



Short communication

Particulate dust emission factors from unpaved roads in the U.S.–Mexico border semi-arid region

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ABSTRACT

Unpaved road dust emissions in El Paso in Texas, Las Cruces in New Mexico and Ciudad Juárez in Mexico were measured using the Testing Re-entrained Aerosol Kinetic Emissions from Roads (TRAKER) system. PM₁₀ (particles with diameter < 10 µm) emissions factors from unpaved roads in Ciudad Juárez, Mexico increased by a factor of five as compared to those measured in El Paso, TX and Las Cruces, NM. The highest emission factors were observed in spring. A strong exponential dependence of PM₁₀ emissions factors on vehicle speed was observed in Ciudad Juárez, Mexico and El Paso, TX, whereas they remained constant in Las Cruces, NM reflecting differences in soil surface characteristics. The highest PM₁₀ emissions in Las Cruces and Ciudad Juárez originated from the sideline tire, indicating the possible influence of accumulated loose soil and debris on the side of the unpaved roads. Overall, strong spatial and temporal variability of PM₁₀ emission factors were computed in the Paso del Norte region, reflecting differences in road surface and vehicle traffic characteristics and further underscored the need for high spatiotemporal resolution of emission inventories to accurately identify the most susceptible unpaved roads and control their burden on particulate pollution.

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Urban communities in the Paso del Norte region along the U.S.–Mexico border experience unhealthy levels of particulate matter with road dust from unpaved roads being the most important contributor. The Paso del Norte region is located within the Chihuahuan Desert and encompasses the cities of El Paso in Texas, Las Cruces in New Mexico, and Ciudad Juárez in Mexico. El Paso was designated by the U.S. Environmental Protection Agency (EPA) as a non-attainment (i.e. in violation) area for the National Ambient Air Quality Standards (NAAQS) for PM₁₀ in 1990–2000 (TNRCC, 1999). In addition, portions of Doña Ana County exceed the NAAQS for PM₁₀ since 1991. The Mexican ambient air quality standards (Norma Oficial Mexicana; NOM) for PM₁₀ are also exceeded in Ciudad Juárez. Unpaved road dust is a critical issue since many roads in Ciudad Juárez are unpaved (~50%), and vehicle traffic in El Paso's and Las Cruces unpaved roads has rapidly increased due to expansion and growth (TNRCC, 1996; Gonzalez, 1998). Road dust from unpaved and paved roads constitutes the most important

sources of PM₁₀ in El Paso and Ciudad Juárez (~60% on average), followed by windblown dust (~27%) and tailpipe emissions (7%). Thus, controlling direct particulate matter emissions produced by vehicle traffic is essential in reducing particulate pollution in the region.

Dust particles from unpaved roads are lifted and dropped from the rolling wheels as the vehicle travels on an unpaved road (Dyck and Stukel, 1976). Factors that influence the magnitude of dust emissions include the condition of a road surface, the surface material silt and moisture content, the volume and speed of traffic and the vehicle weight. The U.S. EPA developed a methodology (i.e. AP-42) and emission factors for PM₁₀ (particles with diameter < 10 µm) from unpaved road (EPA, 1995). The assumptions, limitations and silt-loading data collection requirements needed to utilize the methodology considerably diminish the accuracy of emissions inventories for road emissions as they assign a constant and temporally invariant emission factor for unpaved roads in large geographic areas. Recently, the Testing Re-entrained Aerosol Kinetic Emissions from Roads (TRAKER) vehicle-based system has been thoroughly field tested against the traditional AP-42 and an instrumented tower system to measure PM₁₀ horizontal fluxes for

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the collection of paved and unpaved road dust as it is aerosolized by driving activities (Kuhns et al., 2001, 2003, 2005; Etyemezian et al., 2003a,b, Etyemezian and Kuhns, 2006). The mobile system correlated well with the tower measurements and comparable PM₁₀ emission factors were obtained. AP-42 emission factors were, in general, lower than those estimated from the tower measurements and the TRAKER van.

The ability of the TRAKER mobile system to continuously measure PM₁₀ emissions along the entire length of unpaved roads behind the two front wheels allows for the precise identification of unpaved roads segments that are most susceptible under typical driving conditions. This is critical in implementing targeted practices to control emissions from unpaved roads in an effective and cost-efficient manner. The objectives of the study were to estimate PM₁₀ emission factors from existing unpaved roads in El Paso, TX, Ciudad Juárez, Mexico and Las Cruces, NM; assess the variability of emission factors over time; and determine the relative importance of emissions from the centerline and sideline of the unpaved roads.

Unpaved road PM₁₀ emissions were measured for 138 and 149 km in April 2008 and June 2008, respectively, in the three urban areas. Table 1 shows the summary of the monitoring campaigns, including the number of segments of unpaved roads and the estimated distance of unpaved roads traveled. An observer (same for both surveys) rode and visually classified the road surfaces (gravel, native (fine) soil, rocks and hard surfaces, sandy soil or combination of them). The TRAKER is a cargo van that collects road dust as it is aerosolized on the road through inlets located behind the front tires (Etyemezian et al., 2003a,b, Etyemezian and Kuhns, 2006). Dust concentrations are continuously measured with a nephelometer-type DustTrak monitor (Model 8520, TSI Inc.) with a resolution time of 1-s. The designs of sampling and dilution systems, as well as the data collection system, are presented elsewhere (Etyemezian et al., 2003a,b, Etyemezian and Kuhns, 2006). The signal was transformed to emission factor (EF₁₀) (in g vkt⁻¹ (vehicle kilometer traveled) by using the following equation (Langston et al., 2007)

$$EF_{10} = 0.92 \cdot \left(\frac{1}{2} \cdot \left(\frac{PM_{10,r} \cdot V_{r,\text{main}} - PM_{10,\text{back}} \cdot V_{r,\text{dil}}}{V_{r,\text{main}} - V_{r,\text{dil}}} + \frac{PM_{10,l} \cdot V_{l,\text{main}} - PM_{10,\text{back}} \cdot V_{l,\text{dil}}}{V_{l,\text{main}} - V_{l,\text{dil}}} \right) \right) \quad (1)$$

where PM_{10,r} and PM_{10,l} were the PM₁₀ mass concentrations measured behind the right and left tires (in mg m⁻³); PM_{10,back} was

the background PM₁₀ mass concentrations behind the passenger-side door (in mg m⁻³); V_{r,main} and V_{l,main} were the flow rates at the right and left main inlets (in m s⁻¹); and V_{r,dil} and V_{l,dil} were the flow rates at the right and left dilution channels (in m s⁻¹).

Quality controls were conducted prior and after each of the two measurement periods. There were no problems associated with the performance of the PM₁₀ DustTrak detectors; the monitors showed remarkable consistency and repeatability (slope of 0.96 and intercept of 9 µg m⁻³). Audits and calibrations of the inlet flow rates were completed before each measurement period using a SPER Scientific Hotwire CFM anemometer. The instrument has been calibrated by the manufacturer. Given that the measurement systems are identical and that individual components of error are decoupled or shared between the two systems, the percent precision and relative bias were calculated. The precision and bias, 19.5% and -14.5%, respectively, were within the goals defined for this study. These results indicated that the readings between the instruments were comparable and consistent between each other. A set of validity criteria were applied to compensate for artifacts related to vehicle speed, acceleration and the surface characteristics of the unpaved road disturbed by the tires. The threshold values for vehicle speed (<1.5 m s⁻¹), acceleration (>0.5 m s⁻²) and vehicle body (>3°) used in this study were similar to those used in earlier work (Veranth et al., 2003; Etyemezian et al., 2003; Kuhns et al., 2005).

The descriptive statistics of the estimated EF₁₀ for each segment of unpaved roads for the two monitoring efforts (April and June 2008) are presented in Table 1. In April 2008, EF₁₀ in unpaved roads in Las Cruces, NM varied from 5 g vkt⁻¹ up to 36.82 kg vkt⁻¹ with median (mean) emissions from 67 (97) g vkt⁻¹ in segment#8 to 138 (229) mg vkt⁻¹ in segment#6. In El Paso, TX, EF₁₀ measured in segment#9 were as high as 13.6 kg vkt⁻¹ with a median (mean) of 193 (306) g vkt⁻¹. Mean EF₁₀ in segments#10 and #11 were 30 (37) and 36 (39) g vkt⁻¹, respectively. The highest instantaneous EF₁₀ values were recorded in Ciudad Juárez, Mexico (up to 169.8 kg vkt⁻¹), with a median (mean) value of 114 (606) g vkt⁻¹. In June 2008, median (mean) EF₁₀ in Las Cruces, NM were from 66 (105) g vkt⁻¹ in segment#2 up to 151 (202) g vkt⁻¹ in segment#7. In El Paso, TX, the highest EF₁₀ was 826 g vkt⁻¹ in segment#10a, with median (mean) values ranging from 40 (56) g vkt⁻¹ for segment#10 to 107 (123) g vkt⁻¹ for segment#10a. The maximum instantaneous EF₁₀ in the two segments at Ciudad Juárez were 1.5 kg vkt⁻¹ for segment#12 and 0.9 kg vkt⁻¹ for segment#13 with median (mean) of 75 (108) and 125 (150) g vkt⁻¹, respectively. These estimated were compared to those reported at the Fort Bliss Military Base

Table 1

Description of unpaved roads, distance traveled and mean, median and standard deviation (σ) of measured PM10 emission factor (in g vkt⁻¹) in April and June 2008.

Segment	Description	April				June			
		Distance	Mean	Median	σ	Distance	Mean	Median	σ
Las Cruces, New Mexico									
1	Hornada Rd, Gravel	27 km	210	97	895	24 km	180	99	1034
2	Hornada Rd, Gravel	6 km	144	97	201	7 km	105	66	122
3	Residential, native soil	8 km	119	74	212	4 km	422	126	2335
4	Residential, native soil	6 km	197	136	255	3 km	205	121	257
5	Residential, Gravel	9 km	167	131	361	—	—	—	—
6	Residential, rocks and hard surfaces	5 km	229	138	361	7 km	246	147	397
7	Residential, native fine soil	33 km	149	112	168	29 km	202	151	201
8	Residential and farming, sandy soil	4 km	97	67	170	15 km	166	137	129
El Paso, Texas									
9	Park, gravel	6 km	306	193	630	6 km	56	40	49
10	Open land, gravel and native soil	1 km	37	30	23	5 km	49	43	35
10a	Residential native soil	—	—	—	—	2 km	123	107	99
11	Residential native fine soil	9 km	39	36	26	17 km	61	57	30
Ciudad Juárez, Mexico									
12	Residential, native soil	23 km	606	114	7218	24 km	108	75	125
13	Residential, native soil	—	—	—	—	9 km	150	125	107

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