

Item 9

For Action



Subway Air Quality – Toronto Public Health Study

Date: January 27, 2020
To: TTC Board
From: Chief Safety Officer

Summary

Throughout 2019, Toronto Public Health (TPH) carried out a health assessment that focused on subway passenger exposure to air pollutants using well-established assessment approaches commonly used in the environmental health field: Human Health Risk Assessment and Health Impact Assessment. Those assessments provided new information about the public health risks associated fine particulate matter (PM_{2.5}) in the subway. As well, these risks were considered in the context of the broader potential health impacts (both positive and negative) from using the TTC subway system. It was recommended at the July 10, 2019 TTC Board meeting that staff report back when the Health Assessment Report from Toronto Public Health is complete. A copy of HL13.8 - Subway Health Impacts Study is attached in Appendix A.

The TTC completed its subway air quality study over 2017 and 2018 to provide current information on the air quality in the underground portions of the subway, and to determine employee exposures to airborne contaminants. This was an update to a similar, but smaller study in 1995. Work group specific reports were sent to management, Joint Health and Safety Committees and union safety representatives in February 2019. The summary report was then presented to the TTC's Safety, Security and Environment (SX) Committee in June 2019 and to the TTC Board on July 10, 2019.

A comparison was made between the two TTC studies (1995 and 2018) using several key markers that allowed for direct comparison (lead, barium, copper and manganese for certain job titles). Concentrations of these markers were between 10 and 10,000 times lower in the 2018 study than in the 1995 study. Results from the 1995 study were also well below Occupational Exposure Limits. Based on this, it appears that the subway air quality has shown improvement over time.

Based on the results of 5,697 air samples, the use of respiratory protection is not required for non-maintenance positions. Only one maintenance group, that is already part of the respiratory protection program, requires respirators due to an exceedance of silica and inhalable particulates during structure maintenance activities.

All of the remaining contaminants sampled in this study were well below the applicable occupational exposure limits specified in Ontario Regulation 833, Control of Exposure to Biological or Chemical Agents and Ontario Regulation 490/09, Designated Substances.

The TTC remains committed to identifying, implementing and evaluating particulate matter 2.5 (PM2.5) mitigation measures that will further improve subway air quality for its workers and customers.

Recommendations

It is recommended that the TTC Board:

1. Adopt the recommendations from the report, HL13.8 - Subway Health Impacts Study, including:
 1. Implementing PM2.5 mitigation measures that can be delivered in the short-term, including actions related to employee awareness and training programs, state of good repair (materials, equipment, procurement and procedures) and engineering reviews, as described in the report;
 2. Identifying medium- and long-term mitigation measures, with a priority on Line 2, that can be implemented, to further improve air quality, as described in the report, including:
 - a. Reviewing operational systems and procedures, such as Automatic Train Control (ATC), train frequency and ventilation systems;
 - b. Reviewing procurement specification and deployment plans for replacement trains for future line modernization;
 - c. Including consideration of the potential improvements to air quality in the TTC's study of platform edge doors;
 - d. Monitoring levels of subway PM2.5 and evaluating the PM2.5 mitigation strategies that are implemented;
 3. Requesting that TTC staff report back on opportunities for air quality improvement in the TTC subway system, including a review of emerging information and technology that has the potential to reduce air pollution in the subway system;
 4. Identify funding requirements through future budget processes to develop and implement further PM2.5 mitigation measures;

Financial Summary

The cost of the Subway Air Quality study was approximately \$825,000 and the cost of the health assessment by Toronto Public Health was \$100,000 for a total of \$925,000. Most of the costs of the Subway Air Quality study were incurred in 2017 and 2018, with the balance of \$177,000 incurred in 2019. The total 2019 costs of \$177,000 were

included in the 2019 TTC Operating Budget, which was approved by the Board on January 24, 2019 and by City Council on March 7, 2019.

The TTC anticipates that items under recommendation 1.1 and 1.3 will be completed through existing base budget complement and funding. Requirements under 1.2 will be considered as part of mid and long term planning of relevant capital programs.

The Chief Financial Officer has reviewed this report and agrees with the financial impact information.

Equity/Accessibility Matters

The results of this work enable a fact-based evaluation of the need for any future measures to be taken to address the needs of sensitive populations.

Decision History

Board of Health Motion

At its May 17, 2017 meeting, Board of Health Chair Joe Mihevc put forth a Notice of Motion that:

“Directed the Medical Officer of Health to work with the Toronto Transit Commission, if requested and funded, to oversee an independent study of the health risks for passengers of air quality issues in the subway system, particularly in relation to mitigation measures that could be implemented.”

<http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2017.HL19.15>

TTC Board Motion

At its May 18, 2017 meeting, Commissioner Joe Mihevc put forth a Notice of Motion recommending that:

“TTC evaluate occupational exposures to fine particles and develop appropriate strategies to mitigate potential health impacts in consultation with responsible occupational health authorities; and further, that TTC provide support and resources to the Medical Officer of Health to oversee an independent study of the potential health impacts for passengers of air quality issues in the subway system, particularly in relation to mitigation measures that could be implemented.”

[http://www.ttc.ca/About the TTC/Commission reports and information/Commission meetings/2017/May 18/Reports/19 Notice of Motion Air Quality.pdf](http://www.ttc.ca/About%20the%20TTC/Commission%20reports%20and%20information/Commission%20meetings/2017/May%2018/Reports/19%20Notice%20of%20Motion%20Air%20Quality.pdf)

At its May 18, 2017 meeting, the Board referred the above Notice of Motion for a report that will address ways and means to study the potential impacts of air quality issues in

the subway system and for information on whether any other major subway systems have undertaken similar work.

Board Receives Report on Proposed Approach

At its September 5, 2017 meeting, the proposed approach to studying subway air quality issues was presented and received by the Board.

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2017/September_5/Reports/13_Subway_Air_Quality.pdf

Board Receives TTCs Subway Air Quality Final Report

At its July 10, 2019 meeting, the TTCs Subway Air Quality Final Report was presented and received by the Board.

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2019/July_10/Reports/7_Subway_Air_Quality_Final_Report_updated.pdf

Board of Health receives Toronto Public Health – Subway Health Impacts Study

At its meeting on January 13, 2020 the City of Toronto Board of Health considered HL13.8 – Subway Health Impacts Study. The item will be considered by City Council on January 29, 2020.

[HL13.8 - Subway Health Impacts Study](#)

Issue Background

On April 25, 2017, a Health Canada study entitled, “The Urban Transportation Exposure Study (UTES)” was published in a peer-reviewed scientific journal. The UTES compared particulate matter (PM) exposures between major subway systems in Canada. The purpose of the UTES was to gather information about PM levels and therefore it did not draw conclusions about the impact of the PM levels on health. The UTES confirmed previous internal assessments that found that the PM is primarily iron from steel wheels and rails, and that PM concentrations are higher in an enclosed subway station than outside.

The purpose of the UTES was to better understand commuter exposure to air pollutants in metro systems across three Canadian cities. The UTES found that PM_{2.5} exposures were higher in Toronto (95 µg/m³) than in Montreal (35 µg/m³) and Vancouver (19 µg/m³), which was based primarily on the differences in these agency’s operating systems.

Previous TTC Subway Air Quality Studies

The TTC has conducted comprehensive subway air quality studies in 1977, 1980 and 1995. These were performed to provide information on the air quality in the

underground portions of the subway and determined both employee and customer exposures to airborne contaminants. The 1995 study found that none of the 280 samples taken were above the occupational exposure limits for employees. In those past studies, PM2.5 was never measured because no occupational exposure standards exist to compare to. Respirable dust that includes PM2.5 was measured because it has an occupational exposure limit.

Since that time, numerous job-specific workplace investigations have been completed and recommendations were implemented as required.

Comments

TTC's Commitment to Improving Air Quality

The TTC remains committed to doing its part to improve air quality in the city of Toronto and in its underground subways.

The TTC has been actively pursuing ways to ensure that our fleet is moving to greener technology that will reduce greenhouse gas emissions and outdoor air pollution. The TTC is procuring 255 second generation hybrid buses that are 20% cleaner than the previous generation by the end of 2019, and procuring 60 battery-electric buses that are 95% cleaner than our current diesel fleet by end of Q1 2020.

Subway air quality has improved over time. The PM2.5 levels have decreased since the introduction of the TR subway train on Line 1. Additional measures to reduce greenhouse gas emissions and air pollution in the subway include:

- Retrofitting existing work cars with the latest emission control technologies such as catalytic converters and diesel exhaust filters.
- All new work cars are equipped with the latest emission control technologies.
- On the older T1 revenue fleet, filters are being upgraded to Minimum Efficiency Reporting Value (MERV) 9. These air filters can remove pollutants as small as 1 to 3 microns, including PM2.5.

The TTC will be reviewing, monitoring and evaluating the effectiveness of these various mitigation measures in addition to the introduction of Automatic Train Control on Line 1 with respect to its impact on PM 2.5 levels in the subway.

Limited Research

The existing research on subway PM 2.5 and associated health effects to the public is limited. The TTC has partnered with Health Canada in two separate air quality monitoring campaigns in order to begin to bridge the research gap that exists. Further collaborations with Health Canada are currently being considered.

The TTC has reached out to other transit organizations with similar subway systems, namely New York City Transit Authority and Transport for London as this issue is not unique to the TTC. We have begun to exchange information around PM identification,

potential mitigation measures, emerging technologies, research opportunities and monitoring strategies as we all agree this issue warrants further exploration.

Exposure Limits

The Ontario Ministry of Labour and Health Canada are responsible for establishing safe exposure limits for employees and the public, respectively. The TTC is responsible for complying with all applicable legislation and appropriate industry best practices and standards.

Occupational Exposure Limits

The Ministry of Labour sets out occupational exposure limits in Ontario Regulation 833, Control of Exposure to Biological or Chemical Agents and other related Regulations such as Ontario Regulation 490/09, Designated Substances. An occupational exposure limit is an upper limit on the acceptable concentration of a hazardous substance in workplace air for a particular material or class of materials.

Public Exposure Limits

Public exposures are distinct from employee exposures as they have to take into account vulnerable populations, including; infants, young children, seniors and those in various states of health (e.g., with respiratory illnesses such as Chronic Obstructive Pulmonary Disease (COPD)).

Health Canada has indicated that in regards to public health, there are no directly comparable standards for PM2.5 levels in the subway. Public exposure standards are normally for outdoor air, and are often averaged over 24 hours or even a year, which makes them difficult to apply to typical commuter exposure patterns and durations.

Contact

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Signature

Betty Hasserjian
Chief Safety Officer (Acting)

Attachments

Attachment 1 – HL13.8 - Subway Health Impacts Study



Tracking Status

- This item was considered by [Board of Health](#) on January 13, 2020 and was adopted with amendments. It will be considered by City Council on January 29, 2020.

Board of Health consideration on January 13, 2020

HL13.8	ACTION	Amended		Ward: All
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Subway Health Impacts Study

Board Recommendations

The Board of Health recommends that:

1. City Council request the Toronto Transit Commission Board to implement PM2.5 mitigation measures that can be delivered in the short-term, including actions related to employee awareness and training programs, state of good repair (materials, equipment, procurement, and procedures), and engineering reviews, as described in the report (December 19, 2019) from the Medical Officer of Health.
2. City Council request the Toronto Transit Commission Board to identify medium- and long-term mitigation measures, with a priority on Line 2, that can be implemented to further improve air quality in the Toronto Transit Commission subway system, as described in the report (December 19, 2019) from the Medical Officer of Health, including:
 - a. reviewing operational systems and procedures, such as automatic train control, train frequency, and ventilation systems;
 - b. reviewing procurement specification and deployment plans for replacement trains for future line modernization;
 - c. including consideration of the potential improvements to air quality in the Toronto Transit Commission's study of platform edge doors; and
 - d. monitoring levels of subway PM2.5 and evaluating the PM2.5 mitigation strategies that are implemented.
3. City Council request the Toronto Transit Commission Board to request the Toronto Transit Commission staff to report to City Council on opportunities for air quality improvement in the

Toronto Transit Commission subway system, including a review of emerging information and technology.

4. City Council request the Toronto Transit Commission Board to identify funding requirements through future budget processes to develop and implement further PM2.5 mitigation measures.
5. City Council request Metrolinx to proactively address air quality in future initiatives through consideration of air quality in future station/system design or redesign projects as well as station construction or renovation/reconstruction projects.

Decision Advice and Other Information

The Board of Health:

1. Encouraged Health Canada to continue its research on air quality issues in the Toronto Transit Commission subway system and to establish health-based guidelines for subway PM2.5.
2. Encouraged the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada, the Medical Council of Canada, the Public Health Agency of Canada, and the Transportation Association of Canada to support research into the potential health impacts of exposure to subway particulate matter, with a view to informing subway air quality standards and best practices for supporting passenger health and improving subway air quality.
3. Directed that the report (December 19, 2019) from the Medical Officer of Health be forwarded to the Ontario Ministry of Labour, Training and Skills Development for consideration in any future occupational health standards development.
4. Directed that the report (December 19, 2019) from the Medical Officer of Health be forwarded to the Ontario Ministry of Health, the Ontario Ministry of the Environment, Conservation and Parks, and the Ontario Ministry of Transportation.

Origin

(December 19, 2019) Report from the Medical Officer of Health

Summary

In 2017, the Board of Health requested an independent study of the health impacts of air quality for passengers in the subway system, particularly in relation to mitigation measures that could be implemented.

To understand the overall impact of the Toronto subway on the health of Torontonians, Toronto Public Health carried out a Health Impact Assessment, including a Human Health Risk Assessment of air quality. The Health Impact Assessment concluded that taking the subway is associated with benefits to people's health and wellbeing and is a health-supportive way to travel, especially as an alternative to personal vehicle use. Promoting the use of transit is important because it provides a safer alternative to driving, reduces outdoor air pollution and

greenhouse gases, promotes physical activity, and provides access to employment, education, and social/community services.

The Health Impact Assessment also identified that improving air quality in the Toronto subway system is expected to be associated with health benefits for passengers. Air quality data collected in the Toronto subway system shows that, as is the case for other similar subway systems, levels of fine particulate matter air pollution (PM2.5) are elevated and contain high levels of some metals. The Human Health Risk Assessment, which considered subway PM2.5 overall and individual metal components, concluded that levels of subway PM2.5 warrant mitigation, particularly on Line 2. Other cities with similar systems are also identifying elevated levels of subway PM2.5 and information has been gathered on mitigation options. While a high-level jurisdictional scan shows that Toronto is demonstrating leadership in addressing subway air quality, a continuous improvement approach should be adopted by the Toronto Transit Commission Board to ensure ongoing assessment and improvement of subway air pollution levels in Toronto.

In combination with mitigation actions that can be undertaken in the short-term, developing, implementing, and funding medium- and long-term PM2.5 mitigation measures will improve air quality in the subway and further enhance the health promoting aspects of using public transit. Continued research and collaboration among health, science, transportation, and engineering agencies will fill knowledge gaps within the field of public transit. In particular, a deeper understanding about the relationship between subway PM2.5 and the health of passengers and identification of the most effective mitigation strategies are priority areas of study.

Background Information

(December 19, 2019) Report from the Medical Officer of Health on Subway Health Impacts Study

(<http://www.toronto.ca/legdocs/mmis/2020/hl/bgrd/backgroundfile-141357.pdf>)

Communications

(January 13, 2020) E-mail from Hamish Wilson (HL.New.HL13.8.1)

Speakers

Hamish Wilson

Motions

1 - Motion to Amend Item moved by Trustee Stephanie Donaldson (Carried)

That the Board of Health amend Recommendation 2 so that it now reads as follows:

2. City Council request the Toronto Transit Commission Board to identify medium- and long-term mitigation measures, with a priority on Line 2, that can be implemented to further improve air quality in the Toronto Transit Commission subway system, as described in this report, including:

Vote (Amend Item)

Jan-13-2020

Result: Carried	Majority Required
Yes: 10	Ashna Bowry, Joe Cressy (Chair), Stephanie Donaldson, Mike Layton, Jennifer McKelvie, Kate Mulligan, Gord Perks, Peter Wong, Soo Wong, Kristyn Wong-Tam
No: 0	
Absent: 3	Angela Jonsson, Cynthia Lai, Ida Li Preti

2 - Motion to Amend Item moved by Councillor Joe Cressy (Carried)

That the Board of Health amend Recommendation 6 so that it now reads as follows:

6. The Board of Health encourage Health Canada to continue its research on air quality issues in the Toronto Transit Commission subway system and to establish health-based guidelines for subway PM2.5.

Vote (Amend Item)

Jan-13-2020

Result: Carried	Majority Required
Yes: 10	Ashna Bowry, Joe Cressy (Chair), Stephanie Donaldson, Mike Layton, Jennifer McKelvie, Kate Mulligan, Gord Perks, Peter Wong, Soo Wong, Kristyn Wong-Tam
No: 0	
Absent: 3	Angela Jonsson, Cynthia Lai, Ida Li Preti

3 - Motion to Adopt Item as Amended moved by Councillor Joe Cressy (Carried)

Vote (Adopt Item as Amended)

Jan-13-2020

Result: Carried	Majority Required
Yes: 10	Ashna Bowry, Joe Cressy (Chair), Stephanie Donaldson, Mike Layton, Jennifer McKelvie, Kate Mulligan, Gord Perks, Peter Wong, Soo Wong, Kristyn Wong-Tam
No: 0	
Absent: 3	Angela Jonsson, Cynthia Lai, Ida Li Preti

Source: Toronto City Clerk at www.toronto.ca/council



Subway Health Impacts Study

Date: December 19, 2019

To: Board of Health

From: Medical Officer of Health

Wards: All

SUMMARY

In 2017, the Board of Health requested an independent study of the health impacts of air quality for passengers in the subway system, particularly in relation to mitigation measures that could be implemented.

To understand the overall impact of the Toronto subway on the health of Torontonians, Toronto Public Health carried out a Health Impact Assessment including a Human Health Risk Assessment of air quality. The Health Impact Assessment concluded that taking the subway is associated with benefits to people's health and wellbeing and is a health-supportive way to travel, especially as an alternative to personal vehicle use. Promoting the use of transit is important because it provides a safer alternative to driving, reduces outdoor air pollution and greenhouse gases, promotes physical activity, and provides access to employment, education, and social/community services.

The Health Impact Assessment also identified that improving air quality in the Toronto subway system is expected to be associated with health benefits for passengers. Air quality data collected in the Toronto subway system shows that, as is the case for other similar subway systems, levels of fine particulate matter air pollution (PM_{2.5}) are elevated and contain high levels of some metals. The Human Health Risk Assessment, which considered subway PM_{2.5} overall and individual metal components, concluded that levels of subway PM_{2.5} warrant mitigation, particularly on Line 2. Other cities with similar systems are also identifying elevated levels of subway PM_{2.5} and information has been gathered on mitigation options. While a high-level jurisdictional scan shows that Toronto is demonstrating leadership in addressing subway air quality, a continuous improvement approach should be adopted by the Toronto Transit Commission Board to ensure ongoing assessment and improvement of subway air pollution levels in Toronto.

In combination with mitigation actions that can be undertaken in the short-term, developing, implementing, and funding medium- and long-term PM_{2.5} mitigation measures will improve air quality in the subway and further enhance the health promoting aspects of using public transit. Continued research and collaboration among health, science, transportation, and engineering agencies will fill knowledge gaps within the field of public transit. In particular, a deeper understanding about the relationship

between subway PM2.5 and the health of passengers, and identification of the most effective mitigation strategies are priority areas of study.

RECOMMENDATIONS

The Medical Officer of Health recommends that:

1. City Council request the Toronto Transit Commission Board to implement PM2.5 mitigation measures that can be delivered in the short-term, including actions related to employee awareness and training programs, state of good repair (materials, equipment, procurement, and procedures) and engineering reviews, as described in this report.
2. City Council request the Toronto Transit Commission Board to identify medium- and long-term mitigation measures that can be implemented to further improve air quality in the Toronto Transit Commission subway system, as described in this report, including:
 - a. reviewing operational systems and procedures such as automatic train control, train frequency, and ventilation systems;
 - b. reviewing procurement specification and deployment plans for replacement trains for future line modernization;
 - c. including consideration of the potential improvements to air quality in the Toronto Transit Commission's study of platform edge doors; and
 - d. monitoring levels of subway PM2.5 and evaluating the PM2.5 mitigation strategies that are implemented.
3. City Council request the Toronto Transit Commission Board to request Toronto Transit Commission staff to report to City Council on opportunities for air quality improvement in the Toronto Transit Commission subway system, including a review of emerging information and technology.
4. City Council request the Toronto Transit Commission Board to identify funding requirements through future budget processes to develop and implement further PM2.5 mitigation measures.
5. City Council request Metrolinx to proactively address air quality in future initiatives through consideration of air quality in future station/system design or redesign projects as well as station construction or renovation/reconstruction projects.
6. The Board of Health encourage Health Canada to continue its research on air quality issues in the Toronto Transit Commission subway system.
7. The Board of Health encourage the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada, the Medical Council of Canada, the Public Health Agency of Canada, and the Transportation Association of Canada to support research into potential health impacts of exposure to subway

particulate matter, with a view to informing subway air quality standards and best practices for supporting passenger health and improving subway air quality.

8. The Board of Health forward this report to the Ontario Ministry of Labour, Training and Skills Development for consideration in any future occupational health standards development.

9. The Board of Health forward this report to the Ontario Ministry of Health, the Ontario Ministry of the Environment, Conservation and Parks, and the Ontario Ministry of Transportation.

FINANCIAL IMPACT

There is no financial impact associated with this report beyond what has already been approved in the 2019 Operating Budget for Toronto Public Health.

DECISION HISTORY

At its July 10, 2019 meeting, the Toronto Transit Commission Board received for information, a report from Toronto Transit Commission staff on a 2017-2018 Toronto Transit Commission study of subway air sampling in relation to compliance with provincial Occupational Health and Safety Act occupational exposure standards for employees. This report was subsequently forwarded to the Board of Health.

http://ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2019/July_10/Agenda/index.jsp

At its September 5, 2017 meeting, the Toronto Transit Commission Board received for information, a report from Toronto Transit Commission staff outlining a plan to fulfill requests of the Toronto Transit Commission Board (on May 18, 2017) and the Board of Health (on May 17, 2017) for a study on the potential impacts of air quality issues in the Toronto Transit Commission subway system (see details below).

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2017/September_5/Agenda/index.jsp

At its May 18, 2017 meeting, the Toronto Transit Commission Board moved referral of a motion to request a joint report from Toronto Transit Commission and Toronto Public Health staff on ways and means to study the potential impacts of air quality issues in the subway system and whether other major subway systems have undertaken similar work.

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2017/May_18/Agenda/index.jsp

At its May 17, 2017 meeting, the Board of Health directed that the Medical Officer of Health work with the Toronto Transit Commission (if requested and funded) to oversee an independent study of the health risks for passengers of air quality issues in the subway system, particularly in relation to mitigation measures that could be implemented.

<http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2017.HL19.15>

COMMENTS

Assessing health impacts of subway air quality

In 2017, Health Canada reported levels of air pollution in the Toronto Transit Commission (TTC) subway system that were elevated compared with outdoor air¹. Also in 2017, the Toronto Board of Health requested that Toronto Public Health (TPH) oversee an independent study of the health risks of air quality for passengers in the subway system, particularly in relation to mitigation measures that could be implemented. The study does not apply to occupational exposures as these are under the jurisdiction of the TTC and outside the authority of Toronto Public Health.

The study included three components:

- Health Impact Assessment (HIA) - an established process to identify potential positive and negative public health impacts of a project or policy. In this case, the HIA was conducted to ensure a full understanding of the health impacts of using the TTC subway system, including a focused assessment of potential risks arising from exposure to subway air pollution.
- Human Health Risk Assessment (HHRA) - an established methodology to assess the type and likelihood of negative health effects occurring among people who may be exposed to environmental pollutants (in this case, subway air pollution).
- Expert Panel Consultation - used to gather advice on methodological challenges of conducting a HHRA of subway air pollution, especially with respect to characterizing the risk from subway Particulate Matter (PM2.5), which is higher in metals than outdoor air, given limited research and a lack of subway-specific health benchmarks, as well as accounting for the intermittent exposure patterns usually associated with subway use.

The full HIA report, including a summary of the HHRA findings as well a full technical HHRA report and a summary of the Expert Panel Consultation, is available at www.toronto.ca/health/reports.

In addition, TPH consulted with the TTC about potential mitigation measures that could be implemented to improve subway air quality.

The TTC subway system supports individual, community, and environmental health

The HIA found that Toronto's subway system provides a range of benefits to people's health and wellbeing. Taking the subway is a health-supportive way to travel, especially as an alternative to personal vehicle use. It is associated with fewer injuries than driving,

reduces outdoor air pollution and greenhouse gases, promotes physical activity and provides access to employment, education and social/community services.

Reducing traffic-related health impacts

Subway use benefits the health of all Toronto residents because it reduces vehicle use and congestion in Toronto. The TTC estimates that during rush hour, each subway train replaces 900-990 personal vehicles that would otherwise be on the road². Vehicles emit air pollutants that contribute to heart and lung disease as well as greenhouse gases, which contribute to climate change. Local health impacts expected with climate change include increased incidence of heat-related illness and premature death; injury and water-borne diseases arising from severe weather events; increase in vector-borne diseases; food system impacts including food insecurity and food-borne illness; and cardiovascular and respiratory illness from degraded air pollution³. Use of public transit including the subway system reduces these risks.

Increasing active transportation and travel safety

Subway use also provides health benefits specifically for commuters. People who use transit are likely to include walking as part of their commute, resulting in an increase in regular, routine physical activity, which has been shown to reduce mortality of chronic diseases such as heart attacks, strokes, diabetes and some types of cancers⁴. As well, using the subway is associated with a lower probability of fatality or injury as compared with travel in personal vehicles. For example, in 2018, there were 66 people killed and 346 seriously injured in Toronto in personal vehicle collisions⁵, whereas the TTC recorded only three non-suicide fatalities and estimated ridership injury incidents to be 1.07 per one million boardings for all injury types system-wide, with injury rates declining in recent years^{6,7}.

Ensuring access to health-supportive services

Access to the TTC subway system supports access to employment opportunities, education, and health services that contribute to overall health and well-being. For example, the TTC reported that 21 percent of subway rides in 2018 were between home and school⁸. In a 2012 survey, public transportation was the most commonly used mode of transportation to employment and skills training (66 percent) and language training (49 percent) amongst Toronto's immigrant and refugee population⁹. Affordable subway access to recreational and cultural programs can promote children's health and wellness, and has the potential to increase individual and social cohesion. Affordable and reliable public transportation, including subway access, is especially important for low-income families.

Air quality and health in the subway

The HIA also considered health impacts related to air quality specifically. Many indoor and outdoor air pollutants affect health. The main pollutant of concern for health in the Toronto subway system is PM2.5, or fine particulate matter^{1,10}. PM2.5 includes all solid and liquid droplets suspended in air with a diameter of 2.5 micrometres or less (about 30 times smaller than that of a human hair). PM2.5 can include aerosols, smoke, fumes, dust, ash, pollen and metals. Subway PM2.5 is characterized by high levels of some metals, making it different from outdoor air.

Data about PM_{2.5} were collected in the TTC subway system during 2017-2018 by Health Canada through a project called the Subway Air Quality Initiative¹¹. This information was used, along with information about the typical amount of time a passenger spends both on the platform and in the train to identify the average PM_{2.5} exposure level for a passenger on a typical subway trip. Taking these factors into account, the estimated acute PM_{2.5} exposure concentration for the combined system of Line 1 and Line 2 during weekday rush hours was 130 µg/m³. Other cities with similar systems are also identifying elevated levels of subway PM_{2.5} and information has been gathered on mitigation options. This report makes specific recommendations of short-, medium- and long-term actions for the Toronto Transit Commission Board to implement.

Characterizing health risk from subway PM_{2.5}

The human health risk assessment (HHRA) followed established methodologies to characterize population health risk due to environmental contaminants. It considered potential long-term and short-term effects of subway PM_{2.5}, and of individual metal components of subway PM_{2.5} (arsenic, barium, cadmium, chromium, cobalt, iron, manganese, nickel, and silver) that were chosen based on their presence in subway PM_{2.5} as well as their potential to affect health.

There are currently no health-based standards or guidelines for assessing passenger risk from subway PM_{2.5}. Recognizing a need to pursue further studies in this area, the approach taken in the HHRA is informed by available research¹², and advice from the Expert Panel convened by TPH. Both indicate that although the composition of subway PM_{2.5} is different than that found in outdoor air, its health effects are assumed to be similar.

The links between exposure to outdoor PM_{2.5} and health include symptoms and morbidity related to heart and lung disease such as reduced lung function, asthma attacks, emergency room visits and for respiratory and cardiac causes, elevated mortality rates, and reduced life expectancy. People who are especially sensitive to PM_{2.5} include those with heart or lung conditions such as coronary artery disease, asthma, or chronic obstructive pulmonary disease, older adults, and children. PM_{2.5} is a non-threshold contaminant, which means that there is some potential for health impact at all levels of exposure, and any reductions in exposure offer health benefits.

A full discussion of the methodology and constraints related to comparing subway air quality to outdoor PM_{2.5} is available online in the full HHRA technical document.

There is also evidence of an association between exposure to some metals that are found in subway PM_{2.5} and health outcomes, including both potential cancer and non-cancer risks. The approach taken in the HHRA reflects the Expert Panel's recommendations to characterize risks from subway PM_{2.5} overall and also cancer and non-cancer risks related to the metals exposures, which is similar to approaches taken elsewhere¹³.

Improving subway air quality offers health benefits to passengers

Overall, the results of the assessment indicate that the levels of PM_{2.5} and several of its metal components are high enough to warrant mitigation, particularly on Line 2. Because there is no threshold for PM_{2.5} health impacts, all reductions in PM_{2.5} levels would have potential health benefits. As well, because the metals are components of PM_{2.5}, any efforts to mitigate PM_{2.5} overall will result in decreased levels of the metals.

The HHRA identified that the PM_{2.5} levels measured in the TTC subway are expected to be associated with both short-term and long-term health impacts, including elevated risk of mortality, respiratory and cardiovascular disease, and transient respiratory symptoms. Transient respiratory symptoms can include coughing, shortness of breath, chest tightness, general asthmatic symptoms and/or a temporary decline in lung function, particularly for sensitive groups such as children and adults with asthma and adults with chronic obstructive pulmonary disease (COPD).

Given that subway PM_{2.5} is comprised of a higher concentration of metals as compared with outdoor air, the potential health impacts of exposure to the metals were also explored. Of the nine metals that are found in the greatest concentrations in subway PM_{2.5}, none of them were associated with an increased risk of non-cancer health effects. Three metals (arsenic, cadmium, and chromium) were associated with cancer risk levels above one in a million. In comparison, background incidence of cancer in Canada is approximately 4 in ten. Exposure to metals in subway PM increases this lifetime cancer risk from 4 in ten up to 4.0006 in ten. Mitigation efforts that reduce overall PM_{2.5} are recommended as they will also reduce the presence of metals that are components of PM_{2.5}.

Mitigation is especially important for Line 2

The estimated health impacts from exposure to subway PM_{2.5} were higher for Line 2 (Bloor-Danforth) than Line 1 (Yonge-University-Spadina). Taking into account time spent both on the train and on the platform, the estimated acute PM_{2.5} exposure level during weekday rush hours for Line 1 is 85 µg/m³ and Line 2 is 183 µg/m³. Given this difference, Line 2 needs to be a priority for a range of mitigation measures, including future line modernization.

Further details about these findings are available online in the full HHRA technical document.

Opportunities to reduce PM_{2.5} levels in the subway system

There are several opportunities to reduce PM_{2.5} levels in the subway system. This report recommends that City Council request the Toronto Transit Commission Board to implement short-term mitigation measures to improve air quality. This includes actions related to employee awareness and staff training, for example, about braking practises given that much of the PM_{2.5} in the subway system is expected to be associated with friction generated during braking. Other measures include those related to state of good repair such as consideration of materials, equipment, procurement, and procedures to ensure that critical infrastructure is maintained and incorporates air quality mitigation. Incorporating PM_{2.5} mitigation strategies as part of engineering reviews is another

recommended action as it provides an opportunity for mitigation as part of existing problem-solving approaches and the introduction of new technologies.

In addition, TPH identified potential subway PM2.5 medium- to long-term mitigation measures based on a review of the literature and activities reported by other subway systems. Commonly suggested measures include reviewing and upgrading ventilation and filtration on platforms and in tunnels, reviewing or upgrading on-train ventilation systems, implementing platform-edge doors, adjusting tunnel and track maintenance activities, procuring and using alternative materials for moving parts, measures to reduce brake and wheel emissions, considering air quality issues in system and station design, and conducting additional research including monitoring for PM2.5 and intervention effectiveness^{10,14,15}. As well, the HHRA findings for the TTC suggest that given the differences observed between Lines 1 and 2, Line 2 needs to be a priority for mitigation measures, including future line modernization. The HIA noted differences between the two Lines, including different train types on each line and the use of automatic train control on Line 1. Both are recommended for further exploration in terms of the impact on air quality.

Some mitigation initiatives are currently underway, and others warrant further exploration. Reviewing emerging research, and considering effectiveness, feasibility, and costs associated with implementation will enable the TTC to recommend and implement mitigation measures for the short, medium, and long-term to improve air quality for all riders.

Filling information gaps about subway air quality

The best available research about potential health risks from exposure to subway air was used to inform this report's recommendations. Further research to support development of subway-specific benchmarks or guidelines would enable improved understanding of the specific health risks of subway PM2.5. There is also a need to identify and evaluate mitigation activities suitable for different subway systems and environments. These challenges are not unique to Toronto, and in London UK, new exposure studies are planned and being funded by the Country's Medical Research Council¹⁵. Furthermore, the Paris subway system is piloting innovative PM2.5 reduction technologies such as giant filters to purify the air¹⁶. Canadian health, transportation, and other research agencies need to be aware of the importance of supporting new research about subway PM2.5 and its impacts on passengers. As this is an emerging area of research, the TTC's PM2.5 mitigation efforts will benefit from ongoing review of new information and technology.

In particular, Health Canada has played a role in gathering air quality data in the TTC subway system in two separate air quality monitoring campaigns, and has an interest in encouraging healthy, transit supportive environments. Their continued collaboration with the TTC to develop an increased understanding of health and air quality issues and to evaluate the effectiveness of air quality mitigation activities should be encouraged. This approach will inform the further development and implementation of effective PM2.5 mitigation measures.

The health risk assessment approach used to characterize lifetime environmental health risk for passengers, including vulnerable groups, is very different from the process for occupational assessments, which in comparison, address set timeframes for healthy workers and rely on legislated occupational standards to prevent illness or certain effects in industrial situations. Given that there are currently no established occupational limits for PM2.5 in the subway environment, it is recommended that this report be shared with the Ontario Ministry of Labour for consideration in any future standards development efforts.

Overall, a number of opportunities exist to improve subway air quality in Toronto, with benefits for health. TTC's commitment to continuous improvement is an approach that can offer benefits in the near-term and that will continue to accrue over time. As further information is gathered about the TTC subway system specifically, and by other subway air quality projects internationally, it will advance this evolving area within the field of public transit.

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