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Observation of elevated air pollutant concentrations in a residential neighborhood of Los Angeles California using a mobile platform

Shishan Hu [a,b,c], Suzanne E. Paulson [c,*], Scott Fruin [d], Kathleen Kozawa [e], Steve Mara [e], Arthur M. Winer [b]

[a] California Air Resources Board, Monitoring and Laboratory Division, 9528 Telstar Avenue, El Monte, CA 91731, USA
[b] Environmental Health Sciences Department, School of Public Health, 650 Charles E. Young Drive South, University of California, Los Angeles, CA 90095-1772, USA
[c] Department of Atmospheric and Oceanic Sciences, 405 Hilgard Avenue, University of California, Los Angeles, CA 90095-1565, USA
[d] Environmental Health Division, Keck School of Medicine, University of Southern California, 1540 Alcazar Street, CHP-236 Los Angeles, CA 90032, USA
[e] California Air Resources Board, Research Division, 1001 I Street, Sacramento, CA 95814, USA

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ABSTRACT

We observed elevated air pollutant concentrations, especially of ultrafine particles (UFP), black carbon (BC) and NO, across the residential neighborhood of the Boyle Heights Community (BH) of Los Angeles, California. Using an electric vehicle mobile platform equipped with fast response instruments, real-time air pollutant concentrations were measured in BH in spring and summer of 2008. Pollutant concentrations varied significantly in the two seasons, on different days, and by time of day, with an overall average UFP concentration in the residential areas of $\sim$33 000 cm^{-3}. The averaged UFP, BC, and NO concentrations measured on Soto St, a major surface street in BH, were 57 000 cm^{-3}, 5.1 μg m^{-3}, and 67 ppb, respectively. Concentrations of UFP across the residential areas in BH were nearly uniform spatially, in contrast to other areas in the greater metropolitan area of Los Angeles where UFP concentrations exhibit strong gradients downwind of roadways. We attribute this "UFP cloud" to high traffic volumes, including heavy duty diesel trucks on the freeways which surround and traverse BH, and substantial numbers of high-emitting vehicles (HEVs) on the surface streets traversing BH. Additionally, the high density of stop signs and lights and short block lengths, requiring frequent accelerations of vehicles, may contribute. The data also support a role for photochemical production of UFP in the afternoon. UFP concentration peaks (5 s average) of up to 9 million particles cm^{-3} were also observed immediately behind HEVs when they accelerated from stop lights in the BH neighborhood and areas immediately adjacent. Although encounters with HEV during mornings accounted for only about 6% and 17% of time spent monitoring residential areas and major surface streets, HEV contributed to about 28% and 53% of total ultrafine particles measured on the route, respectively. The observation of elevated pollutant concentrations across the Boyle Heights community highlights how multiple factors combine to create high pollutant levels, and has important human exposure assessment implications, including the potential utility of our data as inputs to epidemiological studies.

1. Introduction

Numerous urban air pollutants, including ultrafine particles (UFP), black carbon (BC), oxides of nitrogen (NOx), particle-bound polycyclic aromatic hydrocarbon (PB-PAH), carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compounds (VOC), are strongly associated with local combustion sources such as motor vehicle emissions. During the daytime, vehicle-related pollutant concentrations exhibit sharp gradients downwind of roadways, spiking at the roadways and then decaying to background levels at about 200–300 m downwind (Hitchins et al., 2000; Zhu et al., 2002). Recently, it has been shown that during pre-sunrise hours the impact distances from roadways are much longer, extending downwind more than 2000 m (Hu et al., 2009), during nocturnal temperature inversions and low wind speeds.

Pollutant concentration gradients surrounding local sources such as roadways are critically important in determining exposure at the individual level. Numerous epidemiological studies have linked close proximity to heavily traveled roadways with significantly increased adverse health effects, including both morbidity and mortality (e.g., Brunekreef et al., 1997; Knox and Gilman, 1997; Pearson et al., 2000;

* Corresponding author.
E-mail addresses: shhu@arb.ca.gov (S. Hu), paulson@atmos.ucla.edu (S.E. Paulson), fruin@usc.edu (S. Fruin), kkozawa@arb.ca.gov (K. Kozawa), smara@arb.ca.gov (S. Mara), amwiner@ucla.edu (A.M. Winer).

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Table 1
Monitoring instruments on the mobile platform.

Instrument	Measurement parameter	Time resolution
TSI Portable CPC, Model 3007	UFP count (10 nm–1 um)	5 s
TSI FMPS, Model 3091	UFP size (5.6–560 nm)	5 s
TSI DustTrak, Model 8520	PM2.5 mass	5 s
Magee Scientific Aethalometer	Black carbon	1 min
EcoChem PAS 2000	Particle bound PAH	5 s
Teledyne API Model 300E	CO	20 s
LI-COR, Model LI-820	CO_2	10 s
Teledyne-API Model 200E	NOx, NO, NO_2	20 s
Vaisala sonic anemometer and temperature/RH sensor	Local wind speed and direction, temperature, relative humidity (RH)	1 s
Stalker LIDAR and vision digital system	Traffic documentation, distance and relative speed	1 s

Hoek et al., 2002; Lin et al., 2002; Gauderman et al., 2007; Kan et al., 2007; Sandstrom and Brunekreef, 2007; Brauer et al., 2008; Hart et al., 2009). Vehicles equipped with fast-response monitoring instruments have recently been providing many insights into pollutant gradients and "hot spots" from a variety of sources (Bukowiecki et al., 2002; Kittelson et al., 2004; Isakov et al., 2007; Baldauf et al., 2008; Fruin et al., 2008; Hu et al., 2009; Kozawa et al., 2009; Ning et al., 2010). While traveling at normal vehicle speeds and on fixed routes, mobile instrumented platforms can capture pollutant concentrations and gradients in proximity to local emission sources, and contrast these with background pollutant concentrations measured in adjacent residential areas (Kozawa et al., 2009).

The current study used a mobile platform (MP) to generate data on vehicle-related pollutant concentrations and gradients in Boyle Heights (BH), California, an area bounded by half a dozen freeways and traversed by several major surface streets with heavy traffic flows, including heavy-duty diesel trucks (HDDT) and high-emitting gasoline vehicles (HEGV). Concentrations of pollutants (primarily UFP, BC, NOx, PB-PAH, CO and CO_2) on roadways, near freeways, and in the residential areas were measured in BH in spring and summer of 2008 to characterize local pollutant sources and their impacts in an area containing and surrounded by an unusually dense set of traffic-related sources.

2. Methods

2.1. Mobile platform and the data collection

A Toyota RAV4 sub-SUV electric vehicle free from self pollution served as the mobile platform. Table 1 lists sampling instruments and equipment installed on the mobile platform. The time resolution for most instruments is between 5 and 20 s; the Aethalometer had one minute time resolution. The average speed of the mobile platform was about 6 m s^{-1} which determined the average spatial resolution of our measurement, e.g. an instrument having a 5 s time resolution would have a spatial resolution of about 30 m. The instrument power supply and sampling manifold were similar to that described by Westerdahl et al. (2005). Calibration and flow checks were conducted on a bi-monthly and daily basis, respectively, as described in Hu et al. (2009) and Kozawa et al. (2009).

Measurement times and associated meteorological conditions are listed in Table 2. For each season, measurements were conducted 4–5 weekdays between Monday and Friday and each day had two measurement periods, one in the morning and one in the afternoon, of about 30–50 min duration. For each morning/afternoon run, the mobile platform was driven on a route developed for BH, starting at approximately the same time each day. In the spring, measurements were also collected on the BH route on a Saturday.

Real-time traffic flow on the freeway was obtained from the Freeway Performance Measurement System (PeMS) provided by the UC Berkeley Institute of Transportation.

2.2. Route

Fig. 1 shows the Boyle Heights route. The community is located east of Downtown Los Angeles, separated by the Los Angeles River. The north, west, and south sides of the BH area are bounded by rail lines, and the east side abuts the community of City Terrace. BH occupies a relatively small area, 5500 m by 3500 m, but the community is surrounded or traversed by segments of five freeways, as well as six major surface streets and tens of minor surface streets, forming a dense roadway network. Houston et al. (2004) showed that although BH and other minority and high-poverty neighborhoods in Los Angeles have among the lowest vehicle ownership rates, they experience more than two times the level of traffic density compared to the rest of the southern California region. Based on the 2000 Census, the population in BH was about 87 000, with 36% under age 18, with about 22 000 housing units (Los Angeles Times database, Laalmanac.com). Land use is primarily residential, with about 5000 residents per square kilometer, but also includes commercial shops and amenities.

The MP route was selected to collect representative air pollutant concentrations and concentration gradients near freeways, on major surface streets with higher traffic densities (such as Soto St and Cesar Chavez Blvd) and in the interiors of the residential neighborhoods in Boyle Heights.

Table 2
Measurement times and meteorological conditions (2008).

Date	Day	Relative humidity[a] (%)		Temperature[a] (°C)		Wind speed[b] (m s^{-1})		Wind direction[b] (degree)	
		AM	PM	AM	PM	AM	PM	AM	PM
March 26	Wednesday	70	59	17.8	20	1.0	1.7	254	282
March 27	Thursday	54	41	19.7	20.2	0.9	1.7	264	262
April 3	Thursday	75	63	14.7	18.3	1.3	1.7	275	266
April 4	Friday	64	–	19.2	–	0.9	–	200	–
April 5	Saturday	65	63	16.4	17.7	1.6	1.2	116	119
April 7	Monday	59	56	18.3	18.3	0.9	1.7	98	354
July 14	Monday	54	41	27.1	28.3	1.2	3.2	300	287
July 16	Wednesday	51	52	28.6	28.1	1.2	1.9	340	143
July 18	Friday	68	61	24.4	26.7	1.6	2.0	142	265
July 22	Tuesday	59	55	25.6	27.5	0.8	1.9	293	308
July 24	Thursday	61	55	24.1	25.9	0.9	1.8	360	287

[a] Data were obtained from a preliminary database provided by California Air Resources Board for the North Main Street air monitoring station about 2 km north of Boyle Heights.
[b] Data were obtained from the instruments on the mobile platform.