Environmental Pollution 193 (2014) 130–137

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Correlation of noise levels and particulate matter concentrations near two major freeways in Los Angeles, California

Shi Shu, Pu Yang, Yifang Zhu*

Department of Environmental Health Sciences, Fielding School of Public Health, University of California Los Angeles, Los Angeles, CA 90095, USA

ARTICLE INFO

Article history:
Received 25 March 2014
Received in revised form
16 June 2014
Accepted 21 June 2014
Available online xxx

Keywords:
Ultrafine particles
$PM_{2.5}$
Noise
Correlations
Freeway
Sound wall

ABSTRACT

Near-freeway environments are important from public health and environmental justice perspectives. This study investigated the spatial profile of and correlations between noise levels and particulate matter concentrations near two major freeways in Los Angeles, CA. Five minutes averages of A-weighted equivalent continuous sound level (LeqA), ultrafine particle (UFP) number concentrations, and fine particle ($PM_{2.5}$) mass concentrations were measured concurrently at increasing distances from the freeways on four streets with or without sound wall. Under upwind conditions, UFP showed relatively low concentrations and no obvious gradient, while LeqA showed decay with increasing distance as it did under downwind conditions. Moderate correlations between LeqA and UFP were observed under downwind conditions on all four streets. The presence of a sound wall changed the linear relationship between LeqA and UFP. These data may be used to study the independent and synergistic health impacts of noise and air pollutants near roadways.

1. Introduction

Near-freeway environments are of special importance when considering human exposure to air pollution and traffic noise. It was estimated that approximately 11% of US households are within the range of 100 m to a 4-lane freeway (Brugge et al., 2007). People of low socioeconomic status are more likely to live in near-freeway communities where the housing prices are usually lower. There is evidence for inequalities in the share of air pollution burden in urban settings (American Lung Association, 2001; Finkelstein et al., 2005).

The generation and propagation of traffic-related noise and air pollutants have been studied individually for decades. Briefly, the burning process in the engines of motor vehicles generates air pollutants including, but not limited to, CO, NO_x, black carbon (BC), and lead, in the forms of gas or particulate matter. When these air pollutants are emitted, they are usually carried to the downwind area by dispersion and convection, with decaying concentrations due to dilution and other loss mechanisms such as evaporation, coagulation, deposition, and chemical reactions (Ketzel and Berkowicz, 2004; Zhu et al., 2002a). The traffic-related noise is mainly generated by (1) the vibration from motor vehicle mechanical systems, such as engine, cooling fan, and air intake inlet, (2) the tire-road surface contact, and (3) the aerodynamic noise, all of which are dependent on vehicle type and speed. These noises will propagate in air and attenuate at the same time because the acoustic energy is transformed into heat and dissipate in the air (De Coensel et al., 2005; Hamet et al., 2010).

Many studies have found evidence that living closer to major roadways is associated with cardiovascular disease (Babisch et al., 2005; Brunekreef et al., 1997; Wjst et al., 1993). Decreased pulmonary function has been reported among children who live less than 300 m away from freeways (Gauderman et al., 2007). Because it has such significant health impacts, particulate matter (PM) has been measured in the near-freeway environment in many studies. Zhu and colleagues have conducted systematic measurements of the concentration and size distribution of ultrafine particles (UFP) near two major freeways in Los Angeles, California (Zhu et al., 2002a, 2002b, 2004, 2006). They found that the relative concentrations of particle number, black carbon, and carbon monoxide tracked each other well, and these pollutants' concentrations dropped exponentially as the distance from freeway increased within 300 m on the downwind side. At night, the UFP concentration also decays downwind from the freeway, but at a slower rate due to the differences in traffic and meteorological conditions (Zhu et al., 2006). For fine particles ($PM_{2.5}$) and coarse particles ($PM_{2.5-10}$), their concentrations in the vicinity of freeways were only slightly above background (Zhu et al., 2006).

* Corresponding author.
E-mail addresses: yifangzhu06@gmail.com, Yifang@ucla.edu (Y. Zhu).

http://dx.doi.org/10.1016/j.envpol.2014.06.025
0269-7491/

The propagation of traffic-emitted noise has also been studied extensively because noise is irritating, distracting, and associated with cardiovascular diseases such as hypertension and coronary artery diseases (Babisch, 2008; Bluhm et al., 2007). Noise barriers such as sound walls have been widely used to mitigate the propagation of traffic-emitted noise. Briefly, sound wall can effectively reflect the noise and therefore decrease the noise level in the area behind it. As for air pollutants, the effect of sound wall is more complicated. On the downwind side, the pollution plumes are forced by the sound wall to move up and the vertical dispersion is enhanced (Finn et al., 2010). Recent studies have shown that air pollutants such as carbon monoxide, UFP, and $PM_{2.5}$ have lower concentrations behind noise barriers (Baldauf et al., 2008; Bowker et al., 2007; Finn et al., 2010; Hagler et al., 2011; Heist et al., 2009; Wang and Zhang, 2009). These studies also acknowledged that factors such as meteorological conditions, design of roads, and vehicle-induced turbulence can play important roles in affecting the dispersion of pollutants.

Both traffic-related air pollution and noise are associated with cardiovascular disease, and a couple of studies have investigated their joint effects on human health (Beelen et al., 2009; Gan et al., 2012). Data suggest that there are not only independent but also interactive health effects of air pollution and noise. Huang et al. (2013) found that high noise levels can amplify the effects of traffic-related air pollution on heart rate variability in young healthy adults. Several modeling studies have investigated the correlation between traffic-related air pollutants and noise on the metropolitan scale (Gan et al., 2012; Van den Hooven et al., 2012). Field measurements were relatively sparse and limited to urban areas (Foraster et al., 2011; Kim et al., 2012; Weber, 2009) and street canyons (Can et al., 2011).

The objectives of this study are: (1) to investigate the spatial distribution of three traffic-related pollutants: UFP, $PM_{2.5}$, and noise; (2) to investigate if the noise is correlated with UFP or $PM_{2.5}$; and (3) to examine if the presence of sound wall can affect these correlations. This study focused on the transient (5-min average) air pollutants concentrations and noise levels in the near-freeway environment, instead of investigating the long-term (over-seasons) spatial relationship and correlation as in a previous study (Allen et al., 2009). The results from this study may help design future health studies to investigate the independent and synergistic effects of UFP, $PM_{2.5}$, and noise.

2. Experimental methods

2.1. Sites description

The field measurements were conducted on four streets in Los Angeles, CA from February to June 2013. The site map is shown in Fig. 1. The 405 site, referring to Constitution Avenue in Westwood of Los Angeles, CA, is located 6.4 km east of Santa Monica Bay. The Interstate 405 runs north to south at 330 degrees, with the Los Angeles National Cemetery on its eastern side and the Veterans Affair facility on its western side. Several measurements of air quality have been conducted at this site (Zhu et al., 2002b, 2004, 2006). Sampling locations in this study were set on both sides of Interstate 405 along the Constitution Avenue, which is perpendicular to and runs through Interstate 405 by a tunnel underneath. The topography on each side of Interstate 405 at this site is different: the eastern side was embedded in large flat grass field, while the western side was mainly surrounded by concrete streets and parking lot, with some low level buildings.

The 710 site, a collective name for the three test streets (Gotham Street, Quinn Street, and Southern Avenue), is located in South Gate City of Los Angeles County 26 km east of the Pacific Ocean. Interstate 710 runs north to south at 10 degrees with all three streets on the eastern side. Gotham Street and Quinn Street are 200 m apart and both behind a 4 m high sound wall. There is a residential area between these two streets. The buildings in this area are all low-rise residential buildings. Southern Avenue, which does not have a sound wall, is about 1.6 km south of Quinn Street, as shown in Fig. 1. It is located in an industrial area with a parking lot on the southern side, and a public storage place and an asphalt processing company on the north side. There are only a few low-rise commercial or industrial buildings on both sides of the Southern Avenue.

2.2. Sampling schedule

Twenty sampling sessions were conducted on nine different days from February to June 2013. The details of each test session are listed in Table 1. Each session involved a series of 5-min concurrent measurements of noise and PM at a given location, starting close to the freeway and then moving further away. It usually takes 30–40 min to complete a session. For the 405 site, the sampling sessions were scheduled at different hours of the day to cover different traffic and meteorological conditions. For the 710 site, the sampling sessions were scheduled during both daytime and nighttime to capture different meteorological conditions.

2.3. Meteorological data

Wind speed, wind direction, ambient temperature, and relative humidity data were obtained from nearby weather stations operated by National Weather Service. Data during each sampling session were retrieved from two weather stations, one for the 405 site (weather station ID: KCALOSAN56) and the other for the 710 site (KCADOWNE4). These two stations are no more than 2 miles away from the 405 site and 710 sites, respectively. The weather data had a time resolution of 15 min. The locations of these two weather stations are also shown in Fig. 1a.

2.4. Traffic data

The traffic volume data were obtained from the California Department of Transportation Performance Measurement System (PeMS). Traffic data from station NO.717989, which is located about 900 m north of Gotham Street, were used for the Gotham Street and Quinn Street. This traffic census station provides a complete record of traffic volumes during the measurement sessions at a 5-min resolution. These data were used to analyze how the traffic volume affects the UFP concentration, LeqA level, and their correlations.

2.5. UFP, $PM_{2.5}$, and noise

The 5-min A-weighted equivalent continuous noise level, LeqA, was measured by a Quest 2900 Sound Level Meter (3 M, St. Paul, MN). The sound level meter was calibrated with a Quest Noise Calibration Source (100 dBA Standard, 3 M, St. Paul, MN) on each sampling day. The uncertainty associated with the final readings was ± 1.0 dB. UFP and $PM_{2.5}$ were measured by a portable Condensation Particle Counter (CPC 3007) and a Dusttrak Aerosol Monitor Model 8520 (Dusttrak), both manufactured by TSI Inc. (Shoreview, MN). Both the CPC 3007 and the Dusttrak were manufacturer-calibrated and a zero-check was performed on each sampling day. For the Dusttrak, all the readings were normalized by a factor of 2.4 to compensate the difference in the light-scattering property between the real environmental particles and the lab calibration standard particles (Quiros et al., 2013). This correction does not affect the results of the correlation calculations.