Cumulative Health Impact Assessment of Air Quality

Toronto Public Health, February 2014

As a complement to the air modelling study conducted by Toronto's Environment and Energy Division (EED) for Etobicoke-Lakeshore (Wards 5 and 6), Toronto Public Health (TPH) prepared a health assessment estimating the cumulative health impacts of air pollution in the area. The health assessment considered the thirty pollutants included in EED's air quality model, which includes the 25 priority substances in Toronto's Environmental Reporting and Disclosure Bylaw (ChemTRAC program) and five other common air pollutants.

This is the second local air quality study conducted for Toronto. The first study was completed for South Riverdale, Leslieville, and the Beach. Toronto Public Health's full assessments of both studies are available at http://www.toronto.ca/health/reports). Each local air quality health assessment report covers:

- The background of the study;

- The modelling approach used and substances chosen for the air quality assessment;

- The health impacts, including the methods and findings; and

- A discussion of the results of the study.

Air modelling studies typically compare the estimated levels of pollutants against air standards or health benchmarks to identify if releases could result in levels of concern in a specific area. The predicted ambient concentrations of most the individual pollutants considered in this study were below Ontario's Ambient Air Quality Criteria (AAQCs). However, the model predicted that levels of nitrogen dioxide (NO_2), coarse particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), benzene, and benzo[a]pyrene[1] (used as an indicator of polycyclic aromatic hydrocarbons) might exceed air quality objectives in some areas, some of the time. The modelling study showed that transportation is the largest local source of these pollutants.

As people are exposed to a mixture of pollutants, it is useful to also consider the combined impacts of these pollutants, even when most are individually below levels of concern. The science for assessing the health impacts of mixtures of chemicals continues to evolve and there is no common approach to combined exposures from the complete range of substances considered in this study. This study grouped pollutants according to similar mechanisms of action. This resulted in three categories of health effects, with the

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[1] The findings for benzo[a]pyrene require further review and validation.

cumulative impact estimated for each group of pollutants separately. These categories were:

1) Substances associated with non-cancer effects, for which there is a health threshold;

2) Substances associated with cancer; and

3) Common air contaminants (CACs), which are mainly associated with cardiovascular and respiratory diseases, and which are assumed to have no health threshold.

The results of these separate cumulative assessments are described below.

1) Cumulative risk for non-cancer effects

In this study, non-cancer health effects include neurological, immunological, and developmental health impacts. In general, for non-cancer effects it is assumed that there is a threshold of effect – a level below which exposure to the substance will have no adverse health impacts. By comparing an exposure level with the threshold, it is possible to assess whether a health impact is expected.

Each pollutant considered in the health assessment has a different threshold. To be able to compare them all on the same scale, a measure called the *hazard ratio* is obtained for each pollutant by dividing the exposure level for that pollutant by its health threshold. If the hazard ratio is less than one, then a person or community is being exposed at a level which current knowledge suggests is not a concern. As well, hazard ratios for multiple substances can be added to estimate a cumulative hazard.

Of the 30 substances included in EED's modelling study, 22 are potentially associated with non-cancer health effects. The hazard ratio values for each of the individual non-carcinogenic substances are all much less than one; nickel had the largest hazard ratio at 0.1. This confirms that there is little or no risk of adverse health effects from exposures to these substances individually. When the hazard ratios for the 22 pollutants were added together, the cumulative hazard index is 0.42; this is still well below one. This suggests that the combined exposure to these air pollutants do not pose a health risk for non-cancer effects.[2]

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[2]   There are limitations to this approach. It assumes that the effect of the individual pollutants is in direct proportion to the level of exposure and the effect of each pollutant is additive. In some circumstances, this could overestimate the risk since it does not take into account that different pollutants affect different parts of the body and ignores the natural mechanism of the body to eliminate or detoxify these substances. At the same time, the approach could underestimate the risk since it does not take into account potential interactions between these pollutants that could increase the health impacts.

2) Cumulative risk of cancer

Carcinogens are substances that are associated with an increased risk of developing cancer over a person's lifetime. For carcinogens, it is assumed that every amount of exposure has a risk of causing cancer. Low levels of exposure are associated with low levels of risk, and the risk rises as exposure increases. The risk of cancer for a single carcinogen is calculated by multiplying the level of carcinogen in the air by a risk factor that represents the likelihood of developing cancer over a lifetime. A risk of one in a million means that one out of every million people exposed would be expected to develop cancer during their lifetime. Toronto Public Health encourages actions to reduce exposures when the risk is above one in one million.

In this study, eight of the 19 carcinogens had modeled annual concentrations above the one in one million excess lifetime cancer risk benchmark in parts or the whole of the two wards. These carcinogens were: benzene, chromium (VI), 1,3-butadiene, tetrachloroethylene (or perchloroethylene), formaldehyde, 1,4-dichlorobenzene, acetaldehyde, and benzo[a]pyrene. Toronto Public Health has low confidence in the results for one of the carcinogens, benzo[a]pyrene. The City will gather additional information to verify the estimate of risk for this substance. Except for two of the substances (chromium and tetrachloroethylene), vehicles (on and off-road) are the largest local source of these carcinogens.

The estimated risk for the carcinogens, excluding benzo[a]pyrene, was added to give a total estimate of the risk. When the average annual risk is summed across these 18 carcinogenic substances, the average cumulative cancer risk in these two wards is 44 in one million. While 44 in a million is greater than the benchmark that TPH uses for individual cancer risk, the total risk is still quite small. This total risk is less than two percent of the overall cancer incidence rate in Toronto – which was around 400 per 100,000 in 2007. However, because benzo[a]pyrene was excluded from the risk estimates until further validation is possible, this value is expected to be an underestimate of the average cancer risk in the area.

While the cumulative risk was above the one in a million cancer risk benchmark in all parts of the two wards, the areas with more elevated risks tend to be close the Gardiner Expressway and Highway 427. The elevated risk next to these highways is mostly from benzene and 1,3-butadiene. Although the contribution of benzo[a]pyrene to cancer risk was removed from the model pending further validation, this pollutant is also expected to contribute to cancer risk near major transportation corridors.

Overall, the largest part of the total estimated cancer risk in these two wards comes from benzene and chromium (VI). Benzene emissions arise mainly from transportation sources. Most of the chromium comes from sources outside Toronto and thus is a health risk that is likely common to all parts of the city.

3) Cumulative risk from common air contaminants (CACs)

Common air contaminants (CACs) are a group of air pollutants that are mainly associated with respiratory and cardiovascular health outcomes. There is no established threshold for the health effects from these five CACs, which are carbon monoxide, ozone, nitrogen dioxide, particulate matter (PM) and sulphur dioxide. Therefore, TPH used an approach similar to the one used for carcinogens to estimate the cumulative risk from this group of pollutants. Instead of excess cancer risk, TPH used the estimate of excess risk of premature death to calculate the cumulative impact. Premature death was selected because it is the most severe health outcome associated with exposure to CACs. Findings of elevated risk of premature death from cardiovascular and respiratory disease suggest that risk of other outcomes related to heart and lung conditions will also be elevated.

The cumulative excess risk of premature mortality attributable to the CACs is 7.4 per cent. That is, together they increase the existing mortality rate for respiratory and cardiovascular diseases by this amount. Fine particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) are the pollutants that contribute most to this risk.

Figure 1 shows the spatial distribution for health risk from CACs. Similar to the analysis for carcinogens, there is higher risk from exposure to CACs in the area close to the local highways including Highway 427. There are also several industrial sources in the area that appear to emit CACs. Changes have taken place in the industrial facilities in the study area since the emissions data was compiled for this study. Several local industries have reduced their emissions of particulate matter and nitrogen oxides, and in the case of the most concentrated area of elevated risk located North of the Queensway and East of Kipling, the main facility associated with CAC emissions in that area is now closed.

Figure 1: Pattern in increased risk of premature mortality from cardiovascular and respiratory causes as a result of exposure to CACs
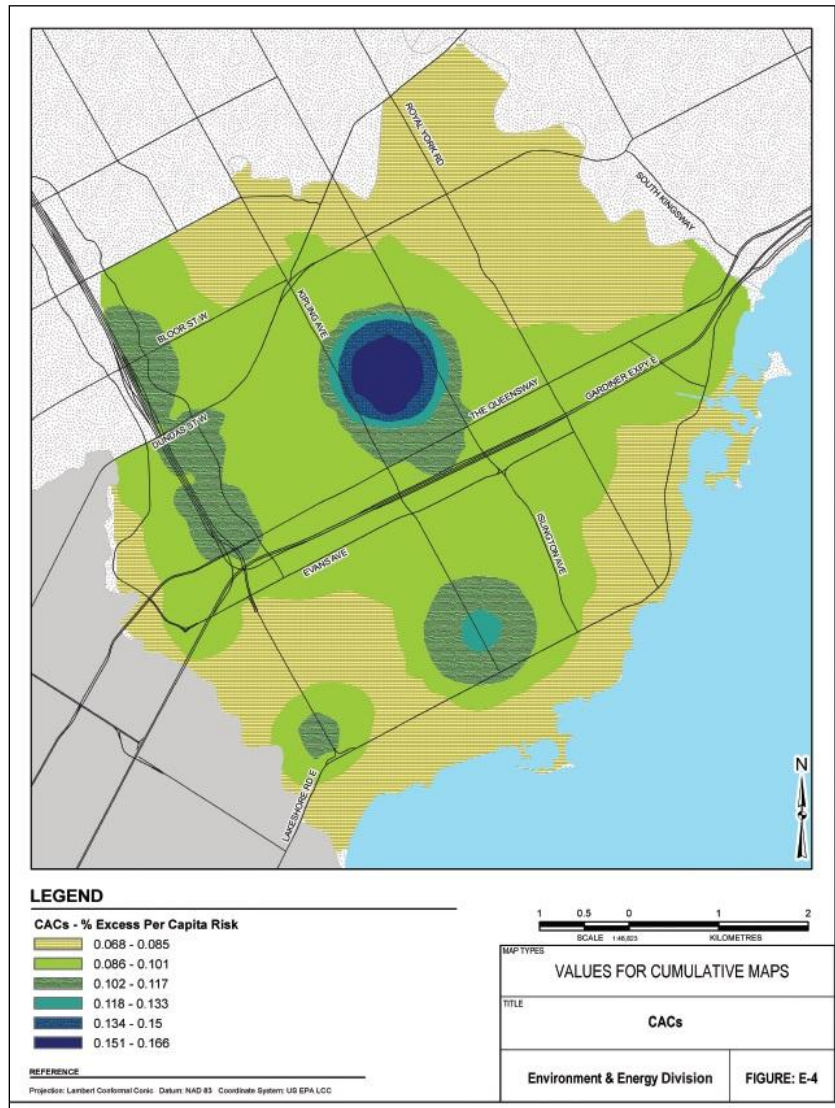
How does this compare with the rest of the City?

The findings from the two local air quality studies that have been completed to date (South Riverdale, Leslieville and the Beach, and Etobicoke-Lakeshore) show similar patterns. In both, the same five substances exceed ambient air quality criteria or standards. Table 1 shows that the calculated cumulative health risks are of similar magnitude in both areas. Given that some uncertainty is inherent in any modelling exercise, it is reasonable to conclude that there may not be much difference in average risk for these two areas. In the case of carcinogens, benzene, chromium, and 1,3-

butadiene are all among the top contributors to health risk in both areas. Among the CACs, $PM_{2.5}$ and NO_2 are the primary contributors to excess risk in both neighbourhoods. As well, transportation is an important source of local pollution and related health risk in both areas.

Table 1: comparing health risks from air pollution in two Toronto neighbourhoods

Type of Health outcome	South Riverdale and Beach	Etobicoke-Lakeshore
Noncancer (eg.,immunological, neurological, developmental)	No risk	No risk
Cancer	83 in one million[*]	44 in one million*
Respiratory and Cardiovascular	8.9% increase	7.4% increase

[*] The cancer risk results are not directly comparable between neighbourhoods, as the findings from South Riverdale and the Beach include the contribution of Benzo[a]pyrene, while those from Etobicoke-Lakeshore do not. TPH is reviewing the B[a]P findings from both studies.

Conclusions

This health assessment suggests that many of the thirty air contaminants selected for this study, mainly the non-carcinogenic ones, occur below levels of concern to health in Wards 5 and 6 even when the combined exposure is taken into account. However, there is an indication that some carcinogens are present at levels above the one in one million excess cancer risk benchmark. Other pollutants such as ozone, nitrogen dioxides, and particulate matter are also found at levels that are known to have an adverse impact on health. For many substances of greatest concern, both among those related to cancer, and those related to cardiovascular and lung disease, the locally generated emissions are mainly from transportation sources. Therefore, it is important to continue efforts to reduce air pollution from both on and off-road transportation sources.

The study and modelling used to estimate cumulative health effects have several limitations. It is difficult to compare the multiple health impacts into a single measure of health risk for the community. As the modelling is based on one year, 2006, the lifetime risk of diseases such as cancer are being estimated based on the air quality situation from one year. This assessment cannot account for past exposures from sources in the community that may contribute to current and future health problems.

This study is a way of assessing cumulative health risks from multiple pollutants for a specific neighbourhood within a large urban area. The contribution of pollution from different geographic areas and sectors to health risks at the local level was also assessed. Newly available data available about emissions from the small commercial and industrial sources of air pollutants in the area of study will improve the air quality model. This data is being collected through the Environmental Reporting and Disclosure Bylaw (ChemTRAC program) and will help improve future estimate of the cumulative exposure in these and other Toronto neighbourhoods. The results aid in setting priorities and

determining effective strategies for pollution prevention to reduce exposures and improve the health of Toronto residents.

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