# APPENDIX E

## Health Assessment for the Cumulative Air Modelling - Wards 19, 20, 27, 28 30 and 32

# 1.0 HEALTH ASSESSMENT METHODS FOR CUMULATIVE AIR QUALITY MODELLING

The approach for the health assessment for air quality was adopted from TPH (2011) in the "Health Assessment for the Cumulative Air Quality Modelling Study – Wards 30 and 32 including the South Riverdale and The Beaches neighbourhoods".

## 1.1 Cancer Risk

Cancer risks can be assessed using inhalation unit risk (IUR) values for each carcinogenic compound. The inhalation unit risk is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/m$^3$ in air. Estimated cancer risks for each carcinogenic substance at each location can therefore be calculated using the formula:

$$R_{ij} = C_{ij} \times IUR_j$$

Where $R_{ij}$ is the estimate of individual lifetime cancer risk from pollutant *j* at location *i*, $C_{ij}$ is the concentration of pollutant *j* at location *i* in µg/m$^3$, and $IUR_j$ is the inhalation unit risk for a 70-year lifetime, for pollutant *j* in (µg/m$^3$)$^{-1}$.

The cancer risks of different air toxics are assumed to be additive, and can be summed together at each location to estimate a total individual lifetime cancer risk for that location:

$$Cumulative\ cancer\ risk_i = \sum_i R_{ij}$$

The calculated cumulative risk can then be compared to a benchmark to characterize the level of concern that may be associated with the cumulative risk. The definition of tolerable risk may vary by jurisdiction. Many jurisdictions, including the United States Environmental Protection Agency (US EPA) uses one-in-one million ($10^{-6}$) as the maximum lifetime risk benchmark for carcinogen. Health Canada often uses as a benchmark from one-in-one hundred thousand to one-in-one million. Typically, Toronto Public Health uses one-in-one million.

A common health-protective approach is to assume that most cancer types develop according to a similar multi-stage biological mechanism. Under this assumption, it makes sense to add the potential risk from different substances (which may be linked to different types of cancer) to estimate a cumulative cancer risk arising from multiple substances.

The inhalation unit risk values for all substances except chloromethane are drawn from the California Office of Environmental Health Hazard Assessment (Cal OEHHA) database (Cal OEHHA, 2009). This database includes values for almost all of the priority air contaminants, and is regularly updated. The Cal OEHHA method is respected and viewed as being health-protective. The database does not include an inhalation unit risk value for chloromethane, so for this substance, an inhalation unit risk derived by the state of New Jersey was used (New Jersey Department of Environmental Protection 2008). Inhalation unit risk values are provided in Table 1.

**Table 1: Inhalation Unit Risk Values**

| Chemical | Inhalation Unit Risk (µg/m$^3$) |
|---|---|
| Acetaldehyde | 2. 7 x $10^{-6}$ |
| Benzene | 2.9 x $10^{-5}$ |

| Chemical | Inhalation Unit Risk (µg/m$^3$) |
|---|---|
| Benzo[a]pyrene | $8.7 \times 10^{-2}$ |
| 1,3-Butadiene | $5.0 \times 10^{-7}$ |
| Cadmium | $4.2 \times 10^{-3}$ |
| Carbon tetrachloride | $4.2 \times 10^{-5}$ |
| Chloroform | $5.3 \times 10^{-6}$ |
| Chloromethane | $1.8 \times 10^{-6}$ |
| Chromium VI | $2.4 \times 10^{-2}$ |
| 1,4-Dichlorobenzene | $1.1 \times 10^{-5}$ |
| 1,2-Dichloroethane | $2.1 \times 10^{-5}$ |
| Dichloromethane | $1.0 \times 10^{-6}$ |
| Ethylene dibromide | $7.1 \times 10^{-5}$ |
| Formaldehyde | $6.0 \times 10^{-6}$ |
| Lead | $1.2 \times 10^{-5}$ |
| Nickel compounds | $2.6 \times 10^{-4}$ |
| Tetrachloroethylene | $5.9 \times 10^{-6}$ |
| Trichloroethylene | $2.0 \times 10^{-6}$ |
| Vinyl chloride | $7.8 \times 10^{-5}$ |

The air quality modelling was done for total chromium. However, the health effects associated with exposures to different forms of chromium vary. For example, the predominant form of chromium in environmental media is chromium III ($Cr^{3+}$) which is associated with impaired lung function and irritation, whereas chromium VI ($Cr^{6+}$) is associated with lung cancer. In estimating the health risk associated with exposures to chromium, the assessment conservatively assumed that the ratio of $Cr^{3+}$:$Cr^{6+}$ in ambient air is 85:15; that is, 15% of chromium in ambient air is present as $Cr^{6+}$. TPH (2011) selected 15% to be a health-protective and conservative estimate for the proportion of $Cr^{6+}$ that is likely to be present in ambient air.

## 1.2 Non-Cancer Risks

The hazard posed by air pollutants that exhibit non-cancer effects can be assessed using a reference concentration (RfC). The RfC is an estimate of a continuous inhalation exposure by the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. To assess non-cancer risks, the Hazard Ratio (HR) for each pollutant is calculated at each location by dividing the modelled concentration by its RfC using the following equation:

$$HR_{ij} = {C_{ij}}/{RfC_j}$$

Where $HR_{ij}$ is the hazard ratio for pollutant *j* at location *i*, $C_{ij}$ is the concentration of pollutant *j* at location *i* in µg/m$^3$, and $RfC_j$ is the Reference Concentration for pollutant *j* in µg/m$^3$.

An indicator of total non-cancer hazard can be calculated by summing together the hazard ratios for each pollutant to derive a total hazard index:

$$HI_i = \sum_i HR_{ij}$$

There are no universal values for tolerable hazard ratios. The value of a tolerable hazard ratio depends upon the jurisdiction using it. Many agencies, including Health Canada and the US EPA, assume that a hazard ratio of less than one means that the concentration is less than the benchmark and so is not expected to be a concern for health. Health Canada considers hazard ratios of 0.2 or less as not of concern for health for a single exposure pathway or when exposure is compared to the total acceptable daily intake. This reflects the possibility that hazard may accumulate from exposure through multiple exposure pathways.

RfCs can be developed for various averaging time periods. The values in Table 2 represent chronic values, wherever possible. There are five substances where RfCs are based on 24-hour averaging times because RfCs were unavailable for longer averaging times (denoted with "**" in Table 2). All others are based on annual averaging periods.

The chronic reference exposure levels used were drawn mainly from Cal OEHHA's database and existing or proposed ambient air quality criteria set by the Ontario Ministry of the Environment (MOE) (Cal OEHHA 2008; Ontario Ministry of the Environment 2008). Both databases include values for almost every priority air contaminant, and are regularly updated (i.e., new values were adopted for acrolein, manganese, and mercury by Cal OEHHA in 2008, and the MOE adopted new standards for chromium on June 2011). Where an MOE annual ambient air quality criterion value for a non-carcinogen endpoint was lower than a California reference concentration, the MOE value was adopted. Otherwise, California's values were used.

**Table 2: Reference Concentrations**

| Chemical | Reference Concentration (µg/m$^3$) |
|---|---|
| Acetaldehyde | 140 |
| Acrolein | 0.35 |
| Benzene | 60 |
| 1,3-Butadiene | 20 |
| Cadmium | 0.005 |
| Carbon tetrachloride** | 2.4 |
| Chloroform | 300 |
| Chloromethane** | 320 |
| Chromium III** | 0.5 |
| Chromium VI | 0.2 |
| 1,4-Dichlorobenzene** | 95 |
| 1,2-Dichloroethane | 400 |
| Dichloromethane | 400 |
| Ethylene dibromide | 0.8 |
| Formaldehyde | 9 |
| Lead** | 0.2 |
| Manganese | 0.09 |
| Mercury compounds | 0.03 |
| Nickel compounds | 0.014 |
| Tetrachloroethylene | 35 |

| Chemical | Reference Concentration (µg/m$^3$) |
|---|---|
| Trichloroethylene | 600 |
| Toluene | 300 |

Some substances are classified as both carcinogens and non-carcinogens. These substances were included in the estimate of cumulative cancer risk as well as the hazard index calculation.

## 1.3 Cumulative Risk from Common Air Contaminants (CACs)

Common air contaminants (CACs) are associated with multiple respiratory and cardiovascular outcomes. The risk from CACs was evaluated for an endpoint which is common to all CACs and for which rigorous risk coefficients exist: premature mortality. Using acute premature mortality may be akin to selecting a single most significant endpoint: it is the most severe outcome, and enables the risks associated with each individual CAC to be compared to the others. However, it should be recognized that CACs are associated with a significant burden of illness from respiratory and cardiovascular health conditions in Toronto.

The outcomes associated with CAC exposure are common, and would occur in the population even in the absence of CAC exposure. Thus, to characterize the risk posed by CACs, it is best to assess the additional or excess risk posed above baseline levels. The excess risk of premature mortality due to CAC exposure can be estimated based on the set of concentration response function (CRF) coefficients endorsed by Health Canada for use in its Air Quality Benefits Assessment Tool (AQBAT). These CRF coefficients represent statistically derived estimates of the percent (%) excess health endpoint associated with a unit increase in the pollutant concentration (Health Canada, 2006).

Estimated percent excess per capita risk for each CAC at each location can be calculated using the formula:

$$R_{ijk}\left(e^{C_{ij}CRF} - 1\right) \times 100$$

Where $R_{ijk}$ is the estimate of percent excess per capita risk for a one unit increase in pollutant *j* at location *i* for outcome *k*, $C_{ij}$ is the concentration of pollutant *j* at location *i* in µg/m$^3$, and $CRF_{ijk}$ is the coefficient representing percent excess per capita risk for outcome *k* associated with a unit increase in pollutant *j* (in applicable units). Overall, the approach is analogous to the approach used for calculating cumulative risk from carcinogens.

The percent excess per capita risks from four of the individual CACs ($NO_2$, $O_3$, CO, and $SO_2$) are assumed to be additive, and can be summed together at each location to estimate a total percent excess individual lifetime risk for that location:

$$Cumulative\ CAC\ risk_{ik} = \sum_i R_{ijk}$$

As Table 3 suggests, the estimates for premature mortality for $PM_{2.5}$ are based on chronic exposure, whereas those for the remaining CACs ($NO_2$, $O_3$, CO, and $SO_2$) are for acute exposure. They are added together to derive a cumulative percent excess per capita risk under the assumption that over the long-term, the acute risk posed by $PM_{2.5}$ each day reaches a steady-state, and can be adequately represented as an annual risk.

The approach described above is consistent with methods previously used by TPH to calculate the burden of illness from CACs (Toronto Public Health 2004, 2007). The above calculations generate percent excess per

capita risk values, while the burden of illness reports applied percent excess per capita risks to current population incidence to estimate the number of people affected.

The concentration response function coefficients for the CACs are regression coefficients drawn from Health Canada's Air Quality Benefits Assessment Tool (AQBAT) (Health Canada, 2006). The substances treated as CACs are shown in Table 3. The CRF values were obtained directly from Health Canada.

**Table 3: Concentration Response Function Coefficients**

| Chemical (CRF units) | Acute Premature Mortality CRF Coefficient (concentration)$^{-1}$ | Chronic Premature Mortality CRF Coefficient (concentration)$^{-1}$ |
|---|---|---|
| NO2 ($ppb^{-1}$) | $7.48 \times 10^{-4}$ | - |
| PM2.5 ($\mu g/m^3)^{-1}$ | - | $6.76 \times 10^{-3}$ |
| O3 ($ppb^{-1}$) | $8.39 \times 10^{-4}$ | - |
| CO ($ppm^{-1}$) | $1.90 \times 10^{-3}$ | - |
| SO2 ($ppb^{-1}$) | $4.59 \times 10^{-4}$ | |

Note: While the CRFs for $NO_2$, CO, $PM_{2.5}$ and $SO_2$ are based on 24-hour averaging times, the CRF for $O_3$ is based on a 1-hour averaging time.

$PM_{10}$ and total VOCs were not included in this analysis. This is to prevent double-counting when estimating cumulative risk. $PM_{10}$ includes $PM_{2.5}$, and there is general consensus that of the two measures for particulate matter, $PM_{2.5}$ is the best indicator of health risk and the best target for policy interventions (COMEAP, 2009). Several of the individual substances modelled including benzene, 1,3-butadiene, and formaldehyde qualify as VOCs, so including total VOCs would double-count these substances. Additionally, there is no health benchmark available for total VOCs. Such a benchmark would be difficult to identify because the toxicity of any VOC mixture depends on the specific combination of VOCs under consideration.

## 1.4 Summary

The methods described in this appendix were applied in the HIA to evaluate the non-cancer risks, cancer risks and percent excess risk of premature mortality based on air quality predictions for the Proposal. The results are presented in Section 5.1.6 of the HIA report.

## 2.0 REFERENCES

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