind of the road.

- Pollutant concentrations decreased by a factor of four with increasing wind speed from 4 to 40 km/h.

- Under stagnant wind conditions, little dilution occurred and concentrations were similar across a region up to 150 metres from the road.

Canada's winters can increase concentrations.

Poor air quality is often incorrectly associated only with hot and humid summer days. Our data revealed some unexpected consequences of cold winters that show why Canada needs to place greater emphasis on understanding how its seasons affect near-road air pollution across the country.

Colder winter temperatures increased near-road concentrations of nitrogen oxides. As seen in Figure 10, these concentrations were up to four times higher in cold conditions than in mild conditions on weekdays at the highway site. This pattern was much less evident on weekends when truck traffic is lower. As number and types of vehicles was not influenced by the temperature outside, this pattern reflected a change in the emissions per vehicle. Because diesel fuel is the major source of these pollutants at this site (Figures 5 and 7), these data suggest that the emission treatment systems on diesel vehicles may not function as effectively under cold winter temperatures. Improving treatment technologies to better perform in Canada's cold winter climate may offer an opportunity to reduce nitrogen oxide emissions.

NO_x Concentrations (ppb) at Different Temperatures (°C)

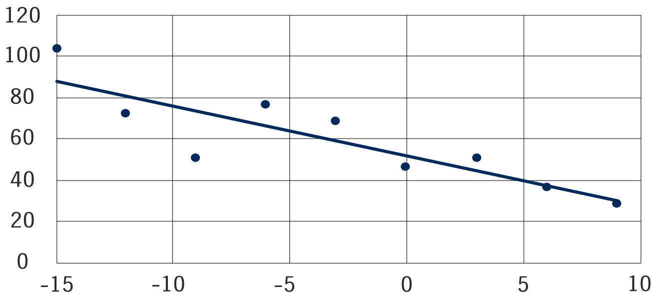

Figure 10. Concentrations of nitrogen oxides on weekdays at different ambient temperatures. These data indicate higher emissions under colder temperatures at the highway site, suggesting that the emission treatment systems of trucks do not perform as effectively.

WIND AND WINTER

The near-road concentrations of ultrafine particles were also higher in winter than summer. This seasonal effect is believed to be due to increased evaporation of ultrafine particles in summer and more being formed in winter through condensation. Thus, this seasonal change is believed to arise through processes that occur in the atmosphere after the exhaust leaves a tailpipe.

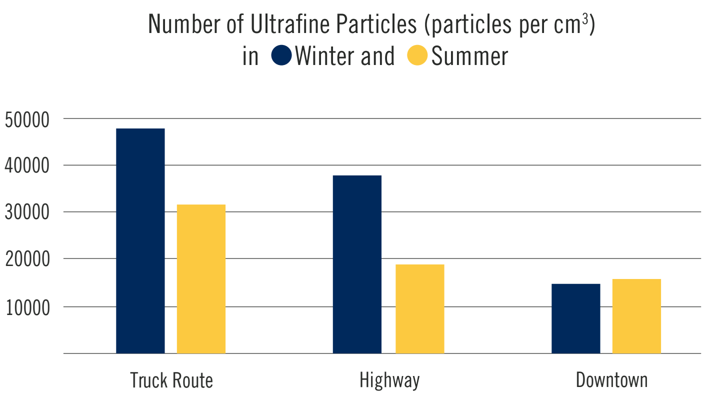

Figure 11. Ultrafine particle concentrations in winter and summer. The higher concentrations in winter are believed to be due to fast processes occurring in the atmosphere after the exhaust has left vehicle tailpipes.

Toronto site data (Figure 12) showed that **summer concentrations of black carbon were almost twice those of winter.**

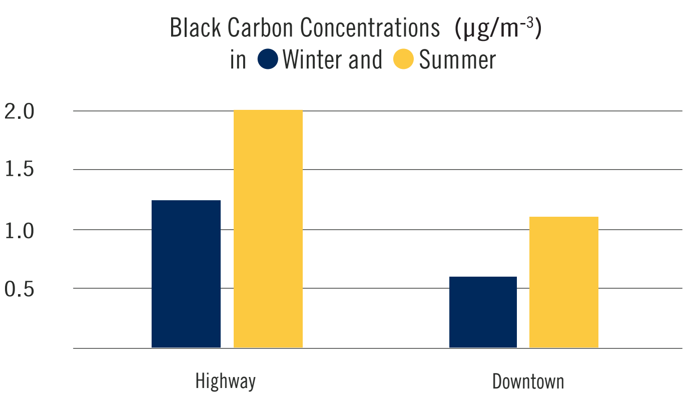

Figure 12. Seasonal concentrations of black carbon at the Toronto sites. The higher concentrations in summer may be due to the summer diesel fuel formulation.

This annual summer increase in black carbon in Toronto, but not Vancouver, suggested that **seasonal changes in Ontario fuel formulation may inadvertently be affecting tailpipe emissions of black carbon**. In Canada, companies change fuel formulations to improve starting in winter and reduce evaporation in summer. These seasonal changes can differ in different regions across our country. More study is needed, but these data suggest that optimising summer diesel fuel formulations may offer an opportunity to reduce black carbon emissions from vehicles.

TIRE AND BRAKE WEAR

Improvements to vehicle technologies since the early 2000s have led to an overall reduction in tailpipe emissions of many pollutants. However, non-tailpipe emissions, including particles from tire wear, brake wear, road surface wear, and resuspension of road dust are on the rise.

As tailpipe emissions drop, non-tailpipe emissions are emerging

In a disturbing trend, long term data from the downtown site showed that **non-tailpipe emissions of primary particulate matter ($PM_{2.5}$) have been rising since 2012 and now exceed primary tailpipe emissions** (Figure 13).

These non-tailpipe emissions are also changing the composition of $PM_{2.5}$ in the air, increasing concentrations of metal dust, including barium and copper, beside roads.

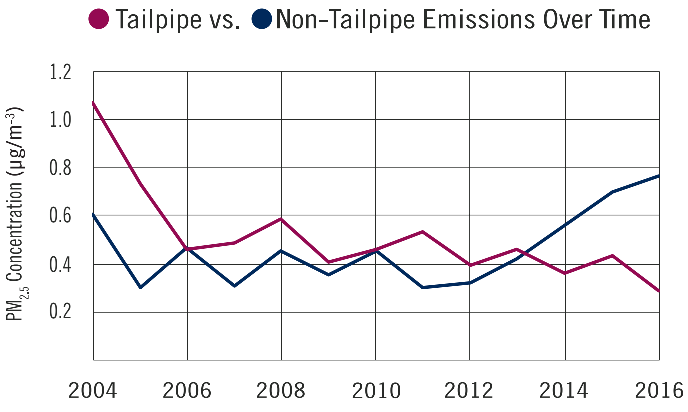

Figure 13. Contribution of tailpipe and non-tailpipe emissions to fine particulate matter in downtown Toronto site over the last 13 years. Non-tailpipe emissions started to rise in 2012 and overtook tailpipe emissions in 2014.

Data suggest that **the rise in more efficient engines has seen a corresponding rise in larger, heavier vehicles**, including pick-up trucks and sports utility vehicles. Longer term, widespread adoption of electric vehicles, which are heavier than conventional cars, could also increase non-tailpipe emissions.

This trend towards heavier vehicles in urban environments may nullify progress in reducing particulate matter in the air. More research is urgently needed to understand this trend and consider the implications of heavy vehicles adversely affecting the wear and tear of tires, brakes, and road surfaces, and the resultant metal dust that becomes airborne.

SUMMARY AND RECOMMENDATIONS

This research has demonstrated that vehicle emissions can dramatically increase the concentrations of some air pollutants near major roads. This excess pollution can create concentrations two to five times higher than that at locations with little traffic. A third of Canadians live close enough to major roads to be potentially affected.

Highly polluting diesel trucks are making a disproportionate contribution and they represent the major source of key pollutants such as nitrogen oxides and black carbon. Data for these pollutants indicate that excessive exposure to diesel exhaust can occur near roads with a significant proportion of truck traffic.

Wind direction and speed creates substantial day to day variability in pollutant concentrations. Traffic pollutant concentrations are much higher downwind of roads and when wind speed is low. Moreover, Canada's cold winters can further increase concentrations. Ultrafine particle concentrations, for example, are higher in winter. Nitrogen oxide concentrations are higher on cold winter days, suggesting that the emission control systems for diesel vehicles may not perform well at low temperatures. Further, black carbon concentrations in Toronto are higher in summer, suggesting that optimising summer diesel fuel formulations may offer an opportunity to reduce black carbon emissions.

Finally, non-tailpipe emissions of particles from brakes and tires have been rising in Toronto since 2012 and now exceed primary emissions through tailpipes.

In summary:

- Many Canadians live close to roadways and are potentially being exposed.
- Vehicle emissions are changing. New emission sources are emerging along with new opportunities to mitigate these exposures.
- Pollutant concentrations near roads depend on the volume and type of traffic, with diesel vehicles making a disproportionate contribution. As a result, exposure to traffic-related air pollutants can vary a lot across cities.

These findings all indicate that Canadians need to pay much more attention to air quality near roads.

The policy implications referenced in the report were proposed by SOCAAR based on the key science findings resulting for the pilot study.

RECOMMENDATIONS

Canada has the unique opportunity to be at the forefront of near-road pollution research and policy, to provide insight into the causes and solutions of how new vehicle technologies affect air quality in a variety of contexts, and to implement effective policies and interventions at multiple levels of government. The findings of this study offer implications related to:

- Air quality standards
- Vehicle emissions standards
- Vehicle emission testing
- Fuel composition regulations
- Siting of facilities for vulnerable populations (e.g., daycares, schools, parks, sports fields, hospitals, long-term care)
- Urban freight and trucking strategies
- Vehicle design
- Road upkeep

Individuals, community groups, and companies can also contribute so that we can collectively mitigate the impacts arising from traffic related air pollution. For example, we can individually reduce our emissions by walking, cycling and using public transit. Further, we can support implementing government initiatives such as those identified below. We can also encourage and recognise good corporate citizens who are equally committed to reducing emissions.

1 Reduce near-road diesel exhaust concentrations.

A major finding from this study is the disproportionate role of emissions from diesel vehicles. Policies and interventions should be created to reduce emission of diesel exhaust in populated areas, particularly near facilities used by our more vulnerable members of society.

TARGET HIGHLY POLLUTING TRUCKS.

Targeting the most highly polluting trucks likely offers the most effective opportunity to achieve rapid reductions in diesel emissions. Methods are needed to distinguish between low emitting, average, and highly polluting trucks. Technologies need to be developed and validated to more easily allow on-road or roadside identification and testing of truck emissions.

ELIMINATE TAMPERING.

Given the serious potential burden on health, severe consequences, such as substantial fines or loss of license, should be imposed on operators caught tampering with vehicle emission systems. Trucks equipped with modern emission treatment systems should not be highly polluting.

REPAIR, RETROFIT, RETIRE OR RELOCATE.

Older trucks identified as highly polluting should be repaired, retrofitted, retired or restricted in their operation away from neighbourhoods or facilities for vulnerable populations. Exposure could also be reduced by constraining their operation to designated off-hour time windows.

RECOMMENDATIONS

RECOGNISE AND REWARD LOW EMITTERS.

Government should create standards and processes to identify and certify diesel vehicles that are low emitting. Operators with certified low-emitting diesel vehicles could display this certification on their vehicles and web site. Further, these low-emitting vehicles might be allowed to operate in otherwise restricted locations. For example, municipalities may wish to restrict trucking in some of parts of their towns or cities to low-emitting trucks.

INCORPORATE TRAFFIC EARLY IN FACILITY SITING.

Increased and earlier consideration should be given to nearby traffic when siting facilities for society's more vulnerable members, such as playgrounds, hospitals, daycares, schools and retirement homes. Urban planning should be guided by the knowledge that not all urban areas are suitable for all purposes. A preliminary screening tool should be developed for urban planners in order to alert them at an early stage when traffic may require a more in-depth assessment for a candidate site.

IMPROVE DATA ON TRUCK TRAFFIC.

Better estimates are needed of the proportion of trucks of different sizes on major roads across Canada. The data will allow better estimation of the number of Canadians being exposed to diesel exhaust.

BETTER ESTIMATE THE HEALTH BURDEN.

While over 10 million Canadians live near major roads, only some of these roads presumably have a high proportion of truck traffic. The health burden arising from this nation-wide exposure to diesel exhaust, and its geographic variability, need to be better understood.

DEVELOP AMBIENT AIR QUALITY STANDARD FOR DIESEL EXHAUST.

Canada should develop an index or ambient air quality standard for diesel exhaust. Such a standard will provide a useful reference to assess and compare the levels at different sites. Using a combination of black carbon and nitrogen oxides appears to provide a very promising option.

INCORPORATE CANADA'S WINTERS IN EMISSION REGULATIONS.

The effect of cold winter temperatures on emission of nitrogen oxides from trucks needs to be better understood. Specifically, more direct testing of the associated emission treatment technologies is needed. This may provide an opportunity to reduce emissions by creating a technology better suited for cold winter climates. Winter conditions may need to be better incorporated into vehicle emission testing and standards.

INVESTIGATE THE INFLUENCE OF SEASONAL FUEL FORMULATIONS.

Higher concentrations of black carbon were observed at the Toronto sites in summer. This may be due to increased emissions from diesel vehicles caused by changes in diesel fuel formulation. More research is needed to verify this finding. Further, adjusting summer fuel formulation may provide an opportunity to reduce black carbon emissions.

RECOMMENDATIONS

2 Investigate non-tailpipe emissions.

While most of the findings from this study focused on truck emissions, the rise in non-tailpipe emissions in Toronto is believed to be due to a change to gasoline vehicles. Similar data analysis needs to be performed for other Canadian cities to see if a similar rise in non-tailpipe emissions is evident. Further, research is also needed to understand the potential health impact of increased exposure to these metal-rich particles. Finally, the effectiveness of mitigation strategies, such as increased street cleaning or regulations for the composition of brake pads, needs to be explored.

3 Create a national traffic-related air pollution monitoring network.

Long-term near-road monitoring stations should be established in Canada's largest cities. Our larger study (available at www.socaar.ca) offers detailed suggestions into the implementation of a national system of near-road stations that would be an efficient and strategic use of resources.

Site selection for these stations should provide geographic coverage across Canada from east to west and take into consideration population and traffic density. These stations should use quality instruments with high accuracy and reliability to create a consistent standard for traffic-related air pollution monitoring across the country.

This foundation of permanent stations should be supplemented by smaller and more easily deployable technologies to allow shorter term investigations at locations of specific concern, such as sites with high truck traffic; new neighbourhoods, schools and daycares; or developments near populations that will substantially increase vehicle traffic.

To encourage outreach and promote public engagement with this important issue, we encourage using an open platform to share data for key pollutants, such as those described in this summary report. By making research available to a wide range of interested parties, the network will be more effective in mobilising its findings.

Canadian scientists are seen throughout the world as open collaborators. In an age of rapid change in vehicle technology, air quality and climate, creating a national near-road monitoring network would uphold this reputation.