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

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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).

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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.

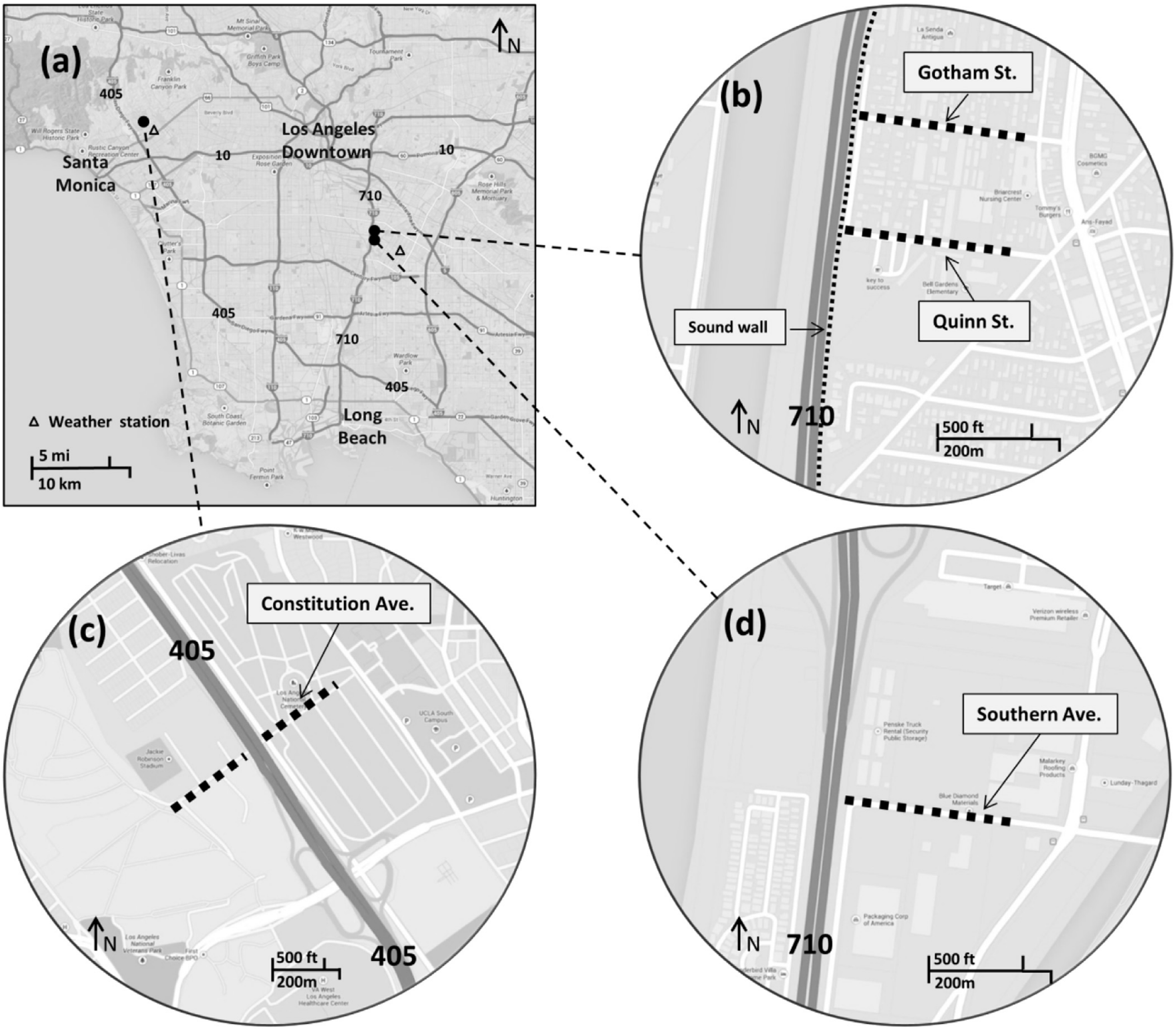

Fig. 1. Maps of the sampling locations. Panel (a) shows the locations of each site (dot) and near-by weather stations (triangle). Panels (b), (c), and (d) show the details of each street labeled individually.

The sampling locations were set at increasing distances from the freeways along each street. For the 405 site, the sampling locations were 45, 75, 105, 165, and 285 m away from the center line of Interstate 405, on both sides. For the 710 sites, the sampling locations were on the eastern side of Interstate 710 only, 15, 45, 75, 105, 165, and 285 m away from the center line. At each sampling location, 5-min concurrent measurements on UFP, $PM_{2.5}$, and LeqA were conducted. The sampling always started from the closest location and moved to those further away from the freeway. Each session consisted of 5 or 6 periods of 5-min sampling, for 405 site and 710 site, respectively. Therefore each session lasted about 30–40 min, including the time to move the instruments between locations. The details of these measurement sessions are listed in Table 1.

2.6. Data analysis

After removing the outliers that are outside the range of average ±3 standard deviations (ASTM E178, 2008), the geometric means of UFP and $PM_{2.5}$ of each 5-min measurement were calculated. To calculate the average of LeqA in each 5 min, the direct readings from the sound level meter were log-transform averaged. Pearson Correlation Coefficient, r, and its statistical significance, p, were used to assess the correlation among average LeqA and average concentrations of UFP and $PM_{2.5}$.

3. Results

3.1. Meteorological and traffic conditions

The 405 site and the 710 site, approximately 20 miles apart, had similar meteorological conditions during all sampling days. The detailed meteorological conditions of each sampling sessions are shown in Table 1. The wind speed and direction generally followed the typical diurnal change pattern in the southern California coast area: the wind speed during night and early morning was low (mostly 0–2 m s^{-1}) and the direction ranged from 0 to 150 degrees.

Table 1
Detailed time, meteorological and traffic conditions of each sampling session.

Street	Session	Date	Time	Wind direction (Degree)	Wind speed (m/s)	Traffic volume (# vehicle/5 min)	Temp. (°C)	RH (%)
Constitution	1	Feb.12	15:50–17:05	221	5 ± 3	792 ± 48	19	24
	2	Feb.17	15:20–16:40	219	7 ± 2	800 ± 90	15	63
	3	Mar 10	09:30–11:00	206	7 ± 3	909 ± 54	20	42
	4	Apr 05	10:00–12:00	205	6 ± 2	748 ± 372	28	29
Gotham	1	Apr 06	13:10–13:47	225	12 ± 2	917 ± 36	21	51
	2	Apr 07	03:02–03:50[a]	96	3 ± 2	110 ± 16	16	76
	3	Apr 11	14:46–15:24	206	7 ± 2	804 ± 122	28	32
	4	Apr 12	03:53–04:30[a]	80	3 ± 2	189 ± 56	16	70
	5	Jun 29	14:40–15:20	187	6 ± 2	861 ± 48	36	32
	6	Jun 29	17:10–17:48	178	4 ± 1	897 ± 24	39	23
Quinn	1	Apr 06	14:05–14:51	155	4 ± 1	932 ± 36	19	57
	2	Apr 07	04:03–04:37[a]	145	2 ± 2	108 ± 17	16	76
	3	Apr 11	15:34–16:21	196	5 ± 2	981 ± 35	25	41
	4	Apr 12	04:33–05:12[a]	161	1 ± 2	362 ± 64	15	72
	5	Jun 29	15:24–16:00	170	6 ± 1	897 ± 24	35	32
	6	Jun 29	16:24–17:05	174	4 ± 2	874 ± 49	35	31
Southern	1	Apr 06	15:01–15:45	197	6 ± 2	1129 ± 97	21	54
	2	Apr 07	04:51–05:35[a]	189	0 ± 1	168 ± 18	16	75
	3	Apr 11	16:32–17:26	176	5 ± 1	1297 ± 36	30	30
	4	Apr 12	05:37–06:15[a]	277	1 ± 1	988 ± 117	15	70

[a] Nighttime sampling sessions.

The late morning, afternoon, and early evening wind directions were usually between 150 and 270 degrees (from ocean to land) and the wind speeds were much higher. Therefore, the meteorological data were divided into two groups: nighttime (21:00–08:59) and daytime (09:00–20:59), as shown in Fig. 2. For the 405 site, all the sampling sessions were conducted during the daytime, which made the western side of Constitution Avenue always upwind and eastern side downwind, as shown in Fig. 2a. For the 710 sites, the daytime sampling sessions were under upwind condition while all the nighttime sessions were under downwind or no-wind conditions, as shown in Fig. 2b.

Traffic volume data collected during each sampling session were also listed in Table 1. The daytime traffic volume was generally 6–8 times higher than that in nighttime. The heavy duty truck percentage on Interstate 710 sometimes peaks to about 30% from midnight to 2 am, because Interstate 710 is the most direct route that connects the Long Beach port and Downtown Los Angeles. No sampling sessions in this study covered this time frame, therefore on average, both daytime sampling sessions and night time sessions had about 7% of heavy duty trucks. The effect of traffic composition on the near-freeway environment requires future studies. For a given session, the meteorological and traffic conditions did not change significantly, as indicated by the small standard deviations shown in Table 1.

3.2. 405 site results

The UFP number concentration, $PM_{2.5}$ mass concentrations, and LeqA level along the Constitution Avenue are shown in Fig. 3. The UFP concentrations measured on the downwind (eastern) side of Interstate 405 showed an obvious gradient while those at the upwind (western) side did not. UFP rapidly decayed within 90 m

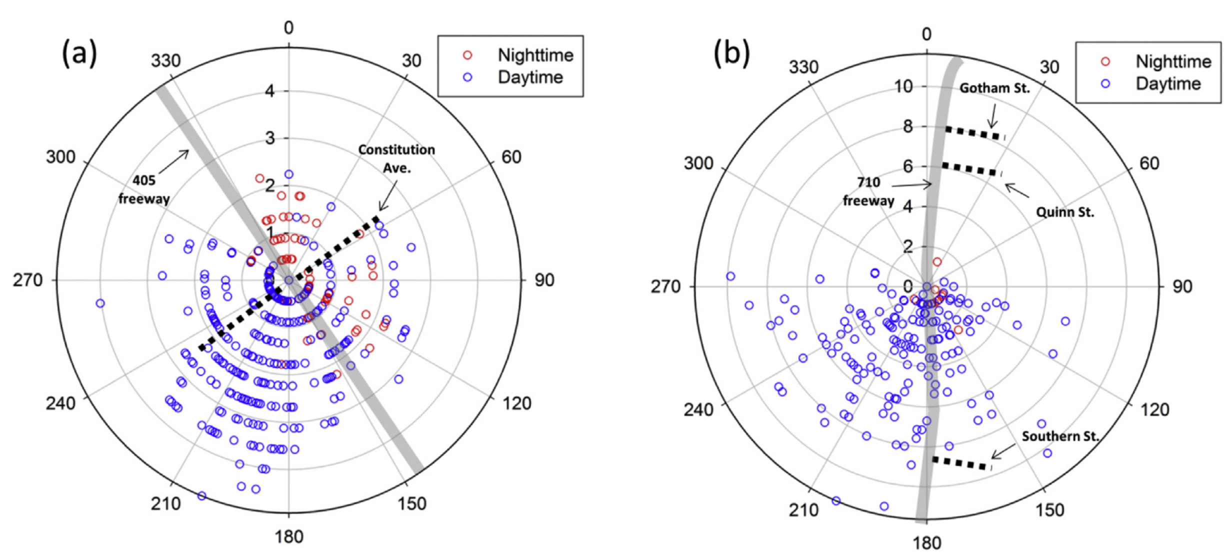

Fig. 2. Wind direction and speed during the sampling days at (a) the 405 site and (b) the 710 site.

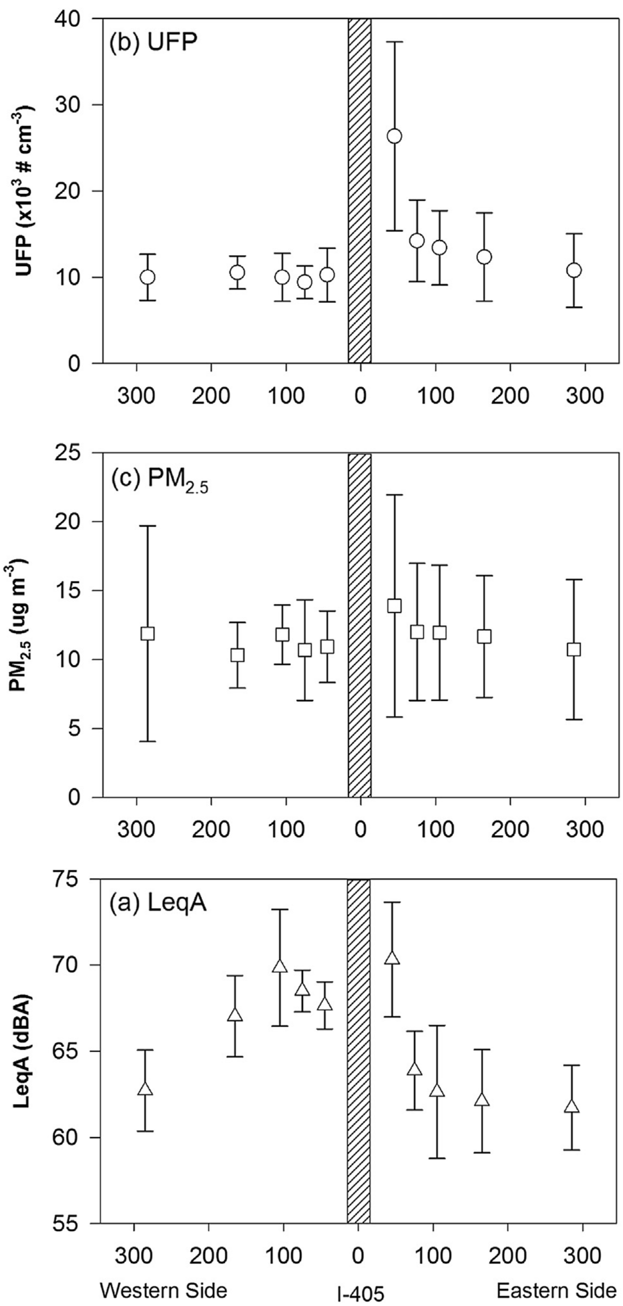

Fig. 3. Ultrafine particle number concentrations, $PM_{2.5}$ mass concentrations, and LeqA levels measured along Constitution Avenue at the 405 site.

distance to Interstate 405 and slowly approached to background level within 300 m distance. The $PM_{2.5}$, as expected, showed no obvious gradient on both sides and the concentrations on each side were similar. These findings are highly consistent with two previous studies conducted at the same site (Zhu et al., 2002b, 2006). These data also support the hypothesis that the direct contribution to particle mass concentration by traffic emission near-roadway is small (Zheng et al., 2002; Zhu et al., 2006).

The LeqA decreased as the distance to the center of Interstate 405 increased on both upwind (western) and downwind (eastern) sides. On the downwind (eastern) side, LeqA showed very similar decay pattern as UFP did: rapidly dropped within 90 m distance and slowly approached to background level. Although the drop of LeqA was obvious, the curves at each side of Interstate 405 were asymmetric. On the western side, the LeqA peaked at location 105 m instead of 45 m away from Interstate 405. There are several possible reasons that may explain this asymmetric noise profile. First, the LeqA measurements on the western side of Interstate 405 were more prone to interference since there was slight traffic on this section of Constitution Avenue while the eastern side had no traffic at all because it is a cemetery. Second, the terrain characteristics on each side of Interstate 405 were different, as described in Section 2.1. The identification of actual reason requires further study.

3.3. 710 site results

The LeqA, UFP, and $PM_{2.5}$ measured from the 710 site are shown in Fig. 4. For UFP, daytime sessions at all 710 sites showed similar decay-with-distance pattern, as found in the downwind side of I-405. In nighttime sessions, UFP concentrations showed less concentration gradient. In addition, because of less traffic volume on the I-710, the UFP concentration in the nighttime was about 25% of that in the daytime. For $PM_{2.5}$, there was no obvious concentration gradient near the I-710. The daytime and nighttime readings were not significantly different either. These observations are in agreement with those found at the 405 site.

At the 15 m locations, the Southern Avenue (without sound wall) showed an average LeqA of 70 dBA, while the daytime averages of LeqA from Gotham Street and Quinn Street (with sound wall) were 63 dBA and 62 dBA, respectively. This indicates that the sound wall effectively reduced the noise level in the near-freeway environment. The noise decay patterns on all three streets were similar to that of the 405 site, decaying within the 90 m distance and then flat out to background level. The noise decay also matched the UFP decay profile, but not the $PM_{2.5}$ profile, on these streets. The noise level showed an increase at the 285 m location because this location is close to an intersection where local traffic was observed.

4. Discussion

4.1. Correlations between LeqA and PM

The correlations between transient (5-min average) LeqA, UFP, and $PM_{2.5}$ were calculated using MATLAB® built-in functions. The Pearson correlation coefficients and their significance levels are summarized in Table 2. Under upwind conditions on the Constitution Avenue, no statistically significant correlation was observed between any pairs among LeqA, UFP, and $PM_{2.5}$. Under downwind conditions on the same street, LeqA-UFP and UFP-$PM_{2.5}$ showed moderate but statistically significant positive correlations. Similarly, LeqA-UFP and UFP-$PM_{2.5}$ were found moderately correlated on Gotham Street and Quinn Street. On Southern Avenue, the correlation between LeqA and UFP was not statistically significant, but the p value is close to 0.05. It is possible that the measurements of UFP on Southern Avenue were affected by the asphalt processing factory because volatile organic compounds emitted from this facility may condensate and form particulates (Rogge et al., 1997).

No statistically significant correlation was found between LeqA and $PM_{2.5}$ in any sampling sessions in this study. Mathematically, it is not necessary for LeqA and $PM_{2.5}$ to be correlated even though both of them are correlated to UFP. It suggests that the LeqA and $PM_{2.5}$ are two independent (or almost so) variables, both of which are correlated to UFP. The noise and UFP were emitted from vehicles and rapidly decayed as they propagated in the air. Therefore these two short-lived traffic-related pollutants, LeqA and UFP, were correlated with each other. The fact that the traffic-related noise

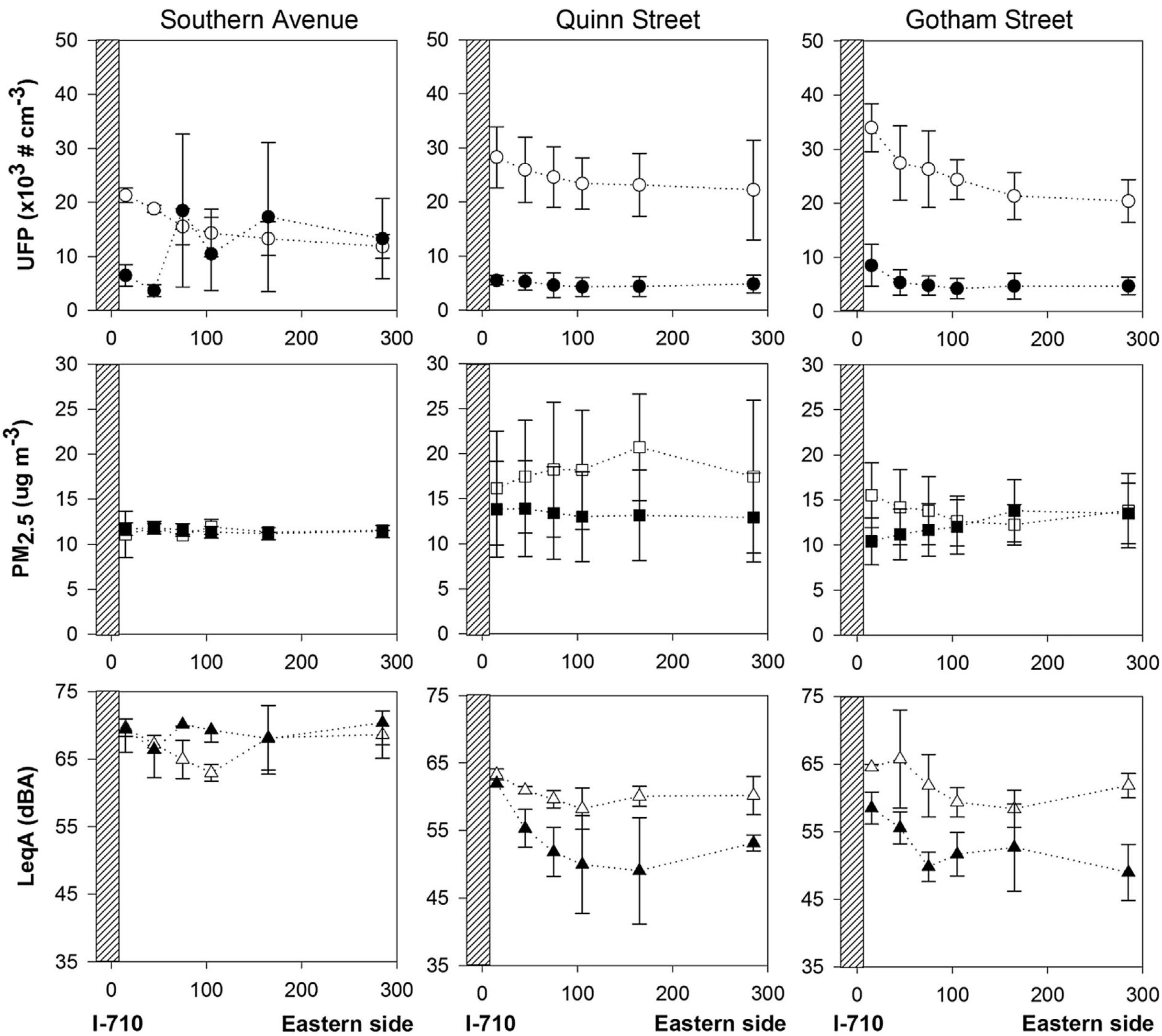

Fig. 4. Noise level, ultrafine particles concentration, and $PM_{2.5}$ measured at the 710 site. The hollow symbols show daytime sessions and the solid symbols show nighttime sessions.

was more correlated to smaller particles has been also demonstrated by Can et al. (2011).

UFP and $PM_{2.5}$ were also found to be correlated on the downwind side of Constitution Avenue and 710 site with sound wall streets (Quinn and Gotham). A recent study showed that, on a busy street, the particle number concentration is moderately correlated with $PM_{2.5}$ and even weakly correlated with PM_{10} (Dos Santos-Juusela et al., 2013). UFP-$PM_{2.5}$ correlations have been identified in near-road environments but not reported in the urban environment.

Allen et al. (2009) studied the correlations between traffic-emitted noise and air pollutions during "none rush hours" in different seasons. In contrast, this study focused on the correlations of 5-min average noise and PM levels under different traffic conditions, because both the noise level and PM levels in near-freeway environments are changing with traffic conditions over time in a day and become attenuated over space rapidly. Regardless of the differences in the research methodologies, both Allen et al. (2009) and this study identified moderate correlations between LeqA and UFP, suggesting that the LeqA can be potentially used as a surrogate for UFP concentration in the near-freeway environment. Davies et al. (2009) also found noise levels are moderately correlated with NO_2 and NO_x, suggesting that the noise level can be potentially used as surrogate for many different air pollutants. Furthermore, all these studies indicated that there is an uneven share of environmental burdens in the near-freeway areas: people who live closer to the freeway are exposed to higher noise levels and higher UFP concentrations at the same time.

Table 2
Pearson correlation coefficients between LeqA, UFP, and $PM_{2.5}$.

Site	Street	Sound wall	Wind direction	Pearson correlation coefficient[a]		
				LeqA – UFP	UFP – $PM_{2.5}$	LeqA – $PM_{2.5}$
405	Constitution Avenue	No	Upwind	0.261 ($p = 0.267$)	0.127 ($p = 0.650$)	−0.361 ($p = 0.817$)
		No	Downwind	**0.514** (**$p = 0.019$**)	**0.722** (**$p = <0.01$**)	−0.409 ($p = 0.873$)
710	Gotham Street	Yes	Downwind	**0.605** (**$p < 0.01$**)	**0.391** (**$p = 0.032$**)	−0.047 ($p = 0.195$)
710	Quinn Street	Yes	Downwind	**0.515** (**$p < 0.01$**)	**0.662** (**$p < 0.01$**)	0.124 ($p = 0.513$)
710	Southern Avenue	No	Downwind	0.359 ($p = 0.09$)	−0.047 ($p = 0.148$)	−0.238 ($p = 0.659$)

[a] Bold font indicates statistically significant results ($p < 0.05$).

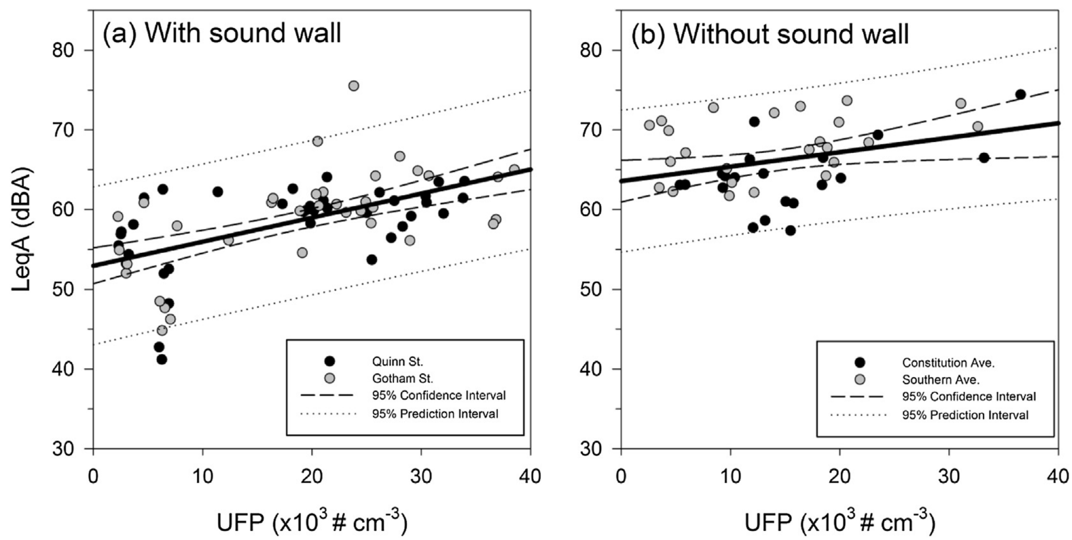

Fig. 5. Correlations between UFP concentrations and noise levels (a) with and (b) without sound wall. For Constitution Avenue, only the eastern side (downwind) data were used. The linear regression and confidence intervals are shown by the solid line and dotted lines, respectively.

4.2. Effects of sound wall on noise and UFP propagation

In this study, the presence of a sound wall had a substantial impact on the correlation between LeqA and UFP. As shown in Fig. 5, the intercept of the linear regression between UFP and LeqA were 52.9 and 63.6 dBA with and without sound wall, respectively. A two-way analysis of variance (ANOVA) test shows there is a statistically significant difference between the LeqA – UFP correlations with and without a sound wall ($p < 0.05$), indicating the presence of a sound wall can change the correlation between LeqA and UFP. However, in this study, no attempt was made to draw any conclusions on the sound wall effects on noise and air pollutant propagation, due to the limited number of test sites. To enhance the capability of UFPs migration in the near-freeway environment, adding large surface area by planting vegetation on the sound wall might be a potential solution (Hagler et al., 2012; Steffens et al., 2012).

4.3. Effects of traffic volume on noise and UFP

Fig. 6 shows how the UFP and LeqA changed with the traffic volume, by using the data collected on Gotham Street and Quinn Street (both with sound wall) at 15 m and 105 m from the center line of Interstate 710. The low traffic volume data were collected during the night time sessions and the high traffic volume data were collected during day time sessions. Linear regression was used to describe the relationship between UFP and traffic volume, while a logarithmic regression was used for the relationship between noise and traffic volume. In general, increases in traffic volume led to increases of UFP and LeqA, at both 15 m and 105 m locations. The 105 m location consistently showed lower noise level and UFP concentrations than those at 15 m locations, suggesting that living about 100 m further away from freeway can lead to considerably less exposure to both traffic noise and air pollutant. Wilcoxon signed rank test shows that the differences in UFP at location 15 m and 105 m are statistically significant, and so are the differences in LeqA.

Allen et al. (2009) found that the noise levels measured during “none rush hours” on different days were very repeatable. This reproducibility of noise level is due to the fact that the traffic conditions usually have little variation in the same time period from day to day. In this study, it was observed that the LeqA levels at different time of a day had a substantial variability, demonstrating

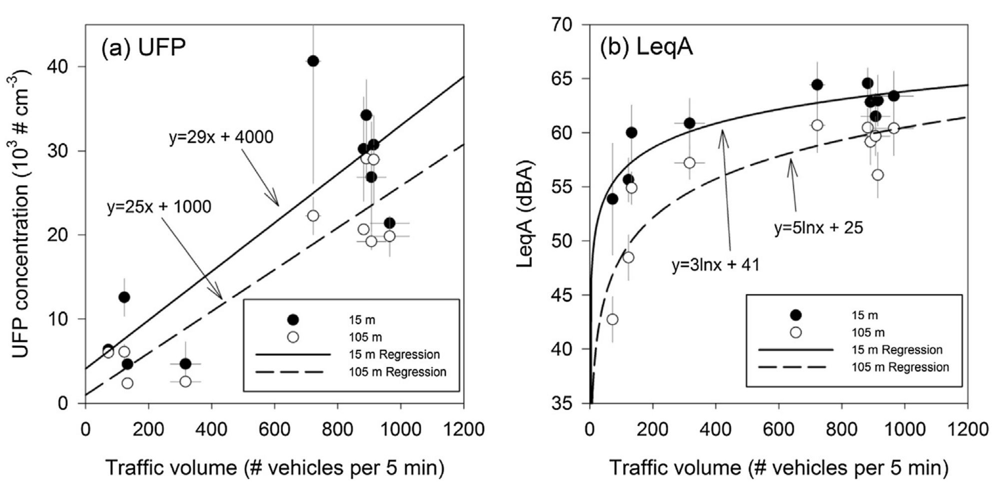

Fig. 6. Traffic volume effects on UFP and noise measured on Gotham Street and Quinn Street (with sound wall) at 15 m and 105 m distance from the I-710.

the traffic volume is a good predictor for LeqA and UFP concentrations in the near-freeway environment.

5. Conclusions

Data from this study suggest that the residents who live on the dominantly downwind side of a freeway are exposed to higher UFP and similar noise level when compared to the residents who live on the upwind side of the freeway. UFP number concentrations and noise levels were usually found to be positively correlated, under downwind conditions, within 300 m to freeways. The only exception is on Southern Avenue, where measurement interference may have occurred. $PM_{2.5}$ mass concentrations were moderately correlated with UFP number concentrations, but not with LeqA. These data indicate that the presence of a sound wall may impact the correlations between LeqA and UFP, but the effects of sound walls on noise propagation and air pollutants propagation is beyond the scope of this study. Higher traffic volume leads to a substantial increase in UFPs and a smaller increase in noise levels.

Although only four test streets were used, the findings from this study have several practical implications for environmental health, epidemiology study, and urban planning. The data suggest that there is a possibility of separating the two factors, UFP and noise, by using the upwind side of freeway as a control group and downwind side as an exposure group. For urban planning, this study suggests that there is clear evidence that the environmental pollution burden is not equally shared, even for one community that covers both sides of a freeway. More consideration should be given to local dominant wind directions, distance to freeways, and the placement of sound wall during planning process.

The authors acknowledge that, even though the correlation between noise and UFP could be expected near other freeways, the slope of their linear relationship might be street-specific. Possible affecting factors include, but are not limited to, the roadway design, sound barrier structure, building layout near freeway, composition of motorized vehicles, and meteorological conditions. The correlations identified in this study should not be applied to other streets without careful examination of all of these factors. Also, the sound wall effects found in this study shall not be applied to other locations without careful consideration, because other factors, such as meteorological conditions can also play an important role on the noise and air pollutant propagation.

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