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Evaluation of Coarse and Fine Particulate Sources Using a Portable Aerosol Monitor in a Desert Community

Robert N. Phalen · Ted Coleman

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Abstract The purpose of this study was to use a portable aerosol monitor as a preliminary screening tool to identify local sources of coarse ($PM_{10–2.5}$) and fine ($PM_{2.5}$) particulate matter within the Coachella Valley, a low-elevation desert community. The portable aerosol monitor proved to be useful in identifying particle sources unique to the region, namely, sand dunes with sparse ground cover (vegetation), a river wash, and diesel truck and freight train traffic. The general limitations relate to discrepancies in the fraction of $PM_{10–2.5}$ when compared to regional air quality data and a lack of accurate mass-based data.

Keywords Coarse particulates · Fine particulates · Air pollution · Emission sources

Coachella Valley is a unique low-desert air basin within the Southern California region that is affected by particulate matter less than 10 µm in aerodynamic diameter (PM_{10}), more specifically the coarse particle fraction ($PM_{10–2.5}$). Within the region, coarse particles have been associated with increased mortality (Ostro et al. 1999, 2000) and cardiovascular health effects (Lipsett et al. 2006). Similar studies have found an association between $PM_{10–2.5}$ and reduced cardiovascular health (Chang et al. 2007). The region was classified as a serious nonattainment area for PM_{10} by the US Environmental Protection Agency (US EPA 2011). As with similar cities and regions affected by particulate matter, recent control efforts have focused on identifying particle sources (Almeida et al. 2005; Chelani et al. 2005, 2008; Zhu et al. 2010). Zhu et al. (2010) indicated that modeling based on identified sources was an improvement over general ambient measures, which tend to underestimate exposures.

Located approximately 160 km east of Los Angeles, the Coachella Valley is a low desert with elevations ranging from just above sea level to about 150 m. It is surrounded by steeply rising mountains to the north and southwest. The combination of its natural environmental characteristics, climate, and expanding population makes the Coachella Valley a microcosm for issues of environmental sustainability and health disparity. The present study can provide a model for other such regions where unique conditions essentially demand local attention to environmental agents that influence human health and well-being. The primary aim was to use a portable aerosol monitor as a preliminary screening tool to identify local sources of coarse and fine ($PM_{2.5}$) particles within the region.

Materials and Methods

Monitoring of $PM_{2.5}$ and PM_{10} was conducted during the spring months of 2009 using a DustTrak DRX Model 8530 aerosol monitor (TSI, Shoreview, Minnesota, USA). The DustTrak has four channels for simultaneous separation and measurement of PM_1, $PM_{2.5}$, PM_{10}, and respirable particulate matter. Only $PM_{2.5}$ and PM_{10} data were evaluated in this study. The coarse particulate fraction (i.e., $PM_{10–2.5}$) was calculated by subtracting the average $PM_{2.5}$ (fine) fraction from the average PM_{10} value. The DustTrak was calibrated according to factory specifications and checked before and after monitoring activities. During the

R. N. Phalen (✉) · T. Coleman
Department of Health Science and Human Ecology,
Palm Springs Institute for Environmental Sustainability,
California State University, San Bernardino, 5500 University
Parkway, San Bernardino, CA 92407-2393, USA
e-mail: phalen@csusb.edu

study, monitoring data were collected at two South Coast Air Quality Management District (SCAQMD) air quality monitoring stations within the air basin. The SCAQMD data were used to establish a relative correction factor for the DustTrak, representative of the region. The resulting correction factor used was 1.55 (95 % CI, 1.49–1.61), which represents the difference between the instrument calibration to Arizona road dust and mass corrected data for the air basin (CARB 2008). However, the correction factor does not apply specifically to each source. The data were used to evaluate the relative fractions of coarse and fine particulate, as well as the relative amount attributed to each source. The primary goal was to use the aerosol monitor as a preliminary screening tool to identify local sources of coarse and fine particulates within the air basin. To determine exact mass per volume concentrations, typical 24-h gravimetric analysis of each source would be required.

Five-minute average samples were collected at each location to reduce sampling times between adjacent sources. All daily measurements were taken within 15 min between adjacent locations to reduce the effects of temporary excursions in weather patterns. Identified gusty wind conditions and times were avoided during the study. No major weather excursions were noted during the study. To reduce temporal effects of increasing or decreasing concentrations with time, the sampling route between the two air monitoring stations was reversed and changed each day. All measurements were taken downwind and at a distance of 10–20 m from the potential emission source. A total of 82 samples were collected for twelve identified potential sources for the region (Table 1).

Statistical tests were performed using STATA Version 12 (StataCorp, College Station, TX). Initial tests for the normal distribution of individual variables indicated that non-parametric analyses were best suited for the data. Comparisons of the fine and coarse particulate matter concentrations by location were performed using Kruskal–Wallis analysis of variance (ANOVA) and Fisher's exact median tests. The criterion for significance was a p value ≤ 0.05.

Results and Discussion

The average $PM_{10-2.5}$ concentrations and fractions are summarized in Table 2. Significant differences ($p \leq 0.05$) in $PM_{10-2.5}$ were observed between the sources. The average for all samples combined was used to differentiate sources with higher than average particulate concentrations. The uppermost sources, above the average for all samples, were associated with the sandy river wash; sand dunes with sparse ground cover; and major intersections with diesel freight truck travel. Passing trains were also identified as a potential source of $PM_{10-2.5}$; however, the number and frequency of passing trains were low in comparison to the other sources.

Figure 1 shows the fraction of $PM_{10-2.5}$ to total PM_{10} with standard error bars included. The differences between the sources were significant ($p \leq 0.05$). The largest identified source of coarse particulate matter during the monitoring project was the sandy river wash along the Whitewater River. The wash consisted of fine sand and sparse ground cover (vegetation). The other identified sources of significant $PM_{10-2.5}$ were major intersections with diesel truck traffic and passing diesel freight trains. These results are consistent with the data provided in Table 2. Accordingly, the primary sources of $PM_{10-2.5}$ were sand/silt locations with sparse ground cover and diesel traffic from trucks and passing freight trains.

The results for natural sources with sparse ground cover/vegetation were consistent with previous studies indicating that land cover data are predictive of dust concentrations in

Table 1 Sources of coarse and fine particulates evaluated

ID	Source	Location details	Characteristics
1	Residential	Various locations	Established residential areas; paved roads, sidewalks, and foliage
2	Construction	Various locations	Sites mostly inactive; wind fencing and ground cover present
3	Major intersections	Various locations	Busy intersections with gasoline and diesel vehicle traffic
4	Airport	Palm Springs International Airport	Airport boundary (fence line) and downwind adjacent locations
5	Airport plus intersections	Palm Springs International Airport	Moderate traffic and downwind from airport
6	Interstate freeway—west	Interstate 10 freeway	Various downwind locations; western end of region
7	Interstate freeway—east	Interstate 10 freeway	Various downwind locations; eastern end of region
8	Sand dunes	Dunes at state highway 111	Sparse ground cover (vegetation); off-road vehicle activity; windy
9	Sand dunes with ground cover	Ramon Drive, Palm Springs	Moderate ground cover (small shrubs)
10	Sandy river wash	Whitewater River	Sparse ground cover; dry conditions (no visible water)
11	Sandy lots with ground cover	Various locations	Commercial and residential areas; moderate ground cover
12	Passing freight train	Various locations	Downwind from passing freight train; 5-min monitoring interval

Table 2 Aerosol monitor coarse particulate matter ($PM_{10–2.5}$) concentrations

Relationship to the average for all samples[a]	Location/source (source ID)	Coarse particulate concentration (μg/m^3)[b]	Fraction of $PM_{10–2.5}$ to PM_{10}
Above	Sandy river wash (10)	10.5 ± 8.7	0.28 ± 0.16
	Passing freight train (12)	8.2 ± 3.9	0.23 ± 0.05
	Sand dunes (8)	3.7 ± 1.7	0.10 ± 0.07
	Intersection; diesel traffic (3)	3.4 ± 0.6	0.17 ± 0.06
Below	Residential (1)	2.6 ± 1.4	0.12 ± 0.07
	Interstate freeway east (7)	2.6 ± 0.9	0.12 ± 0.02
	Interstate freeway west (6)	2.3 ± 1.2	0.13 ± 0.09
	Airport plus intersection (5)	2.3 ± 1.5	0.14 ± 0.08
	Airport (4)	1.5 ± 0.8	0.10 ± 0.09
	Construction (2)	1.5 ± 0.9	0.08 ± 0.05
	Sand dunes; ground cover (9)	1.5 ± 0.9	0.07 ± 0.04
	Sand lots; ground cover (11)	1.2 ± 0.6	0.10 ± 0.09

[a] The average for all samples (n = 82) was 2.8 ± 2.8 μg/m^3

[b] Aerosol monitor concentration corrected for region using a correction factor of 1.55 based on local mass-based air quality monitoring data for the air basin (SCAQMD 2009)

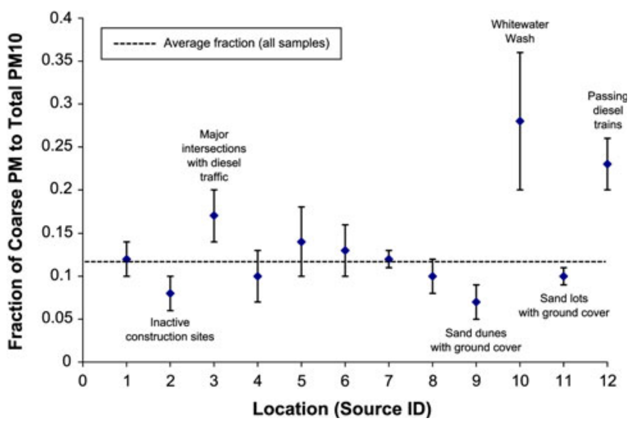

Fig. 1 Fraction of $PM_{10–2.5}$ (coarse) to total PM_{10} for each identified source

desert regions (Kimura et al. 2009). This conclusion is supported by Fig. 1. Soil type and moisture are also important considerations, with sand and silt concentrations playing an important role in dust generation (Carvacho et al. 2004; Kimura et al. 2009). Similarly, Almeida et al. (2005) found a higher association of $PM_{10–2.5}$ with wind-blown desert dust. However, the coarse fractions for natural sources (7 %–28 %) were lower than previous studies using SCAQMD data within the same air basin, which reported coarse fractions of natural PM often ranging from 50 % to 60 % (Ostro et al. 1999, 2000). These differences may be attributed to seasonal and daily fluctuations (higher winds), as well as differences between particle separation and analysis methods.

The results for diesel emission sources were consistent with previous findings that diesel emissions from vehicles are major sources of PM_{10} and $PM_{2.5}$ within residential and commercial sectors (Chelani et al. 2005, 2008; Mohanraj et al. 2011). The portable aerosol monitor findings indicated that diesel emissions associated with trains and major intersections with diesel truck traffic contributed a significantly higher fraction of $PM_{10–25}$. A limitation of this study is that the aerosol monitor uses light scattering to measure relative particle concentrations, whereas diesel particulate matter (DPM) and its higher elemental carbon (EC) content are likely to absorb a larger fraction of light than normal dust particles. This would theoretically lower particle detection and concentrations, which were observed with the correction factor in this study. Recent studies have indicated that portable photometers such as the TSI DustTrak provide comparable measures of DPM and EC mass concentrations (Kittelson et al. 2010). In summary, portable light scattering aerosol monitors are a valuable screening device for source identification of DPM emissions.

Table 3 summarizes the average fine particulate matter ($PM_{2.5}$) concentrations and fractions. Unlike the observed differences with $PM_{10–2.5}$, analysis of variance revealed no significant differences ($p > 0.05$) in $PM_{2.5}$ between the sources. The relative rankings from high to low were similar for both fine and coarse particles; however, the data indicate that the PM_{10} concentrations are dominated by $PM_{2.5}$ concentrations. Strong correlations between $PM_{2.5}$ and PM_{10} have been observed (Carvacho et al. 2004). In our study, a strong relationship between $PM_{2.5}$ and PM_{10} (Pearson $r = 0.9631$; $p \leq 0.05$) also existed, indicating that air samples were dominated by fine particles. In contrast, the association between $PM_{10–2.5}$ and $PM_{2.5}$ was less (Pearson $r = 0.3814$; $p \leq 0.05$). These results support the ability of the aerosol monitor to detect differences in coarse

Table 3 Aerosol monitor fine particulate matter ($PM_{2.5}$) concentrations

Location/source (source ID)[a]	Fine particulate concentration ($\mu g/m^3$)[b,c]	Fraction of $PM_{2.5}$ to PM_{10}
Sand dunes (8)	37 ± 9	0.90 ± 0.07
Passing freight train (12)	26 ± 5	0.77 ± 0.05
Sandy river wash (10)	22 ± 9	0.72 ± 0.16
Intersection with diesel traffic (3)	19 ± 6	0.83 ± 0.06
Residential (1)	19 ± 6	0.88 ± 0.07
Interstate freeway east (7)	19 ± 5	0.88 ± 0.02
Construction (2)	19 ± 3	0.92 ± 0.05
Airport plus intersection (5)	17 ± 8	0.86 ± 0.08
Interstate freeway west (6)	17 ± 8	0.87 ± 0.09
Sand dunes with ground cover (9)	17 ± 6	0.93 ± 0.04
Airport (4)	15 ± 8	0.90 ± 0.09
Sandy lots with ground cover (11)	15 ± 6	0.90 ± 0.09

[a] Ordered from highest to lowest average concentration

[b] Aerosol monitor concentration corrected for region using a correction factor of 1.55 based on local mass-based air quality monitoring data for the air basin (SCAQMD 2009)

[c] No significant differences (ANOVA; $p > 0.05$) were found between the $PM_{2.5}$ source concentrations

and fine particle fractions, primarily with the sandy river wash and diesel emissions.

As a screening tool, the portable aerosol monitor proved to be useful in identifying potential sources of $PM_{10-2.5}$ and $PM_{2.5}$. Particle sources unique to the region were identified in this study. The general limitations relate to discrepancies in the fraction of $PM_{10-2.5}$ when compared to regional air quality data and lack of accurate mass-based data. Finally, based on these preliminary results, local controls for improving PM_{10} and $PM_{2.5}$ air pollution should be focused on sand dunes with sparse ground cover; the Whitewater River wash; and local diesel truck and train traffic near residential areas. The focus on controls should consider vegetative ground cover in high wind areas (Kimura et al. 2009).

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References

Almeida SM, Pio CA, Freitas MC, Reis MA, Trancoso MA (2005) Source apportionment of fine and coarse particulate matter in a sub-urban area at the Western European Coast. Atomos Environ 39:3127–3138

CARB (California Air Resource Board) (2008) Data retreived from air quality and meteorological information system (AQMIS2). California air resource board. Available online. http://www.arb.ca.gov/aqmis2/aqinfo.php. Accessed 3 July 2008

Carvacho OF, Ashbaugh LL, Brown MS, Flocchini RG (2004) Measurement of $PM_{2.5}$ emission potential from soil using the UC Davis resuspension test chamber. Geomorphology 59:75–80

Chang L-T, Tang C-S, Pan Y-Z, Chan C-C (2007) Association of heart rate variability of the elderly with personal exposure to PM_1, $PM_{2.5}$, and $PM_{10\text{-}2.5}$. Bull Environ Contam Toxicol 79:552–556

Chelani AB, Gajghate DJ, Phadke KM, Gavane AG, Nema P, Hasan MZ (2005) Air quality status and sources of PM10 in Kanpur City, India. Bull Environ Contam Toxicol 74:421–428

Chelani AB, Gajghate DJ, Devotta S (2008) Source apportionment of PM10 in Mumbai, India using CMB model. Bull Environ Contam Toxicol 81:190–195

Kimura R, Bai L, Wang J (2009) Relationships among dust outbreaks, vegetation cover, and surface soil water content on the Loess Plateau of China, 1999–2000. Catena 77:292–296

Kittelson DB, Watts WF, Johnson JP, Ragatz AC (2010) A new method for the real-time measurement of diesel aerosol. In: Center for Diesel Research. University of Minnesota Mechanical Engineering. Available online. http://www.me.umn.edu/centers/cdr/reports/nioshrealtime.pdf. Accessed 18 Nov 2011

Lipsett MJ, Tsai FC, Roger L, Woo M, Ostro BD (2006) Coarse particles and heart rate variability among older adults with coronary artery disease in the Coachella Valley, Caliornia. Environ Health Perspec 114:1215–1220

Mohanraj R, Solaraj G, Dhanakumar S (2011) PM 2.5 and PAH concentrations in urban atmosphere of Tiruchirappalli, India. Bull Environ Contam Toxicol 87:330–335

Ostro B, Hurley S, Lipsett M (1999) Air pollution and daily mortality in the Coachella Valley, California: a study of PM10 dominated by coarse particles. Environ Res 81:231–238

Ostro BD, Broadwin R, Lipsett MJ (2000) Coarse and fine particles and daily mortality in the Coachella Valley, California: a follow-up study. J Expo Anal Environ Epidemiol 10:412–419

US EPA (United States Environmental Protection Agency) (2011) Particulate matter (PM-10) nonattainment area/state/county report. In EPA Green Book. US EPA. Available online. http://www.epa.gov/oaqps001/greenbk/pnca.html. Accessed 10 Nov 2011

Zhu X, Ma F, Luan H, Wu D, Wang T (2010) Evaluation and comparison of measurement methods for personal exposure to fine particles in Beijing, China. Bull Environ Contam Toxicol 84:29–33