Application of a Transport and Emission Model in a Study of Air Pollution Exposure and Health Effects

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Introduction

Two recent studies conducted in the City of Montreal, Canada, have shown positive associations between the incidence of postmenopausal breast cancer (Crouse et al. 2010) and estimates of concentrations of nitrogen dioxide (NO_2), an accepted marker of traffic-related air pollution.

In this paper, we use a transportation model (Sider et al. 2013) with traffic emission modelling capability for the City of Montreal to simulate traffic emissions of nitrogen oxides (NO_x) at the level of individual roadway links. We also make use of a LUR model for nitrogen dioxide (NO_2) (Crouse et al. 2009) and data from a case-control study of postmenopausal breast cancer (Crouse et al. 2010). Our specific objectives are: 1) To compare NO_x emissions simulated by a transportation model with NO2 concentrations obtained from a land-use regression model across the Montreal Island; 2) To investigate the associations between NO_x emissions and the incidence of breast cancer and answer the question: can NO_x emissions act as a proxy for NO2 concentrations?

Materials and Methods

In this paper, we evaluate whether the residential locations of participants in the case-control study are in the areas with the best or the worst agreement between our transport model output (NO_x emissions) and the LUR model output (NO_2 concentrations). If the areas where poor agreement exists between the two measures are also the areas with low population densities and low rates of air pollution related sickness, then this relaxes the condition that our transport model should agree with the NO_2 levels over the entire domain. In addition, we plan to evaluate whether the NO_x values derived from the transport model can predict the odds of breast cancer in a similar way as the NO_2 concentrations.

Our methodology consists of transport model development, validating the estimates of NO_x against NO_2 data across the Island of Montreal, and using unconditional logistic regression to estimate odds ratios (OR) for breast cancer using both exposure metrics.

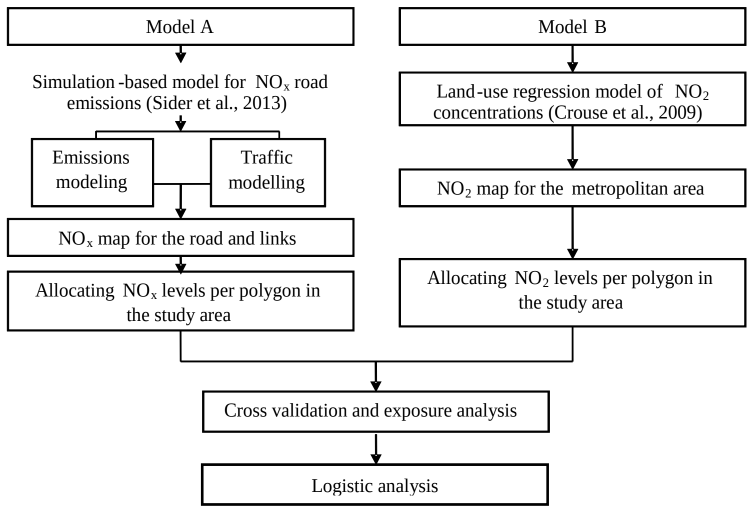

Figure 1. Study methodology

Description of models used to derive exposures

Integrated transport-emissions model

We developed a traffic assignment model for the Montreal region linked with an emission post-processor capable of simulating traffic emissions occurring on the road network at the level of each individual driver (Sider et al., 2013). The traffic assignment model (PTV VISUM platform; PTV Vision, 2009) allocates vehicle flows on the road network using 2008 Origin-Destination data (AMT). We allocated vehicles to individuals and households based on vehicle ownership information and estimated link-level emissions using the USPA Mobile Vehicle Emissions Simulator (MOVES).

Land-use regression model

We made use of estimates of concentrations of NO_2 from a LUR model described in Crouse et al. (2009). Briefly, a series of dense sampling campaigns were conducted in 2005 and 2006 to estimate integrated two-week NO_2 concentrations at individual points throughout the entire island. Then, a land use regression model was estimated to predict concentrations of NO_2 where measurements were not taken.

NO_2-NO_x validation

We compared the NO_x emission load with concentrations of NO_2 for 75,000 polygons in the study area. We categorized the raw values of NO_x and NO_2 into deciles that range from 1 to 10 (1 indicating the lowest decile). Using the scaled difference values, we generated an 'agreement map' highlighting the areas where the two measures agree and areas with high disparities.

Exposures and associations with cancer

The estimated spatial emissions of NO_x and concentrations of NO_2 were linked to the residences of the 792 participants in the breast cancer study (Crouse et al. 2010). We estimate the ORs for breast cancer using estimates of NO_2 and NO_x. For this purpose, an unconditional logistic regression model is used to estimate ORs and associated 95% CI. Different sets of covariates were included, e.g., age at diagnosis, first degree family history, etc. We present ORs for an increase across the interquartile range (IQR) of NO_2 and NO_x which was 2.71 ppb and 481.37 grams, respectively.

Results

NO_2-NO_x validation

Figure 2 shows the difference between the scaled values of NO_2 minus NO_x (ranging from -9 to +9) as an 'index of agreement'. When the difference is close to 0 (between -1 and +1), it indicates a good agreement between both measures. A large positive difference indicates that the NO_2 scaled value is much higher while a large negative difference indicates that the NO_x value is larger (this is expected to occur in the vicinity of roadways).

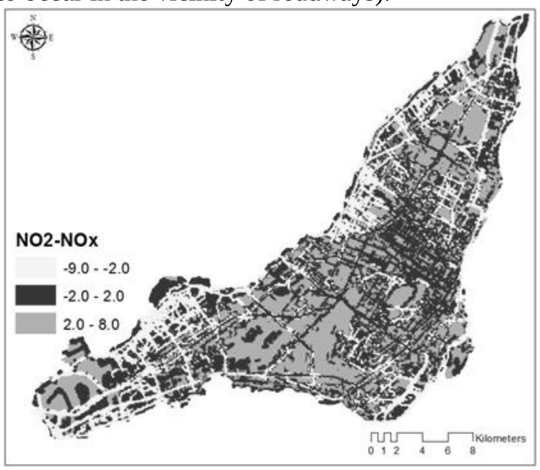

Figure 2. Difference between the scaled values of NO_2 minus NO_x

Individual exposures and associations with cancer

The previous section points to the fact that the two potential measures of exposure are in good agreement around roadways and within the dense central parts of Montreal. This observation indicates the possibility of achieving better agreement when evaluating population exposure since Montreal's population is concentrated around the main corridors and in the central parts. Indeed, we found that 75% of the participants in the breast cancer study lived either in areas with good agreement between both measures or in areas where the NO_x values were higher than the NO_2 values, indicating very close proximity to roadways. Figure 3 shows that for 50% of the participants, the correlation between NO_x and NO_2 values is 0.5 or higher (up to 0.9).

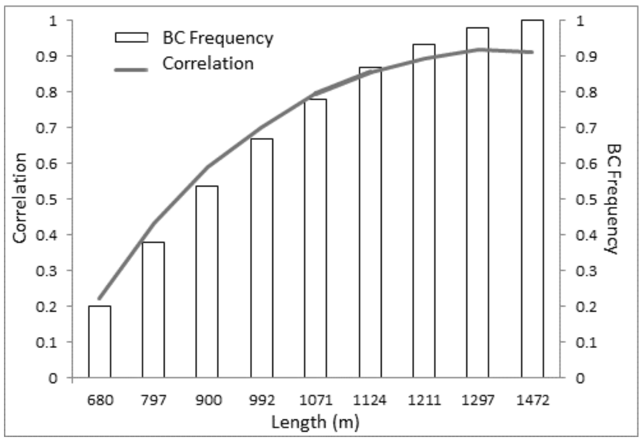

Figure 3. Frequency of breast cancer subjects and correlation between NO_x and NO_2 at different levels of link densities.

We estimated separate odds ratios for concentrations of NO_2 and emissions of NO_x (Table 1). In both cases, we observe significant OR indicating that the association with breast cancer is present. We also observe lower OR when using the NO_x data which may indicate mis-specification in the simulated emissions compared to the NO_2 concentrations derived from the LUR. However, the OR derived from NO_x data has a smaller confidence interval (CI) which is contained within the CI for the OR based on NO_2 data.

5. CONCLUSION

In this study, an integrated transport-emissions model is used to generate a measure of exposure to traffic emissions and validated against a LUR model developed for the same region. Results indicate reasonable agreement between the two models in terms of the spatial distribution of emissions and air quality. In addition, a sample of breast cancer survivors in Montreal is used to evaluate whether the exposures derived from the transport model can predict the odds of breast cancer in a similar way as the LUR output. The results of analysis indicate that while the use of a transport model leads to significant odds of breast cancer, the OR is smaller than the one derived used the LUR data indicating possible mis-specification in the simulated emissions.

Table 1. Odds ratio for risk of breast cancer

Variable	**Age-adjusted**		**Fully-adjusted**	
	OR	**95% CI**	**OR**	**95% CI**
Aug NO2 (ppb)	1.09	0.924, 1.28	1.14	0.941, 1.38
Summer NOx (gr)	1.04	0.990, 1.1	1.04	0.98, 1.1

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