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Modeling the impacts of NO_2 vehicular emissions: A case study in Florianópolis, Brazil

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Abstract: Air pollution has been recognized as one of the worst environmental health risks at the present time. Recognizing potential impacts from road transport, the present study aimed to assess the impact of vehicular emissions of NO_2 in Beira Mar Norte Avenue, in Florianopolis, Brazil. A bottom-up approach was applied in order to estimate emissions, and then AERMOD was used to simulate pollutant dispersion. The highest hourly concentration resulted in 932.7 µg/m³, and annual arithmetical average found was 120.9 µg/m³. Comparing simulations results with Brazilian air quality standards for NO_2, primary standards were exceeded 4,646 times, comprehending 68.6 hectares; and secondary standards, 12,186 times in 333.6 hectares. These concentrations were also considered high compared to literature, therefore the present study demonstrated that individuals in Beira Mar Norte Avenue surroundings were exposed to health effects from NO_2 exposition.

Keywords: Vehicular emissions, air quality control, dispersion modeling, AERMOD.

INTRODUCTION

In urbanized cities, exhaust emissions from road transport represent one of the main sources of ambient air pollution. They arise from the combustion of fuels in internal combustion engines (EEA, 2013). In the Metropolitan Area of Sao Paulo, Brazil, of all atmospheric emissions in 2014, vehicles were responsible for 97.5% of all carbon monoxide (CO), 79% of hydrocarbons (HC), 67.5% of nitrogen oxides (NO_x), 21.8% of sulfur oxides (SO_x), 40% of MP_{10} and 37% of $MP_{2.5}$ (CETESB, 2016). It demonstrates, thus, that vehicular emissions need to be assessed as a significant source of air pollution.

In Florianopolis, Brazil, there are no emissions inventories to account for mobile contribution. However, it is known this city has the highest number of vehicles per capita in Brazil: 0.79 vehicles/inhabitants (DENATRAN, 2016). Therefore, impacts from road transport in Florianopolis should be a major concern for ambient air quality control.

Recognizing risks associated to air pollution, countries all over the world have developed goals and limit values to control pollutant concentrations in ambient air (WHO, 2000). In Brazil, air quality standards have been defined by CONAMA N. 003/1990. This legislation defines as primary standards those concentrations of pollutants which should not be exceeded in order to prevent health effects; and as secondary standards, those concentrations which would result in minimum harm to individuals and the environment (BRAZIL, 1990).

Taking into consideration the Brazilian air quality standards, the present study aims to assess the impacts of vehicular emissions of NO_2 in Florianopolis. The chosen study area is an important traffic route called Beira Mar Norte Avenue. In order to estimate NO_2 emissions, a bottom-up approach was applied. To simulate pollutant dispersion, the model AERMOD was used.

It was the first time a dispersion study for vehicular sources was conducted in the city, evidencing pollution from mobile sources is still an emerging issue in developing countries, even though emissions from vehicles have shown to be significant.

METHODS

Study area

Beira Mar Norte Avenue is located in Florianopolis, Brazil. The city has 421,240 inhabitants and total area of 675,409 km² (IBGE, 2010). The Avenue is considered the main route between Florianopolis' insular and continental portions. It also plays an important social role, considering its surroundings serve as an area for sports practice and recreation.

Estimating NO_2 emissions

Vehicular emissions were estimated for Beira Mar Norte Avenue following a bottom-up approach (Eq. 1). The method was applied in an extension (D) of 5,91 km along the Avenue, using Eq. 1:

$$E_{NO_2} = \sum N_{if}\ X\ FE_{if}\ X\ D \quad (1)$$

Emissions (E_{NO_2}) were calculated using vehicular count for each category of vehicles (car, motorcycle, bus, etc.), with data collected from 14th to 20th December 2010 provided by the Environmental Protection Agency of Santa Catarina state (FATMA). The Agency provided the number (N) of automobiles, light commercial vehicles, motorcycles, trucks and buses going through Beira Mar Norte Avenue. Categorization of vehicles occurred in terms of model year (i) and fuel type (f). For each category, emission was calculated according to its emission factor (FE). Total emissions were used in AERMOD to simulate NO_2 dispersion.

Meteorological and terrain preprocessing

Meteorological and upper air data from observations, combined with estimated surface characteristics were processed using AERMET, which provided the necessary boundary layer parameters to be used in AERMOD.

Meteorological data from observations were collected from a station located in Florianopolis and provided by Instituto Nacional de Meteorologia (INMET). From January 1st to December 31st of 2015, medium temperature was found to be 21.9 °C; dew point, 18.0 °C; relative humidity, 79.3 % and pressure readings reduced to mean sea level, 1015 mbar. Winds were predominant from North, with velocity up to 8 m/s and 7.5% of calms. Observed upper air data were obtained from National Oceanic and Atmospheric Administration (NOAA) website, collected from a station located in Florianopolis airport, with data from January 1st to December 31st of 2015.

Surface characteristics depend on surface uses and seasonal conditions. They were estimated according to AERMET User's Guide.

Terrain particularities were incorporated to simulations through AERMAP. In this case, the region's Digital Elevation Model from SRTM/NASA-SC was used as input, providing base elevation at each receptor and source, and terrain hill height scale.

Modelling options

In order to simulate receptors, a grid of 40.000 points was created. In relation to sources, they were formed by 30 polygons along three ways in the Avenue, constituting line sources. Total area summed up 147,657.43 m².

Compliance with ambient air quality standards

The compliance with ambient air quality standards was evaluated by comparing NO_2 concentrations to the Brazilian legislation established by CONAMA N. 003/1990. Reference values are summarized in Table 1.

Table 1. Primary and secondary air quality standards stablished by CONAMA N. 003/1990. AAA: annual arithmetical average.

Average time	Primary standard	Secondary standard
1 hour	320 µg/m³	190 µg/m³
AAA	100 µg/m³	100 µg/m³

Reference: BRAZIL, 1990

FINDINGS AND ARGUMENT

Emissions estimation

It was estimated, for the considered period, that vehicles emitted 5.45 g/s of NO_x. It is known that only a parcel of NO converts to NO_2, which is highly influenced by environmental conditions. As there has not been any previous studies in the region to evaluate NO_2/NO relationship, a conservative approach has been adopted based on US EPA recommendations for AERMOD use (EPA, 2014). It means full conversion of NO to NO_2 was adopted for this case.

NO_2 dispersion

Short and long term areas of exposition to NO_2 are shown in Figure 1 and 2 respectively.

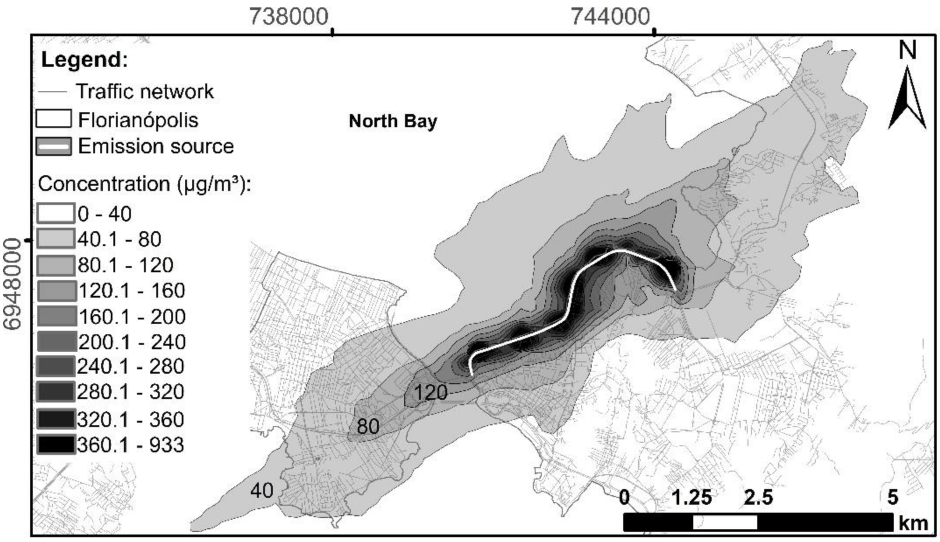

Figure 1. Maximum 1-hour concentrations of NO_2 in Beira Mar Norte Avenue surroundings

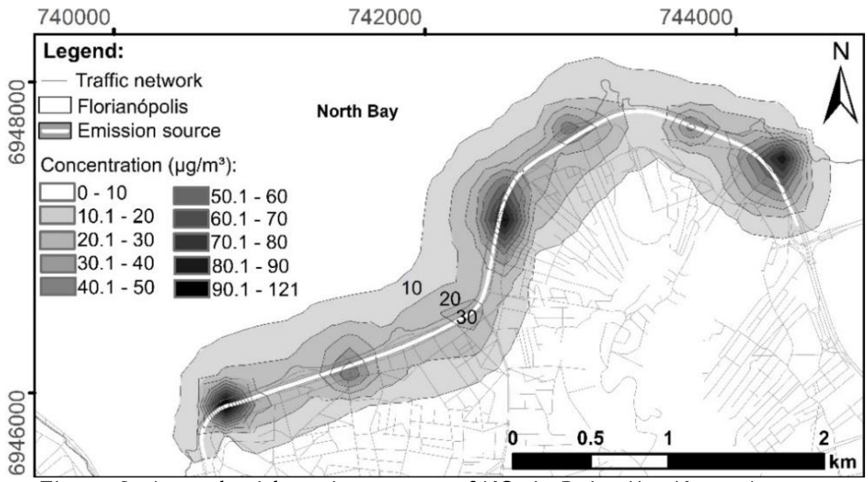

Figure 2. Annual arithmetic average of NO_2 in Beira Mar Norte Avenue

Concerning both primary and secondary standards, critical 1-hour concentrations were found all along the Avenue. The highest concentration resulted in 932.7 µg/m³. In relation to the annual arithmetical average (AAA), concentrations were critical in three locations along the Avenue and the highest value was 120.9 µg/m³. In both cases concentrations were higher than those reported by the World Health organization. In the United Kingdom, NO_2 near road maximum concentrations were listed from 470 to 750 µg/m³. AAA around the world ranged from 20 to 90 µg/m³ (WHO, 2000).

As summarized in Table 2, It was found 4,646 occurrences of non-compliance with primary standards within 68.6 hectares. And also, 12,186 occurrences of non-compliance with secondary standards were found in 333.6 hectares.

Table 2. Results summary

Parameter	Result
Maximum 1-hour concentration	932.7 µg/m³
Maximum Annual arithmetic average concentration	120.9 µg/m³
Frequency of primary standards non-compliance occurrences	4,646
Primary standards non-compliance area	68.6 ha
Frequency of secundary standards non-compliance occurrences	12,186
Secondary standard non-compliance area	333.6 ha

CONCLUSIONS

Simulations demonstrated that both standards for NO_2 were exceeded. Also, reference values were exceeded thousands of times, even though they should not be exceeded more than once a year. These results show that critical concentrations were not isolated cases.

Despite of important findings reached by this work, there are some concerns about the present evaluation, due to the lack of field measurements to validate the model results. Moreover, undefined NO_2/NO relationship in the study area was a limiting factor, which may have kept the present study from getting closer to reality.

Finally, the present study demonstrated that individuals in Beira Mar Norte Avenue surroundings could be exposed to health effects from NO_2 exposition, even considering only vehicular emissions of Beira Mar Norte Avenue. Therefore it evidences the importance of conducting a complete emission inventory in Florianopolis to assess all sources of air pollution. Also, it is recommended for future studies to monitor air quality in the area, to provide data for comparison with simulations.

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