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Implementation of a low emission zone and evaluation of effects on air quality by long-term monitoring

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ABSTRACT

A regulation was implemented on 9/1/2009, excluding Euro 0, I and II heavy duty vehicles from entering Amsterdam's Low Emission Zone (LEZA). The current study investigated whether and to what extent this regulation had an effect on air quality. Data for a period starting two years before the regulation up to 31 December 2010 were obtained from two monitoring sites within the LEZA, one located in a street frequently used by heavy-duty vehicles, and one at an urban background location. The difference in concentrations of NO_2, NO_x, PM_{10} and soot, between the two sites was attributed to traffic. Soot was measured by two proxies, Elemental Carbon (EC) and Absorbance that showed a significant mutual correlation. The traffic contribution concentrations measured were adjusted for wind direction, wind speed, type of day (weekday/weekend) and traffic intensity. Since the implementation of the LEZA, the traffic contribution concentrations compared to the roadside site concentrations were decreased by 4.9% (95%-CI: 3.0–6.9%) for NO_2, 5.9% (95%-CI: 3.7–6.4%) for NO_x, 5.8% (95%-CI: 3.3–8.4%) for PM_{10}, 7.7% (95%-CI: 2.3–13.0%) for Absorbance and 12.9% (95%-CI: 5.2–20.5%) for EC. The current study demonstrated significant decreases in traffic-related air pollution concentrations in the vicinity of a roadside monitoring station after the implementation of a low emission zone in Amsterdam.

1. Introduction

Epidemiological studies have consistently documented adverse effects of air pollution on respiratory and cardiovascular health (Brunekreef and Holgate, 2002; Dockery et al., 1993; Cohen et al., 2005; Pope and Dockery, 2006). Additionally, traffic-related air pollution is considered to be of particular importance (Brunekreef et al., 2009; Jerrett et al., 2009; Zuurbier et al., 2011). In order to reduce the impact of traffic on air quality and meet the European Union limit values, local authorities have to take action and attempt to reduce the emissions of the most influential sources within their jurisdiction. As a result, air quality action plans are applied which have a strong emphasis on traffic regulation and involve policies such as stimulation of public transportation usage, ring road utilization, traffic flow improvement, speed limit reduction and implementation of low emission zones (LEZs). LEZs are areas where only vehicles with pollutant emission levels lower than a certain limit are allowed to enter. This paper deals with the effects of the implementation of LEZ in Amsterdam, the Netherlands.

More than 200 low emission zones have already been implemented in Europe (www.lowemissionzones.eu). LEZs are a fairly harsh measure since they affect driving habits and involve fleet renewal. In addition, the evidence of their effectiveness until now is somewhat inconsistent often making their application debatable. Davis (2008) investigated the LEZ in Mexico City, Mexico, which excluded most vehicles from entering the specified zone for one weekday each week. His study showed no evidence of air quality improvement, mostly because inhabitants circumvented the restrictions. Rapaport (2002) reports that the implementation of the LEZ in Stockholm would show similar results for NO_2 and $PM_{0.2}$ concentrations when compared to a no-action scenario. Similar conclusions were shown by Carslaw and Beevers (2002), using NO_2 as air pollution indicator and simulating several scenarios for the evaluation of the LEZ in London, UK. On the other hand Invernizzi et al. (2011) showed a measured decrease of black carbon in a

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pedestrian area and the Ecopass Zone in Milan, Italy, in comparison to a non-restriction area. Measured reductions up to 47% in black carbon but no changes for PM_{10} were reported on a limited campaign of 3 days. Cesaroni et al. (2012) suggested in their model-based study, using PM_{10} and NO_2 as air pollution indicators, that LEZ in Rome, Italy, was beneficial from a public health perspective. Traffic contribution reductions up to 2.8 $\mu g\ m^{-3}$ for PM_{10} and 9.8 $\mu g\ m^{-3}$ for NO_2 were calculated, depending on the model scenario used.

In some cases LEZs are implemented in combination with other measures complicating evaluation of LEZs considerably. An example would be the use of sulfur-free diesel fuel (Jones et al., 2012) and the congestion charge scheme (Kelly and Kelly, 2009) of London, UK. The congestion charging zone that required a fee for vehicle entrance in the center of London resulted in a decrease of 0.2 $\mu g\ m^{-3}$ for PM_{10} and 0.7 $\mu g\ m^{-3}$ for NO_2, based on model calculations by Tonne et al. (2008). The model evaluation of Beevers and Carslaw (2005) on the same zone reports a reduction of 12% for NO_x and 11.9% for PM_{10}, whereas Atkinson et al. (2009) report a decrease of 5% in NO_x and an increase of 2.1% NO_2 and 5.6% for PM_{10} on measurements performed at a roadside station within the congestions charging zone.

The city of Amsterdam has been facing high concentrations of air pollution (Van der Zee et al., 2012). Since vehicle emissions in Amsterdam is the most dominant local source of air pollution, local authorities have introduced policy measures to reduce air pollution generated by traffic. The air quality action plan for Amsterdam was first introduced in 2006 (Van Bergen et al., 2006) and part it involved the implementation of an LEZ in Amsterdam city center (LEZA, Fig. 1). The LEZA gradually prohibited the entrance of heavy-duty vehicles based on their emission category, referred to as Euro class (EC, 2007). After an initial trial period (9 October 2008–8 January 2009) without penalizing the violators, heavy-duty vehicles classified as Euro 0, I and II were prohibited from entering LEZA as of 9 January 2009. Since 1 January 2010 regulations are tightened, prohibiting Euro III vehicles not equipped with a diesel particulate filter from entering LEZA. Enforcement of the regulation is highly efficient as all streets toward the LEZA are monitored by traffic control cameras which identify license plates of entering vehicles and apply fines, when required, through an automated system. The regulation applies 24 h a day, 365 days a year and violators face a penalty of 220 Euros (as of 2012).

Newly introduced policies, like the LEZA, are usually implemented after running predictive simulation models (Giannouli et al., 2011; Lefebvre et al., 2011; Stedman, 2011), and their efficiency is usually not thoroughly evaluated by field measurements. When evaluation is performed, most focus is given on NO_x and PM_{10} measurements (Atkinson et al., 2009). Only a limited number of studies extended their evaluations to other indicators of traffic related air pollution such as soot, a byproduct of diesel engines (Dijkema et al., 2008; Jones et al., 2012). Such indicators may however have a stronger association with health effects as observed in epidemiological studies (Janssen et al., 2011; Lena et al., 2002; Schauer, 2003). Several definitions of soot proxies exist, depending on the methods applied to quantify its thermal and/or optical properties. Two such proxies were used for the needs of this paper; a thermal-optical, elemental carbon (EC) and an optical, i.e., absorbance.

Three studies have already investigated the air quality effects of the LEZA so far. A city council report, based on model calculations evaluated the possible outcome of LEZs for streets with heavy-duty vehicles traffic intensity between 600 and 750 vehicles per 24 h. For 2010, no or low reductions were expected for NO_2 and a reduction of 2–7% for traffic-related PM_{10} concentrations (Van den Brink et al., 2010). Keuken et al. (2012) performed model calculations on EC and reported an average population-weighted EC concentration reduction of 0.025 $\mu g\ m^{-3}$ for the full LEZA area. Boogaard et al. (2012), based on a measurement campaign in five Dutch cities including Amsterdam, concluded that the introduction of LEZs has produced non-significant reductions in NO_2, NO_x and soot,

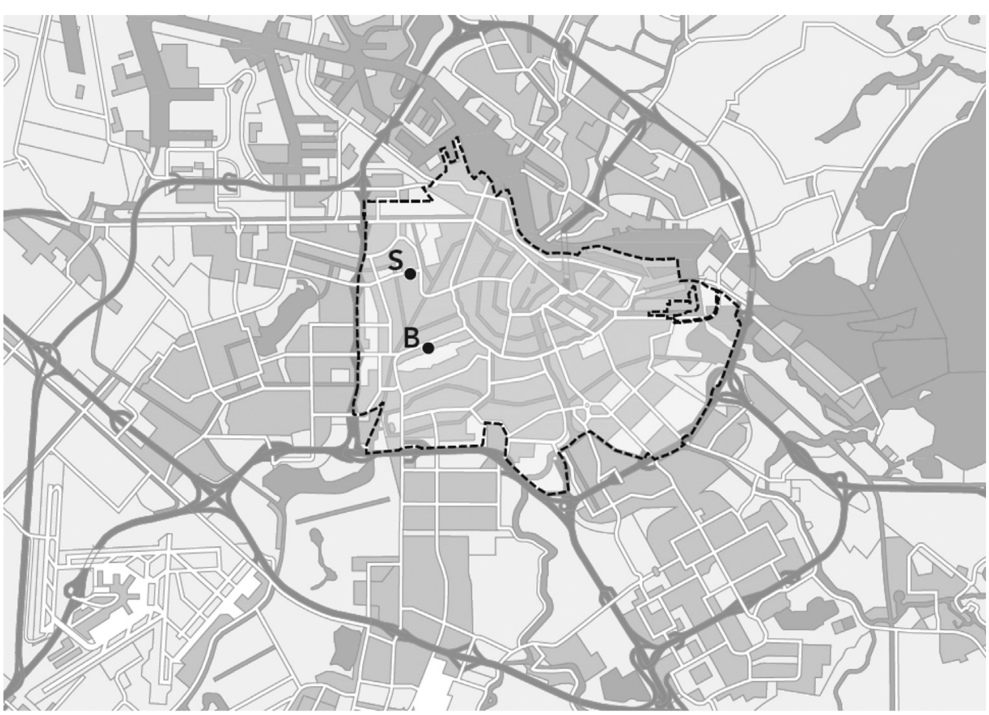

Fig. 1. Amsterdam city map. The dashed line indicates the LEZA area. Borders are roughly set by the IJ river front and A10 ring highway. The monitoring stations are marked with S (roadside monitoring station at Jan van Galenstraat) and B (urban background monitoring station in Vondelpark).