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Comparison of particulate matter inhalation for users of different transport modes in Lisbon

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Abstract

Daily commutes can contribute to high exposure to urban air pollutants, such as particulate matter (PM_{10} and $PM_{2.5}$). Since individuals are inevitably exposed to PM concentrations, it is crucial to study which transport modes present highest health impacts on users in order to provide different and healthier options for daily commutes.

For the purpose of estimating PM inhaled doses, this research relates pedestrians' ventilation rate and ambient PM concentration. The methodology consists on collecting data regarding PM concentrations on a second-by-second basis, using a portable laboratory, which is comprised by a PM analyzer and a laptop. The ventilation rates were found in the literature and adapted according to the intensity of the physical effort during the measurements.

PM_{10} and $PM_{2.5}$ concentrations were measured and compared across different microenvironments, such as walking, train, bus, mini-bus, tram and subway modes during off-peak hours based on a pre-selected round trip route in Lisbon, Portugal. Air quality data was also collected close to a fixed air quality monitoring station which is part of the round trip route, in order to have a reference PM concentration. A comparison of the different microenvironments based on the values obtained close to the fixed air quality station was made for PM concentrations and PM inhalation (which combines PM concentration with the physical effort).

For this case study, results showed that the tram had higher PM_{10} concentrations and inside the subway higher $PM_{2.5}$ concentrations, whilst the train ride had the lowest for both parameters. When considering the inhalation, the results were similar. The tram microenvironment had the highest PM_{10} inhalation while inside the subway train presented the highest $PM_{2.5}$ inhalation. Even though the pedestrian microenvironment is the one with the highest ventilation rate, its low PM concentration leads to a low inhalation value, which proves the importance of considering both concentrations and ventilation.

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1. Introduction

Air pollutants, such as particulate matter (PM), can cause negative health effects on those who are exposed, including a variety of cardiovascular and respiratory diseases, reduced life expectancy and also mortality (Russell and Brunekreef, 2009). Road vehicles, through fuel combustion, are a great PM emitter, which contributes to a more polluted urban environment. In Lisbon, motorized modes represent around 82 per cent of the daily trips (INE, 2012). Even though non-motorized modes (walking and cycling) are more environmentally friendly, commuters are subjected to high PM concentrations and also to high inhalation rates, due to the higher physical effort (Nazelle et al., 2012).

Even though air pollutant emissions per vehicle have been decreasing throughout the past decades (due to vehicles manufacturing restrictions), concentrations are still too high, especially in urban areas, where 54 per cent of the world's population lives (EEA, 2014; UN, 2014). Estimates show that 7 million premature deaths per year are linked to air pollution (WHO, 2014). Thus, since individuals are inevitably exposed to PM concentrations, it is important to study this question in order to provide individuals with healthier choices for daily commutes.

Population exposure to air pollution in urban areas has been studied by several authors over the last years. These studies focus on commuters' exposure and many of them consider different transport modes as an influential factor (Int Panis et al., 2010; Jiao and Frey, 2013; Kam et al., 2011; Martins et al., 2015; Saksena et al., 2008; Tsai et al., 2008).

Jiao and Frey (2013) compared PM exposure across three different transport microenvironments (pedestrian, car and bus), with measurements conducted within one and a half hour time period on pre-selected round trip routes in Raleigh, North Carolina. The study showed that the highest $PM_{2.5}$ concentrations were found in bus and pedestrian modes in comparison with the car mode. Only PM concentrations and travel-time were considered in this study, not the ventilation rates of the user in the different microenvironments.

Int Panis et al. (2010) compared car passengers and cyclists exposure to PM in three Belgium locations (Brussels, Louvain-la-Neuve and Mol). $PM_{2.5}$ and PM_{10} concentrations were measured as well as ventilatory parameters, such as minute ventilation (VE). The relation between these concentrations and VE allowed the estimation of PM inhalation, concluding that due to cyclists' higher ventilation rates when compared to car passengers, the inhaled doses are also higher.

Tsai et al. (2008) estimated commuters' exposures to PM while traveling by motorcycle, bus, car and mass rapid transit (MRT) in Taipei, Taiwan. They found that motorcycle commuters were exposed to higher concentrations of PM_{10}, $PM_{2.5}$ and PM_1. Even though this mode had the shortest travel time among all the transport modes, proximity to traffic emissions and stops at traffic lights are factors that highly contribute to a person's high PM exposure during daily commutes.

Gómez-Perales et al. (2007) studied commuters' exposure to $PM_{2.5}$ while traveling by mini-bus, bus and metro in Mexico City, stating that, even though mini-bus and bus modes had similar concentrations of this air pollutant, mini-bus had the highest concentrations. It was also concluded that wind speed was an important determinant of exposure.

Martins et al. (2015) stated that the PM concentrations inside the trains were lower than those on the platforms, mainly due to air conditioning systems operating on the trains, whose air filters highly reduced concentrations. However, Kam et al. (2011) had opposite results, suggesting that concentrations inside the trains were higher than those on the platform, as a result of airborne PM at stations being the main source of PM inside the trains.

Due to the importance of this thematic several studies have developed research regarding PM exposure. However, studies for the city of Lisbon considering several transport modes are non-existent. Additionally, the PM pollution assessment is extremely dependent on the case study in analysis. Therefore, the aim of this research is to compare different transport microenvironments in a round trip route around Lisbon, Portugal, taking into account PM concentrations and inhalation doses. The work is based on field measurements using a portable laboratory that