Atmospheric Pollution Research 5 (2014) 52–61

Atmospheric Pollution Research

www.atmospolres.com

Chemical characterization of coarse particulate matter in the Desert Southwest – Pinal County Arizona, USA

Andrea L. Clements [1], Matthew P. Fraser [2], Nabin Upadhyay [3], Pierre Herckes [4], Michael Sundblom [5], Jeffrey Lantz [6], Paul A. Solomon [7]

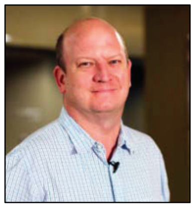
[1] *Department of Civil and Environmental Engineering, Rice University, 6100 Main Street MS–519, Houston, TX 77005 (Currently with the Department of Atmospheric Science at Colorado State University)*
[2] *School of Sustainability and the Built Environment, Arizona State University, PO Box 875306, Tempe, AZ 85287*
[3] *Department of Chemistry and Biochemistry, Arizona State University, PO Box 871604, Tempe, AZ 85287 (Currently with Conoco Phillips–Qatar)*
[4] *Department of Chemistry and Biochemistry, Arizona State University, PO Box 871604, Tempe, AZ 85287*
[5] *Pinal County Air Quality Control District, 31 N Pinal St # F, Florence, AZ 85132 (Currently with the Arizona Department of Environmental Quality)*
[6] *U.S. EPA, Office of Air and Radiation, P.O. Box 98517 Las Vegas, NV 89193*
[7] *U.S. EPA, Office of Research and Development, 944 E. Harmon Ave, Rm. 235, Las Vegas, NV 89119*

ABSTRACT

The Desert Southwest Coarse Particulate Matter Study was undertaken to further our understanding of ambient concentrations and the composition of fine and coarse particles in rural, arid environments. Sampling was conducted in Pinal County, Arizona between February 2009 and February 2010. The goals of this study were to: (1) chemically characterize the coarse and fine fraction of the ambient particulate matter in terms of mass, ions, elements, bulk organic and elemental carbon; (2) examine the temporal and spatial variability of particles within the area using a series of three sampling locations and use this information to determine the contribution of local vs. regional sources; (3) collect, re–suspend, and chemically characterize various crustal sources within the area to identify differences which may isolate them (crustal sources) as independent sources, and; (4) use a receptor based modeling approach to identify particle sources and the relative impact of each on ambient PM concentrations. This work reviews the study objectives, design, site descriptions, and measurement techniques relevant to this research effort and presents the general characteristics of PM during the study period. This unique dataset will support efforts to reduce PM_{10} and $PM_{2.5}$ concentrations in the area to below the National Ambient Air Quality Standards (NAAQS) for these pollutants.

Coarse particle concentrations are, on average, approximately 5 times fine particle mass concentrations within the region. Coarse particle concentrations in Pinal County are highest during spring and fall seasons, consistent with the tilling and harvesting seasons while fine particles concentrations are highest during fall. Crustal material is the dominant component of coarse particle composition, representing 50% of the mass on average followed closely by organic matter representing 15%. Fine particles still contain a significant crustal fraction (30%) but organic matter dominates at 37% of the particle mass.

Keywords: *Desert aerosols, coarse particles, fine particles, chemical composition*



Corresponding Author:
Matthew P. Fraser
☎ : *+1-480-965-3489*
🖷 : *+1-480-965-8087*
✉ : *Matthew.Fraser@asu.edu*

Article History:
Received: 05 August 2013
Revised: 11 October 2013
Accepted: 17 October 2013

doi: 10.5094/APR.2014.007

1. Introduction

In the United States, the National Ambient Air Quality Standards (NAAQS) were promulgated to protect human health, including the health and well–being of susceptible populations (United States Code, 2006). In terms of ambient particles, two standards exist–one for PM_{10} [particles with an aerodynamic diameter (AD) less than or equal to a nominal 10 µm] and another for $PM_{2.5}$ (particles with an AD less than or equal to a nominal 2.5 µm). The PM_{10} size fraction can be considered to be the sum of fine particulate matter (designated as PM_f, or $PM_{2.5}$) and coarse particulate matter (PM_C, particles in the size range between 2.5 and 10 µm AD).

Rural areas of the desert Southwestern United States experience high concentrations of PM_C, and it is often spikes in the PM_C concentrations that drive exceedances of the PM_{10} NAAQS within the region (U.S. EPA, 2007). Exceedance of the NAAQS requires that states formulate plans (State Implementation Plans–SIPs) to reduce the ambient PM concentrations to within acceptable limits. The creation of effective SIPs for achieving this goal relies on knowledge of the current emission sources, the relative impact of each source, and control strategies that might be employed to enact changes in source emissions and ambient concentrations.

Previous research has shown correlations between particular chemical components of ambient PM_f and adverse human health affects (Dockery et al., 1993; Dockery and Pope, 1994; Prahalad et al., 1999; Mar et al., 2000; Pope et al., 2007; Duvall et al., 2008; Happo et al., 2008; Gerlofs–Nijland et al., 2009) calling into question whether the NAAQS based on mass concentrations is sufficiently protective of human health. Consequently, extensive measurements of PM_f mass concentrations and chemical composition have been undertaken worldwide with significant effort given to correlating these measurements with human health outcomes (Dockery et al., 1993; Samet et al., 2000; Belleudi et al., 2010). However, while recent studies revealed that adverse health effects (e.g., asthma, reduced cardiac variability, etc.) are also associated with coarse particulate matter (PM_C) in ambient air

(Mar et al., 2000; Lipsett et al., 2006; Happo et al., 2008), the chemical composition of PM_C remains poorly characterized. Although significant PM_C concentrations are generally only found in rural areas, population and urban sprawl has increased public exposure to these high PM_C concentrations, increasing the importance of understanding the resultant health effects. Improved characterization of coarse particles is the critical first step to understanding the health risk they may pose.

The Desert Southwest Coarse Particulate Matter Study was conducted in and around the town of Casa Grande in Pinal County, Arizona. This region has experienced numerous exceedances of the PM_{10} NAAQS, up to hundreds of exceedances per year, and registered the highest PM_C concentrations in the region (U.S. EPA, 2007). Previous studies in this region have examined ambient mass concentrations in the $PM_{2.5}$ and PM_{10} size range, characterized some bulk chemical characteristics, and implemented Chemical Mass Balance (CMB) modeling on a limited number of samples (Pinal County Air Quality Staff, 2005). This study expands on the previous work by isolating the PM_C and PM_f size fractions, expanding the chemical characterization of the aerosol, creating detailed source profiles for crustal materials within the region, and applying multiple modeling approaches to characterize particle sources and their relative contributions.

This paper, presents the study objectives, design, measurement locations, analysis methods, and general characteristics of PM during the study period. It will describe (a) the physical and chemical characteristics of PM_C and PM_f; (b) how the physical and chemical characteristics of PM vary spatially and temporarily; (c) how chemical characteristics vary by size–fraction; (d) and the relative influence of local versus regionally transported PM.

2. Materials and Methods

2.1. Study area

Between February 2009 and February 2010, ambient aerosol sampling was conducted at three monitoring locations in Pinal County, Arizona in and around the vicinity of the town of Casa Grande. Casa Grande is located to the south of Phoenix, Arizona and is approximately half way between the major metropolitan areas of Phoenix and Tucson. Figure 1 shows the geographic location of the monitoring sites within Pinal County and the proximity to the town of Casa Grande, Arizona. Also shown in the figure is the general land use in the area including undeveloped native desert, agricultural use, and urban areas.

The Casa Grande (CG) site (401 Marshall St.), denoted by A in Figure 1, is on the roof of a one–story building located within the town of Casa Grande, Arizona, a small city with a population of approximately 50 000. The site is situated within a local business district and is immediately surrounded by buildings, paved roads, parking lots, and residential neighborhoods with trees, which are slightly taller than the building. Local emissions from railroad traffic, paved roadway traffic, and a few industrial locations likely impact air quality at this site.

The Cowtown (COW) site (37 580 W. Maricopa–Casa Grande Hwy.), denoted by B in Figure 1, is located approximately 27 km to the northwest of the city of Casa Grande. It is a rural location, located on a 0.1 km by 0.1 km section of native (unaltered with original vegetation) desert adjacent to a two lane highway connecting Casa Grande with the city of Maricopa, located 35 km to the northwest. Agricultural cropping fields, in various stages of rotation or lying fallow, are located in all directions (extending 4 km east and west and 10 km north and south) of the COW site. In the immediate vicinity of the sampling site there are a number of potential sources including fallow cropping fields (within 0.25 km to the west, north, and east), cattle feedlots (within 0.5 km south and southeast), a grain processing operation (0.7 km southwest), a fertilized soil operation, (2 km southwest), railroad traffic (tracks <0.5 km south), and traffic on unpaved (adjacent and at various distances) and paved (adjacent) roads. The regulatory air quality equipment at this site registers numerous 24–hour exceedances of the PM_{10} standard each year (U.S. EPA, 2007).

The Pinal County Housing (PCH) site (970 N. Eleven Mile Corner Rd), denoted by C in Figure 1 is located approximately 17 km to the east of the city of Casa Grande. The site is immediately surrounded by native desert, is approximately 0.2 km west of the Pinal County Housing Projects, and is nearly 0.2 km east–southeast of the wastewater treatment ponds for the complex. Air quality at this site is likely to be influenced by agricultural fields, which are located about one km from the site in all directions, vehicle traffic from the housing project, and traffic over the native desert and unpaved (adjacent and at various distances) and paved roads (0.3 km to the east), and a dairy and cotton gin located within 3 km of the site.

2.2. Ambient sample collection

At each sampling site, four Sierra–Anderson Model 241 dichotomous samplers were deployed to collect equivalent 24–hr samples on a one–in–six day schedule. These samplers collected PM_f and PM_c size fractions simultaneously at a total flow rate of 16.7 Liters per minute (L/min) (approximately 15 L/min and 1.7 L/min to the fine and coarse channels, respectively). Two of the four samplers at each site used Teflon filter media in both channels for analysis of fine and coarse PM mass, ions, and elements. One of the four samplers was equipped with quartz–fiber filters in both channels, which were used for determination of bulk elemental carbon (EC) and organic carbon (OC) content as well as selected organic species using a composite of 6 weeks worth of samples. The remaining sampler was used to collect blanks and other co–located samples for quality assurance/quality control and instrument precision determination.

Filter media was transported between the laboratory and the field seated within the plastic instrument filter holders and sealed inside sterile and cataloged polystyrene Petri dishes (Pall Corporation). Following collection, samples were placed back into their original containers and kept at reduced temperatures ("blue ice" during transport and <–4 °C during storage) until laboratory analysis.

Although not part of the sampling campaign, each sampling site also measured semi–continuous PM_{10} mass concentration using a Thermo Scientific Tapered Element Oscillating Microbalance (TEOM) monitor (Series 1400ab) for compliance monitoring. The unit was operated without a dryer at 50 °C. Data was recorded at 5 minute increments and averaged into 24–hour daily concentrations. Meteorological data presented here was measured by independent monitors in Maricopa, Arizona (8 km northwest of the COW monitoring site).

2.3. Source sample collection

Soil samples were collected from 15 different sites within the sampling region representing a variety of different soil types including agricultural fields, native desert (unaltered desert in close proximity to the site), paved and unpaved road dust, and material representative of a local cattle feedlot. Table 1 details the sampling locations, soil types, soil and source category determinations along with information about the nearest ambient monitoring location. Most sites were sampled during three different seasons including spring, fall, and winter but a few (i.e. cotton field) were sampled during unique events (i.e., cotton defoliation). In total, 35 soil samples were collected. All samples were obtained from the top 15 mm of the surface using a trowel, or by broom on the paved surface, and placed into a pre–baked glass jar for storage and transport (Hagen, 2004).