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Impact of traffic management strategies on air quality and health in a Portuguese urban area

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Abstract

This paper aims to assess the air quality improvement and resulting health implications in a Portuguese urban area, by testing traffic management scenarios focused on nitrogen dioxide (NO_2) emission reduction. To that end, an integrated multiscale modelling system was developed and applied for a typical traffic-activity day using dynamical downscaling to the street level. At this finer scale, the tested scenarios contributed to a reduction of the daily maximum NO_2 concentration and health benefits, though the LEZ effect is more felt within its influence area.

Keywords: Urban NO_2 pollution; Traffic management scenarios; Microscale modelling; Health benefits.

1. Introduction

Urban air pollution and subsequent health risks are closely associated with increased NO_2 emissions from road traffic and reduced natural ventilation, but they can be also influenced by polluted air transported from other regions (Thunis et al., 2016). In order to evaluate the magnitude and spatial distribution of these impacts at different scales, the use of modelling tools is essential for understanding atmospheric and social dynamics, as well as to define preventive action plans (Silveira et al., 2016). Concerning the high air pollution levels typically observed in urban street canyons, microscale dispersion models are often used to numerically and accurately examine the spatial variability of air flows, largely associated to buildings volumetry and streets configuration (Borrego et al., 2003; Vardoulakis et al., 2003). Regarding the human exposure to atmospheric contaminants, many epidemiological studies recognize the air pollution as one of the main environmental causes of numerous diseases, especially respiratory and cardiovascular disorders, triggering millions of deaths per year worldwide (WHO, 2016).

Taking advantage of the scientific developments based on the link between air quality and health, this study addresses less explored aspects, namely, because it is fully focused on the microscale, where traffic-related emission reduction scenarios are tested for assessing the air quality improvement and health benefits:

i) replacing 50% of the vehicle fleet below Euro 4 by electric vehicles (ELEC); and

ii) introducing a Low Emission Zone (LEZ) that bans the movement of vehicles below Euro 4 and trucks (identified in Figure 1).

2. Methodology and Case Study

To analyse the air qualiy and health impacts of the traffic management scenarios, an integrated multiscale modelling system was developed and applied for a typical traffic-activity day. At urban scale, the WRF-Chem model was run over a central region of Portugal with 1×1 km^2 horizontal resolution. Its outputs (NO_2 concentrations, air temperature and wind fields) were used as boundary and background conditions to the microscale case study. At this scale, the Computational Fluid Dynamics VADIS model (Borrego et al., 2003) was applied using a three-dimensional resolution of 4 m and hourly resolution. As inputs to the model, besides the WRF-Chem data, a detailed characterization of the case study, especially with regard to the buildings volumetry, streets configuration and traffic-induced emissions is required.

Figure 1 presents the study domain covering a Portuguese urban area located within the Coimbra city with the obstacles (buildings, roads) interfering in the accumulation and dispersion of air pollutants.

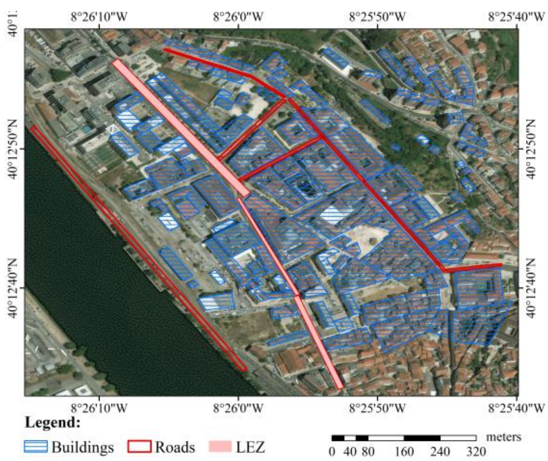

Figure 1. Framework of the study domain.

Road transport emissions for the baseline and tested scenarios were considered for the roads identified in Figure 1, using estimates from the TRansport Emission Model for line sources (TREM) (Borrego et al., 2003) based on available traffic counts and fleet composition statistical data.

For quantifying the extent of the health impacts, the Impact Pathway Approach (IPA) was used. More details on IPA can be found in Silveira et al. (2016). Since the analysis is based on daily NO_2 concentrations, only short-term health effects were considered.

3. Results and Discusion

This section presents the air quality and health outcomes estimated for 26th January 2015, considering the traffic management scenarios. At all hours, an air quality improvement for the tested reduction scenarios was observed, especially in peak hours with higher traffic activity (8-9 h; 18-20 h).

Analyzing the spatial distribution of the health benefits derived from the scenarios, these were most evident in locations with high population density and most significant air quality improvement (Figure 2). In turn, the resulting air quality estimates, besides the determinant role of the emissions, were also strongly influenced by the urban geometry (e.g. height and orientation of buildings) and wind regimes. Accordingly, in both scenarios, air quality improvements and short-term health benefits were higher over the northwest and southeast quadrants of the study domain, due to the prevailing winds in those directions. However, the expected health benefits tend to be underestimated, due to the lack of concentration /dose-response functions for certain health indicators, although there are scientific evidences proving the link between these indicators and the analysed pollutant.

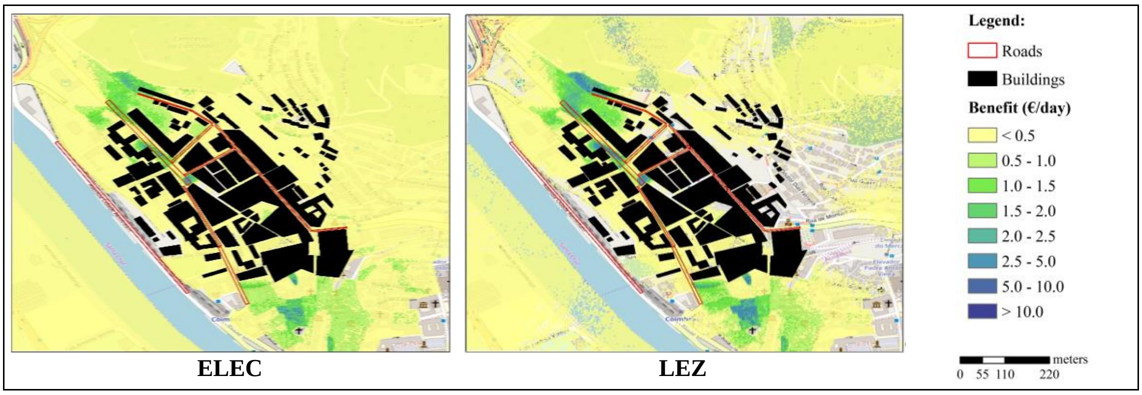

Figure 2. Short-term health benefit (€/day) resulting from the traffic management scenarios.

4. Final Remarks

In this study, the integrated modelling of traffic management scenarios at microscale allowed to assess the impacts chain, comprising the reduction of traffic-induced NO_2 emissions, pollution dispersion around the urban structure (e.g. buildings, roads), and short-term health benefits using detailed population data. However, there are uncertainties and limitations related with the models themselves and input data requiring further research. At the fine scale of urban street canyons, the exposure assessment should be based on monitoring the individual exposure of inhabitants for a certain period of time.

Despite the inherent modelling weaknesses, the results of this case study can be useful to support the local decision-making and selection of the best traffic management strategies for improving air quality and reducing health risks.

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