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Near-road air pollution impacts of goods movement in communities adjacent to the Ports of Los Angeles and Long Beach

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ABSTRACT

A mobile platform was outfitted with real-time instruments to spatially characterize pollution concentrations in communities adjacent to the Ports of Los Angeles and Long Beach, communities heavily impacted by emissions related to dieselized goods movement, with the highest localized air pollution impacts due to heavy-duty diesel trucks (HDDT). Measurements were conducted in the winter and summer of 2007 on fixed routes driven both morning and afternoon. Diesel-related pollutant concentrations such as black carbon, nitric oxide, ultrafine particles, and particle-bound polycyclic aromatic hydrocarbons were frequently elevated two to five times within 150 m downwind of freeways (compared to more than 150 m) and up to two times within 150 m downwind of arterial roads with significant amounts of diesel traffic. While wind direction was the dominant factor associated with downwind impacts, steady and consistent wind direction was not required to produce; high impacts were observed when a given area was downwind of a major roadway for any significant fraction of time. This suggests elevated pollution impacts downwind of freeways and of busy arterials are continuously occurring on one side of the road or the other, depending on wind direction. The diesel truck traffic in the area studied was high, with more than 2000 trucks per peak hour on the freeway and two- to six-hundred trucks per hour on the arterial roads studied. These results suggest that similarly-frequent impacts occur throughout urban areas in rough proportion to diesel truck traffic fractions. Thus, persons living or working near and downwind of busy roadways can have several-fold higher exposures to diesel vehicle-related pollution than would be predicted by ambient measurements in non-impacted locations.

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1. Introduction

Air quality close to and downwind of heavily-trafficked roadways includes localized high pollution concentrations and sharp concentration gradients such as measured by Zhu et al. (2002a,b) and Hitchins et al. (2000). These concentrations are critically important in determining human exposure at the individual and community levels as many people live and work near heavily-trafficked roadways. However, these localized high concentrations cannot be readily estimated by the current network of widely-spaced, fixed-site monitoring stations, even though many studies have shown persons living adjacent to sources like busy roadways exhibit significantly increased incidences of many adverse health effects (Brugge et al., 2007). These include increased risk of reduced lung function (Brunekreef et al., 1997), cancer (Knox and Gilman, 1997; Pearson et al., 2000), respiratory symptoms (van Vliet et al., 1997; Venn et al., 2001; Janssen et al., 2003), asthma (Lin et al., 2002; McConnell et al., 2006), and mortality (Hoek et al., 2002).

The use of a mobile platform outfitted with real-time monitoring instruments provides the necessary temporal and spatial resolution to characterize pollution concentration gradients and on-road concentrations while traveling at normal vehicle speeds. Many studies have demonstrated the usefulness of a mobile platform approach for determining the temporal and spatial distribution of pollutants in Europe (Bukowiecki et al., 2002a,b, 2003; Weijers et al., 2004; Pirjola et al., 2004, 2006), China (Yao et al., 2005) and the United States (Kittelson et al., 2004a,b; Kolb et al., 2004; Unal et al., 2004; Isakov et al., 2007; Baldauf et al., 2008). In Los Angeles, Westerdahl et al. (2005) and Fruin et al. (2008) used a mobile platform to

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demonstrate strong links between high on-road concentrations of pollutants like black carbon (BC) and ultrafine particles (UFP) and various measures of heavy-duty diesel truck (HDDT) traffic. They also demonstrated links between accelerations of gasoline-powered vehicles and UFP, CO, and NO. A similar platform was utilized in the current study to characterize pollution concentrations and their gradients in locations impacted by dieselized-container traffic in the communities near the Ports of Los Angeles and Long Beach.

Freeway and busy roadway impacts, especially those roadways heavily trafficked by HDDTs, are a common urban problem in the United States. However, the tripling of goods movement at the Ports of Los Angeles (POLA) and Long Beach (POLB) over the past 20 years, with a similar increase predicted for the next decade, make current air quality impacts in this location particularly important to characterize and track over time. Up to 600 HDDTs per hour have been observed at various intersections in Wilmington and West Long Beach for several hours a day (Houston et al., 2008), and such emission sources provide the potential for high on-road and near-roadway exposures. The I-710 freeway averages over 1100 diesel trucks per hour (CalTrans, 2006) with peak hours having 2200 (Ntziachristos et al., 2007) to 2600 HDDTs (Zhu et al., 2002b).

While several studies such as Zhu et al. (2002a,b) have measured near-freeway gradients as a function of distance, this paper presents some of the first such measurements made on a large spatial scale during widely-varying wind directions and other meteorological conditions in two seasons, allowing the results to be more generalizable to other near-freeway and near-roadway situations. For example, near-freeway impacts were observed to be significant even when the fraction of actual time downwind was low; during times of variable wind direction; and across a full range of wind directions (from perpendicular to nearly parallel to the roadway).

2. Methods

2.1. Mobile platform

A Toyota RAV4 sub-SUV electric vehicle served as the mobile platform. The non-emitting nature of this vehicle eliminated the possibility of self-pollution and contamination of the measurements. Instruments included were selected for their compact size, ability to report useful data at high time resolution, proven robust operation while on roadways, and for their low power consumption. Special emphasis was placed on measurements of pollutants related to emissions from diesel- and gasoline-powered vehicles. These measurements could also be used to detect emissions from ships, locomotives, ship-yard equipment or other goods movement-related operations, but such emissions were not expected to be major contributors to highly localized pollution concentrations within the port-adjacent communities due to their orders of magnitude greater distance. Table 1 shows a complete list of monitoring instruments and equipment deployed on the mobile platform. BC, nitric oxide (NO), particle-bound polycyclic aromatic hydrocarbons (PB-PAH) and UFP were measured as indicators for diesel exhaust. UFP, CO and NO were sometimes also observed to be indicators of high-emitting or hard-accelerating gasoline vehicles. CO_2 was emitted in large quantities by all vehicles. Most instruments had a time resolution of 20 s or less except for the Aethalometer which had a 1 min time resolution. The instrument power supply and sampling manifold were similar to that described by Westerdahl et al. (2005).

Calibrations of the gas analyzers were conducted at the beginning and end of each 6-week sampling period along with bi-monthly zero and span calibration checks, weekly flow checks, and daily zero checks for particulate analyzers. Winter and summer sampling were conducted on the following days: February 10, 13, 20, 21, 23, 26, 28; March 1, 4, 6, 8; July 10, 13, 14, 17, 19, 25, 27, 29, 31; and August 2, 6, 7, 9, for a total of 24 sampling days. For calibrations, a standard gas containing a mix of NO and CO was diluted using an Environics 9100 Multi-Gas Calibrator and Teledyne API Zero Air System (Model 701) to calibrate the CO and NO/NO_x analyzers. CO_2 was calibrated with zero air and span gas cylinders from Thermo Systems Inc. Flow measurements were conducted with a DryCal DC-lite flow meter with a flow range of 7 l min^{-1}–100 ml min^{-1} with an accuracy of $\pm 1\%$. Bi-monthly calibration checks of the gas analyzers exhibited 10–12% accuracy when challenged with the standard gas. Weekly flow checks indicated flows varied by no more than 5% for any given week.

The mobile platform was driven on two routes during the study: the Residential Route and the Port/Freeway/Truck Route (PFT). The PFT Route was developed to capture impacts from HDDTs and other port-related emissions while the Residential Route was developed to investigate pollution concentrations and gradients at the neighborhood level. A map of the PFT and Residential Routes is shown in Fig. 1, including meteorological and stationary monitoring sites. The routes traveled through the cities of Carson, San Pedro, Wilmington, and West Long Beach. Both routes were about 30 miles long and driven two times per day (once in the morning between 8:00 and 10:30 and once in the afternoon between 14:30 and 17:00), 2–3 times per week, in the winter and summer seasons. For all runs, video-recorded vehicles in front of the mobile platform. Audio was also recorded to keep track of events not recorded by the video.

2.2. Meteorological observations

Recent studies have shown the importance of meteorology on impacts in the near-road environment (Baldauf et al., 2008; Thoma et al., 2008). Wind direction and wind speed were especially important in affecting pollution impacts on near-roadway locations in the study area adjacent to the Ports. Wind patterns in this area are complex due to large changes in elevation and shoreline orientation in the region, and were often observed to vary significantly between sites for the same period. These differences required obtaining wind data near where sampling occurred for accurate evaluation of wind effects. In this study we were able to obtain meteorological data from two nearby sites. The first site, a South Coast Air Quality

Table 1
Monitoring instruments on the mobile platform, including measurement parameter, detection method, flow rate, and time resolution.

Instrument	Measurement Parameter	Detection Method	Instrument Flow Rate	Time Resolution
TSI Portable CPC, Model 3007	UFP Count 10 nm-1 um	Particle growth and light scatter	0.8 lpm	10 s
TSI FMPS, Model 3091	UFP Size Distribution and Count 5.6–560 nm	Electrical mobility sizing	10 lpm	10 s
TSI DustTrak Model 8520	PM2.5 Mass	Light Scatter	1.7 lpm	5 s
Magee Scientific Aethalometer	Black Carbon	Incremental Optical Absorption	2.5–4 lpm	1 min
EcoChem PAS 2000	Particle-Bound PAH	UV Ionization	2 lpm	5 s
Teledyne API, Model 300E	CO	Gas Filter Correlation	0.8 lpm	20 s
LI-COR, Model LI-820	CO_2	Non-Dispersive Infrared	1 lpm	10 s
Teledyne API, Model 200E	NOx, NO, NO_2	Chemi-luminescence	0.5 lpm	20 s
RAE Systems, Model PGM-7240	VOCs	Photoionization Detector	0.4 lpm	5 s