

Air Quality Study: Toronto Environment Office

Background

At the request of the Board of Health, the Toronto Environment Office undertook an air modelling study for the South Riverdale and Beaches neighbourhoods of Toronto.

The study modelled air concentrations for 25 priority substances in Toronto's Environmental Reporting and Disclosure Bylaw (ChemTRAC program) and five other air pollutants in Wards 30 and 32, which include these two neighbourhoods.

Pollutants emitted in Toronto, Southern Ontario and North eastern U.S. were included in the study, as were emissions from all sources including industrial, commercial, residential, agricultural, natural, and transportation-related.

Table 1: The 30 pollutants included in the study model

1. Acetaldehyde	11. 1,2-Dichloroethane	21. PAHs (as B[a]P)
2. Acrolein	12. Dichloromethane	22. PM _{2.5}
3. Benzene	13. Ethylene dibromide	23. Tetrachloroethylene
4. 1,3-Butadiene	14. Formaldehyde	24. Toluene
5. Cadmium	15. Lead	25. Trichloroethylene
6. Carbon tetrachloride	16. Manganese	26. Vinyl Chloride
7. Chloroform	17. Mercury	27. Carbon Monoxide (CO)
8. Chloromethane	18. Nickel compounds	28. PM ₁₀
9. Chromium;	19. Nitrogen Dioxide	29. Sulphur Dioxide
10. 1,4-Dichlorobenzene	20. Ozone	30. VOC (anthopogenic/biogenic)

Key findings

The air modelling study compared 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.

- For 26 of the 30 pollutants modelled, the predicted ambient concentrations of the individual pollutants were below Ontario's Ambient Air Quality Criteria (AAQCs).¹
- Four of the 30 pollutants modelled may exceed either 24-hour or annual AAQC standards in some areas, some of the time. They are:
 - nitrogen oxides;
 - fine particulate matter;
 - PAHs (polycyclic-aromatic hydrocarbons) as represented by B[a]P (benzo[a]pyrene); and
 - benzene.
- The most significant sources of the four pollutants that may exceed standards in the study area are emissions from road vehicles, particularly vehicles on the Don Valley Parkway, and emissions from local industry. See Table 2 (page 4) for more information on sources.

¹ AAQCs are acceptable contaminant concentration levels, as set by the Ministry of the Environment. AAQCs are set at a level below which adverse health and/or environmental effects are not expected.

Four Pollutants of Concern

1. Nitrogen Oxides

Nitrogen oxides (NO_x) in the ambient air consist primarily of nitric oxide (NO) and nitrogen dioxide (NO₂). These two forms of gaseous nitrogen oxides are significant pollutants of the lower atmosphere. Another form, nitrous oxide (N₂O), is a greenhouse gas. At the point of discharge from man-made sources, nitric oxide, a colorless, tasteless gas, is the predominant form of nitrogen oxide. But nitric oxide is very readily and quickly converted to nitrogen dioxide by chemical reactions in air, and especially with ozone in the air. Typically, nitrogen oxides (NO_x) are modelled and monitored as nitrogen dioxide (NO₂).

Sources: In urban areas, sources are mostly man-made sources (see Table 2, page 4) including automobile and truck exhaust, furnace and boiler flues, as well as many manufacturing and industrial activities, including power generation. Indoors, NO₂ is released from unvented gas stoves, other gas appliances and kerosene heaters.

Health Effects: Nitrogen dioxide (NO₂) is a common air pollutant that contributes to formation of smog and is an important contributor to the burden of illness from air pollution in the Toronto area. Both NO₂ and smog are linked to cardiovascular and respiratory illness and death. Exposure to NO₂ affects mainly the respiratory system, causing irritation and decreasing the ability of the lungs to fight infection. People with asthma and bronchitis, young children, older adults, and adults with heart and respiratory disorders are especially sensitive to the adverse effects of NO₂ exposure.

2. Fine Particulate Matter (including PM₁₀ and PM_{2.5})

Fine particulate matter, which includes dust, dirt, soot, smoke, and liquid droplets emitted into the air, is small enough to be suspended in the atmosphere, and the finest particles can remain suspended almost indefinitely. Airborne particulates are typically a complex mixture of organic and inorganic substances. Fine particles are identified as particulate matter smaller than 10 microns diameter (PM₁₀) and particulate matter smaller than 2.5 microns diameter (PM_{2.5}). PM₁₀ includes the smaller PM_{2.5} fraction.

Sources: The fine particles between 10 microns and 2.5 microns come mostly from construction dust and road dust in almost equal proportions. Road dust is created by tire wear and asphalt wear. The finer fraction of particulates, smaller than 2.5 microns) come mostly from combustion of vehicle fuels and building heating fuels, therefore vehicle tail pipes and furnace and boiler flues. But PM_{2.5} can also come from industrial processes. PM₁₀ and PM_{2.5} are also released indoors from furnaces, gas stoves, and wood stoves, and from cigarette smoke, cooking, and mould growth.

Health Effects: PM₁₀ and PM_{2.5} are linked to both respiratory and cardiovascular effects and are important contributors to burden of illness from air pollution in Toronto. Fine particulate matter can also irritate peoples' eyes, throats and lungs. People who are susceptible to the effects of particulates include the elderly, people with existing respiratory disease such as asthma, chronic obstructive pulmonary disease and bronchitis, people with cardiovascular disease, people with infections such as

pneumonia, and children. $PM_{2.5}$ is also a component of smog. $PM_{2.5}$ and smog are linked to cardiovascular and respiratory illness and death.

3. Polycyclic-Aromatic Hydrocarbons (PAHs), as represented by concentrations of Benzo[a]pyrene (B[a]P)

Benzo[a]pyrene is one member of a large group of polycyclic-aromatic compounds (PAHs). Benzo[a]pyrene is not manufactured and has no industrial uses. It is present in the air as a consequence of its formation during the combustion of organic matter. B[a]P is typically used to represent the concentration of all PAHs because where B[a]P is found, other PAHs are probably also present. In ambient air pollution, B[a]P (and all other PAHs) is normally present as fine particulates. Benzo[a]pyrene (B[a]P) is often used to represent a group of PAHs because it is the most toxic member of the PAH family of compounds.

Sources: B[a]P is created by combustion of organic matter. In urban areas the most obvious sources are the combustion of fossil fuels including natural gas in furnaces and boilers, as well as gasoline and diesel fuel in road vehicles. B[a]P can also be emitted indoors in cigarette smoke and from fireplaces, wood stoves, gas burning appliances and kerosene space heaters.

Health Effects: The health effects and degree of risk depends on the specific mixture of PAHs. Studies in humans exposed to mixtures that include PAHs suggest that long-term exposure to airborne PAHs increases the risk of lung cancer. In animal studies, inhalation exposure to PAHs is associated with increased incidence of cancer of the respiratory tract.

4. Benzene

Benzene is an aromatic hydrocarbon that is produced by the burning of natural products. It is a component of products derived from coal and petroleum and is found in gasoline and other fuels. Benzene is used in the manufacture of plastics, detergents, pesticides and other chemicals.

Sources: Industrial plants and facilities that manufacture, use, or distribute oils or lubricants commonly release benzene to air. Benzene is released during the production, storage, transport, venting, and combustion of gasoline (as in road vehicles). Benzene is also released during the manufacture of asphalt roofing tiles and from cement kilns. Cigarette smoke is a source of benzene indoors.

Health Effects: Long-term exposure to low levels of benzene increases the risk of developing cancer. Benzene is mainly linked to acute myeloid leukemia, a cancer of the blood system. Exposure to benzene may also impair blood chemistry and blood cell function.

Table 2: Sources of the four pollutants of concern in the study area

Air Pollutant	North East USA ¹	Southern Ontario	TORONTO				
			Industrial	Residential & Commercial	On Road Vehicles	Off Road Vehicles	Biogenic & Agriculture
Oxides of nitrogen (NO _x)	22%	21%	5.2%	11.30%	32.6%	7.9%	0%
PM ₁₀ ²	30%	20%	5.1%	6.40%	36.3%	2.2%	0%
PM _{2.5} ²	32%	20%	10.9%	16.00%	16.0%	5.1%	0%
PAHs (as B[a]P) ³	68%	8%	0.07%	0%	23.9%	0%	0%
Benzene	26%	19%	8.7%	0%	39%	8.3%	0%

Cumulative Health Assessment: Toronto Public Health

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. For most of the substances modelled, the predicted ambient concentrations of the individual pollutants considered in this study were below Ontario's Ambient Air Quality Criteria (AAQCs). The model predicted that levels of benzene, nitrogen dioxides, polyaromatic hydrocarbons (PAH, measured as benzo[a]pyrene) and particulate matter (PM₁₀) 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 assess the risk of combined exposure from the complete range of substances considered in this study. Therefore pollutants in this study were grouped into three categories and the cumulative impact estimated for each group of substances separately. These categories were:

- 1) Toxic 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 premature death and increased hospitalization from cardiovascular and respiratory diseases.

Conclusions

This health assessment indicates that many of the 30 air contaminants selected for this study, mainly the non-carcinogenic ones, occur below levels of concern to health in Wards 30 and 32 even when the combined exposure is taken into account. However, it is possible 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. These pollutants are produced during combustion of fuels, for example, in vehicles and in furnaces for space heating. For many substances of concern, such as benzene, 1,3-butadiene, and nitrogen dioxides, 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.

This study assesses cumulative health risks from multiple pollutants for a specific neighbourhood within a large urban area. For the first time, the contribution of pollution from different geographic areas and sectors to health risks at the local level was assessed. The results aid in setting priorities and determining effective strategies for pollution prevention to reduce exposures and improve the health of Toronto residents.

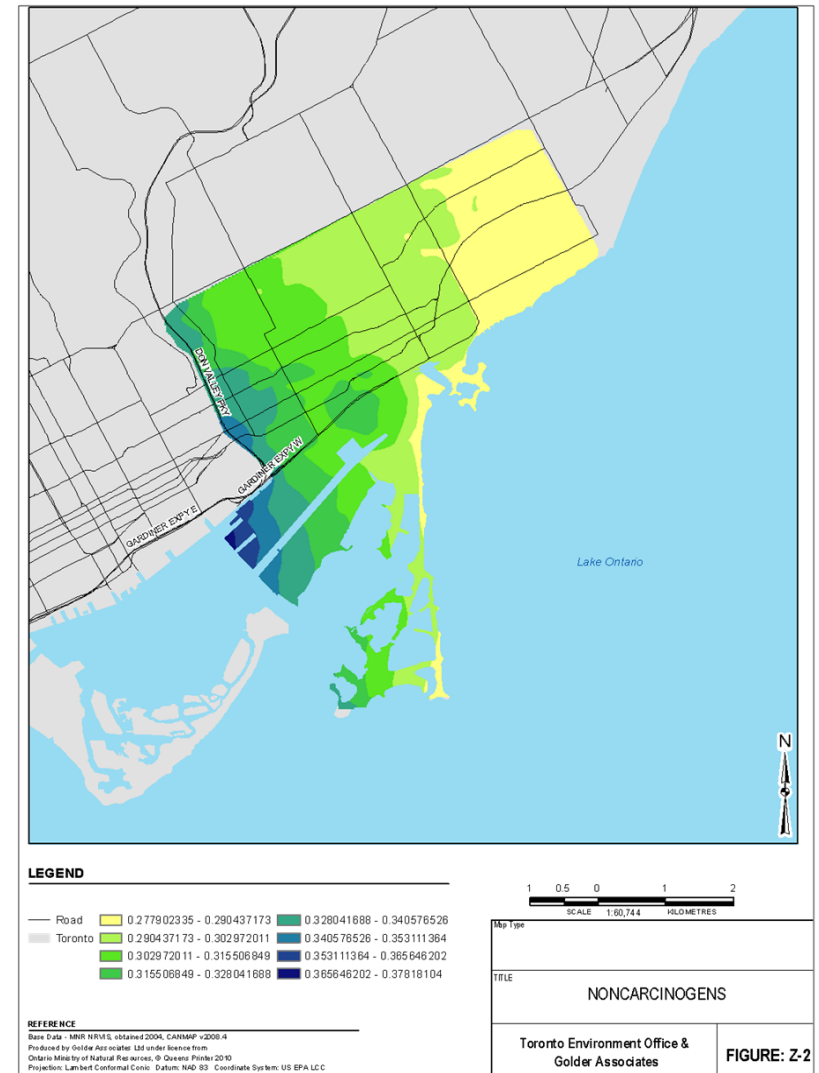
Cumulative risk for non-cancer effects

In general, for non-cancer effects, it is assumed that there is a threshold – a level below which exposure to the substance will have no adverse health impacts. The health benchmark is set at this level. Since substances have different levels of toxicity it is not possible to just add the modelled air concentrations to estimate the cumulative impacts; a common measure is needed. One such measure is the *hazard ratio*, which is obtained by dividing the exposure level with the health benchmark for each pollutant. For each substance this tells us what fraction of the health benchmark a person might be exposed to. 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.

The hazard ratio was calculated for 22 substances with health benchmarks for non-cancer effects. The hazard ratio values for the individual non-carcinogenic substances are all much less than one; acrolein 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 0.31; this is still well below one. This suggests that the combined exposure to these air pollutants does not pose a health risk for non-cancer effects.²

² Limitations of the health assessment: 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.

Modelled distribution of cumulative risk from non-carcinogens



Cumulative risk of cancer

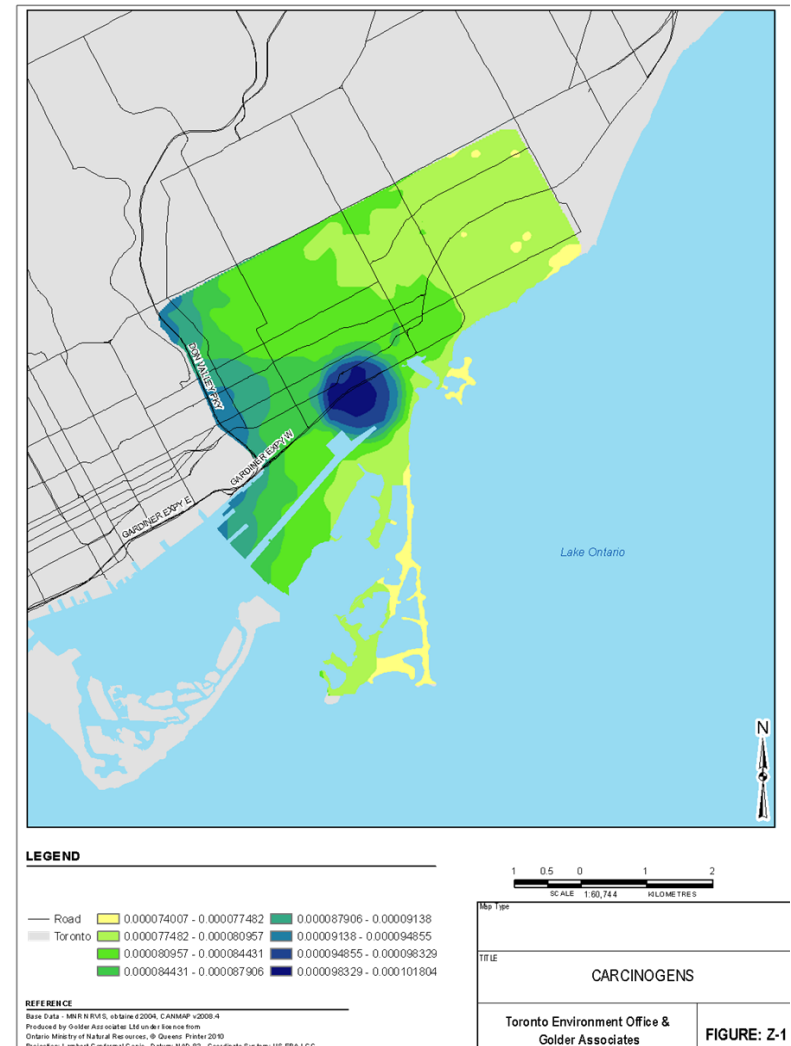
For carcinogens, it is assumed that every amount of exposure has a risk of causing cancer. Toronto Public Health uses a concentration level in air that is associated with increasing cancer by one in one million over a lifetime as the health benchmark for a carcinogen. Seven of the 19 carcinogens had modelled annual concentrations above the one in one million excess lifetime cancer risk benchmark in parts or the whole of the two wards. These were: benzene, benzo[a]pyrene, 1,3-butadiene, chromium (VI), 1,4-dichlorobenzene, formaldehyde and tetrachloroethylene (or perchloroethylene). With the exception of chromium and tetrachloroethylene, on and off-road vehicles are the largest local source of these carcinogens.

The estimated risk for each substance was added to give a total estimate of the risk. If the average annual risk is summed across all 19 carcinogenic substances, the average cumulative cancer risk in these two wards is 83 in one million. While 83 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 around two percent of the overall cancer incidence rate in Toronto – around 400 per 100,000 in 2007.

Chromium (VI), benzene, 1,3-butadiene, and benzo[a]pyrene account for most of this risk. While the cumulative risk was somewhat above the one in a million cancer risk benchmark in all parts of the two wards, only two areas had more elevated risks – one next to the Don Valley Parkway (DVP) and the other around an industrial area close to the Port Lands (see map on right).

The largest part of the total cancer risk in these two wards comes from chromium (VI). The modelling shows that most of this chromium comes from sources outside Toronto and thus is a health risk that is likely common to other parts of the city. The elevated risk next to the DVP is mostly from 1,3-butadiene, benzene, and benzo[a]pyrene. As indicated above, these substances are mostly released from transportation sources. These are also the substances that contribute a large part of the overall cumulative cancer risk in the other parts of the study area. The Toronto Environment Office and the Ontario Ministry of the Environment have investigated the facility near the Port Lands where the higher levels of exposure were seen. The facility has taken steps to reduce its emissions.

Modelled distribution of cumulative risk from carcinogens



Cumulative risk from criteria air contaminants (CACs)

Our current knowledge of the health effects from the five common air pollutants (carbon monoxide, ozone, nitrogen dioxide, particulate matter (PM) and sulphur dioxide) shows that there is no threshold for these effects. Therefore, Toronto Public Health (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, we used the estimate of excess risk of premature death to calculate the cumulative impact.

Annual average values were used for estimating per cent excess risk of premature death, as they are most representative of chronic, long-term exposures. The common air pollutants have a cumulative excess risk of 8.9 per cent (that is, they increase the overall mortality for respiratory and cardiovascular diseases by this amount). Fine particulate matter (PM_{2.5}) and nitrogen dioxide are the pollutants that contribute most to this risk. This level of excess risk is similar to what has previously been calculated in the *Burden of Illness in Toronto* (TPH 2004).

Similar to the analysis for carcinogens, there is a higher risk in the area close to the DVP and industrial sources near the Port Lands. Nitrogen dioxide is the pollutant that accounts for most of the risk near the Don Valley Parkway (DVP), while fine particulate matter (PM_{2.5}) was the pollutant associated with the higher risk around the point sources. Changes that have taken place in one of the industrial facilities in the area since this study was done suggest that this facility has reduced its emissions of particulate matter.

Limitations

The study and modelling utilized for cumulative health effects has 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.

Limited data is available on the small commercial and industrial sources of pollutants in the study area. Data collected through the Environmental Reporting and Disclosure Bylaw (ChemTRAC program) will help improve future estimates of the cumulative exposure in Toronto and direct pollution prevention priorities in these communities.

Modelled distribution of cumulative percent excess risk from criteria air contaminants

