CHARACTERIZATION OF ROAD DUST IN WESTERN NORTH DAKOTA

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Title

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

Samples were collected during summer 2014, at three locations: along 15th St. SW near agricultural test plots, along an access road leading to a newly built oil drilling pad, and adjacent to the pad. MiniVol™ TAS Samplers (Air metrics, Springfield, OR) were used for sampling. Total Suspended Particles (TSP), and particulates less than 10 or 5 microns (PM_{10} and $PM_{2.5}$, respectively) were collected using quartz fiber filters. Samples were collected pre and post access road and pad construction.

The mass concentration of TSP at 15th St. ranged from 365 - 911 µg/m^3. Concentrations at the access road ranged from 8 – 68 µg/m^3 and near the pad from 9 – 42 µg/m^3. SEM/EDS analyses show most particulates are silicate or carbonate mineral fragments or biogenetic particles. The most common particle size is between 2.5µm and 10µm.

The main sources of airborne particulate matter observed were from road dust re-suspension, and biological sources.

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LIST OF ABBREVIATIONS

NAAQS...National Ambient Air Quality Standards

PM..Particulate Matter

$PM_{2.5}$..Particulate Matter less than 2.5 micrometers in diameter

PM_{10} ....Particulate Matter less than 10 micrometers in diameter

TSP ....Total Suspended Particulate

U.S. EPA ....U.S. Environmental Protection Agency

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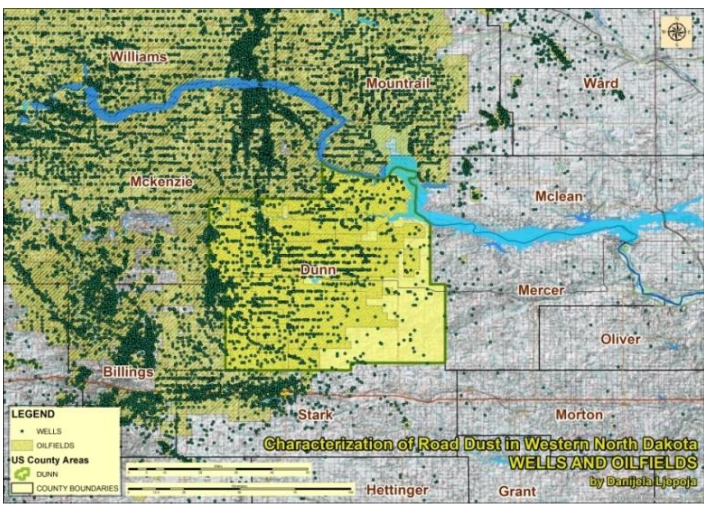
CHAPTER 1. INTRODUCTION

The oil boom in western North Dakota that began several years ago has led to a rapid heavy traffic volume increase in that area. A shale oil well requires 2,300 truck trips in its lifetime driven mostly over unpaved road (High Country News, 2014), and in 2014 there were 190 oil rigs were active in North Dakota (Figure 1, www.dmr.nd.gov) and nearly 6,800 wells operating in the western North Dakota (High Country News, 2014). Even though in May, 2015, the rig count was at 84, there is still significant traffic associated with the industry. One major problem associated with dirty paved and unpaved roads is dust. Health and environment problems are associated with dust. Some of the problems correlated are damage to vegetation, adverse health effects to humans and animals, effects on soil and water quality and traffic hazard due to poor visibility caused by the dust. Due to all of these negative effects dust is still a major under-studied concern in western North Dakota. Limited data is available on this subject.



INDUSTRIAL COMMISSION OF NORTH DAKOTA
OIL & GAS DIVISION
2014 MONTHLY STATISTICAL UPDATE

Month	Monthly Oil Production	Wells Producing	Average Daily Production	Permits				Spuds	Average Rig Count
				Dev	Ext	WC	Total		
Jan	29,053,210	10,129	937,200	250	0	3	253	208	188
Feb	26,692,529	10,211	953,305	178	0	2	180	210	189
Mar	30,280,750	10,491	976,798	248	0	3	251	215	193
Apr	30,127,641	10,688	1,004,255	230	0	2	232	191	188
May	32,259,365	10,916	1,040,625	227	0	7	234	216	189
Jun	32,787,662	11,109	1,092,922	245	0	2	247	245	190
Jul	34,550,160	11,304	1,114,521	265	0	0	265	242	192
Aug	35,118,088	11,580	1,132,842	267	0	5	272	218	193
Sep	35,589,844	11,774	1,186,328	260	0	1	261	253	195
Oct	36,691,154	11,907	1,183,586	324	0	4	328	243	191
Nov	35,647,736	11,951	1,188,258	235	0	0	235	211	188
Dec	38,047,672	12,124	1,227,344	250	0	1	251	172	181
Totals	396,845,811		1,087,249	2979	0	30	3009	2624	190

Figure 1. Oil rigs and wells in western North Dakota. Above: Map of oil wells; bottom: average rig count (www.dmr.nd.gov).

This study provides data to help track changes in air quality and to document baseline values of particle volumes. The main focus of the study is air quality in the Manning Ranch area, using MiniVol™ TAS samplers (Air metrics, Springfield, OR, USA), SEM and Image J Analysis Software. Samples were collected at three different locations near the Dickinson Research Extension Center Ranch Headquarters (DREC). The Manning Ranch is located 22 miles north and 3 miles west of Dickinson, ND.

The main sources of airborne particles observed were traffic emission, road dust re-suspension, and biological sources (Figure 2).These types of dust particles are shown to contribute to aggravated health problems (WHO, 1999).

Figure 2. The main sources of airborne particles at sampling sites. Left: Location 1 - traffic emission; Center: Location 2 - biological sources; Right: Location 1 - road dust re-suspension.

The text is organized as follows: Chapter 2 defines dust for the purposes of this study and why it may be of concern in western North Dakota. Chapter 3 describes the study area and the sampling and analytical methods. Chapters 4 and 5 provide results and discussion.

CHAPTER 2. BACKGROUND AND PREVIOUS WORK OF DUST

2.1. Background

2.1.1. Dust definition and types of dust

“Dust: small, dry, solid particles projected into the air by natural forces, such as wind, volcanic eruption, and by mechanical or man-made processes such as crushing, grinding, drilling, demolition, shoveling, conveying, screening, bagging, and sweeping. Dust particles are usually in the size range from about 1 to 100 µm in diameter, and they settle slowly under the influence of gravity” (IUPAC,1990).The smaller particles have a tendency to stay longer in the air and to travel further because they are lighter a compared with bigger particles which are heavier particles. Smaller particles may be inhaled through the mouth and through the nose easier than the bigger particles. Therefore, they have a stronger impact on human health if exposed to high concentration of particles. Possible health problems including but not limited to irregular heartbeat, irritation of the nose, eyes and throat, coughing, and shortness of breath.

A key part of air quality monitoring is the measurement of levels of atmospheric particulate matter (PM). PM, or particulate matter, pollution is the term for liquid, solid or a complex mixture of liquid and solid particles suspended in air. The particles are classified by size into three categories, coarse, fine and ultrafine particles (Fig.3)

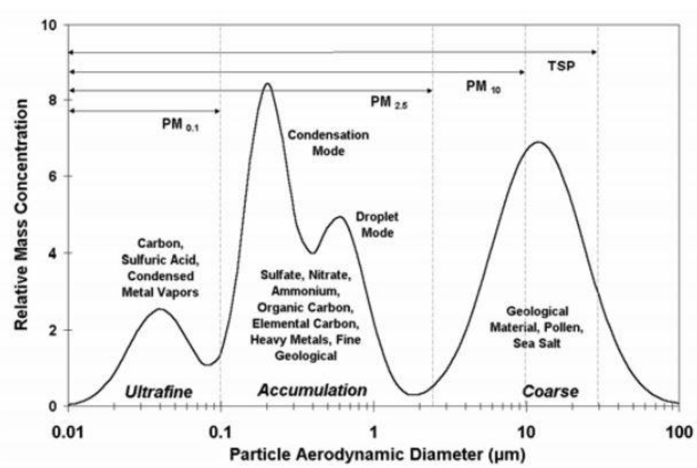


Figure 3. Particle size distribution (Chow, 1995).

A variety of classification systems and terms are used to describe particle matter (Table 1). Terms can be derived from sampling or analytical methods like “total suspended particles, ”suspended particulate matter," or "black smoke." They could be derived from site of deposition in the respiratory tract, e.g.- inhalable, respirable and thoracic particles. The terms "PM_{10}" and "$PM_{2.5}$" are used in both connotations (WHO, 1999). The most important dust characteristics for dust control and sampling are composition and aerodynamic diameter. For sampling purposes, the European Standard Organization (CEN), the American Conference of Governmental Industrial Hygienists (ACGIH), and International Organization for Standardization (ISO) have reached agreement on definitions of the inhalable, respirable and thoracic particulate fractions (ACGIH, 1999; ISO, 1995; CEN, 1993).

Table 1. Classification of particle matter (ACGIH, 1999; ISO, 1995; CEN, 1993; ICRP, 1994, WHO, 2000).

	A. Particle Size (EPA, 2013)	B. By site of deposition in the respiratory tract (ACGIH, 1999; ISO, 1995; CEN, 1993)
Atmospheric dust	Inhalable Coarse Particles (PM_{10})	Inhalable particulate matter, <100µm
	Inhalable Fine Particles ($PM_{2.5}$)	Thoracic particulate matter, <30µm
		Respirable particulate matter, <10µm

Depending on particle size and their predicted penetration into the lung, EPA groups particles into two categories (USEPA, 2013).

- Inhalable coarse particles (PM_{10})–are inhalable particles with size between 2.5 -10 µm.
- Fine particles ($PM_{2.5}$) - are inhalable particle size less than 2.5µm.

In this work, the term Total Suspended Particles (TSP) will refer to a sample that collects all size ranges present in the air.

Depending on the type of source (mechanisms of emissions) PM is classified into two groups:

- Primary particles are emitted directly into the atmosphere from primary sources such as burning (smoke), dirt, road dust, industrial activities, sea spray, mold, pollen, and spores and then blown by wind.
- Secondary particles, which originate from secondary sources, are formed through the chemical transformation of gases (Guttikunda, 2008). They are usually smaller in size compared with particles from primary sources

2.1.2. Sources of dust

Particulate matter may be emitted from a number of sources. Any activity which involves burning of materials or any dust generating activity can be a source of dust.

Sources may be natural (e.g. dust storms, forest fire, pollens, and volcanoes) and anthropogenic (Table 2). Anthropogenic sources are more widespread and more important for public health compared with natural sources (WHO, 2000).

Table 2. Atmospheric Dust - Particulate matter sources (WHO, 2000).

Natural	Anthropogenic
Dust Storms Forest fire Pollen Volcanoes	Construction Sites Factories (mineral dust, chemical dust) Road-cars Farming (agriculture) Mining

.

2.1.3. Routes of exposure

The way the living organism comes into contact with a hazardous substance is called routes of exposure. Three routes of exposure are ingestion, inhalation and direct exposure (Table 3).

Table 3. Important environmental and occupational exposure routes (EPA, 2012).

Ingestion	Occurs when people eat/drink/swallow hazardous material
Inhalation	Occurs when people breathe materials into lungs
Direct (External) Exposure	Touching or direct contact with the skin (absorption)

Suspended particulate matter may have a direct effect on human health if it is inhaled and deposited in the body after inhalation. Particles may be inhaled by the mouth (oral route) and the nose (nasal route). Several factors are involved in the probability of inhalation particles: size, particle aerodynamic diameter, air movement around body and breathing rate. Even inhaled particles may not stay in the body and be deposited and cause health problems (WHO, 1999); they might be exhaled, too. Only particles that remain in the body for a long time may have potential to cause disease.

2.2. Previous work on dust

Extensive research on dust and its effects has been carried out around the world. Some examples are discussed here.

Valavanidis et al. (2008) reviewed several research studies on the role between airborne particulate matter and human health. Results showed that the smaller the size of particulate matter the higher the toxicity in humans, because the smaller PM can penetrate deeper into the airways of the respiratory tract.

Kuhns et al. (2003) examined vehicle based road dust emission using a device (TRAKER) that samples PM on the front and behind a vehicle's tire. The difference measured is related to the airborne flux of particles from the roadway. The authors reported a relationship between PM Emission Factor and vehicle speed.

Čabanova et al. (2012) examined chemical and phase analysis of road dust. Samples were collected near a crosswalk of a busy road and near the parking place, and they were characterized by a combination of analytical and microscopic techniques. SEM/EDS was used for characterization of morphology and size of particles; a total carbon analyzer was used for carbon. Raman micro spectroscopy and Fourier Transform Infrared Spectroscopy were used for determination of phase composition of the dust samples. Major compounds in both samples were quartz, calcium aluminum silicate, titanium dioxide and crystalline carbon.

Schwartz (1994) examined relation between particulate matter and hospital admissions for the elderly in Minneapolis-St. Paul, MN. Data on hospital admission for persons 65 years and older were collected for period of three years (1986-1989) by admission date for chronic obstructive pulmonary disease and for pneumonia. Discharge diagnosis was used for classification. Poisson regression was used to control for three factors (time trends, weather and seasonal fluctuations). Ozone and PM_{10} were risk factors for pneumonia admission, and PM_{10} for chronic obstructive pulmonary disease admissions.

Hefflin et al. (1994) studied effect of dust storm and respiratory diseases in southeast Washington State during October 1991. PM_{10} levels exceeded 1000 $\mu g/m^3$ for two days during the storm. This number is six times greater than the EPA standard for 24-hour period for PM_{10}. Three community hospitals were monitored; emergency room visits for bronchitis were slightly increased, estimated at 3.5% per 100 $\mu g/m^3$

increase in PM_{10}. Results showed that the naturally occurring PM_{10} has a much smaller effect on the respiratory health than anthropogenic occurring PM_{10}.

Gunawardana et al. (2012) analyzed the mineralogy and morphology of dust samples from the Gold Coast, Southeast Queensland, and Australia. Samples were collected from different land uses and background and compared. Road dust samples were collected using a dry and wet vacuuming system. Results showed that the road dust samples consist mainly of mineral source; 60% quartz, clay, albite, microcline, chlorite, and muscovite; 2% of organic matter; 30% potentially pollutants.

Only limited data is available for North Dakota. Cicacek and Todhunter (1999) documented the historical frequency of airborne dust in the Red River Valley of the North. This study is significant because its put together the number of airborne dust observation for the period 1948 to 1994 for the Fargo National Weather Service Office which give us statistical data for a long period (over 46 years) and also this work has implications for global climate changes.

CHAPTER 3. STUDY AREA, SAMPLING AND ANALYTICAL METHODS

3.1. Study area

Samples were collected at the Dickinson Research Extension Center (DREC) Ranch Headquarters, which is located 22 miles North and 3 miles West of Dickinson, ND or 2 miles south and 3 miles west of Manning, ND (Latitude: 47°12' N, Longitude: 102° 50' W). The elevation at the Manning Ranch is approximately 2380 feet above sea level. Manning is located in Dunn County in western North Dakota (Fig.4). The county is known for agriculture and oil activity. One of the characteristics of the Manning site relevant for this study area is strong wind from the northwest (Table 4) (NDAWN).

Table 4. Wind speed (mph) at Dickinson Station 1 NW - North Dakota Agricultural Weather Network (NDAWN) for 5 years.

	June	July	August
2009	6.3	6.8	6.9
2010	7.4	7.2	8
2011	6	7	8
2012	9.1	7.2	7
2013	7.7	7.0	6.7
2014	8	6.7	6.7
Average (mph)	7.4	7	7.2

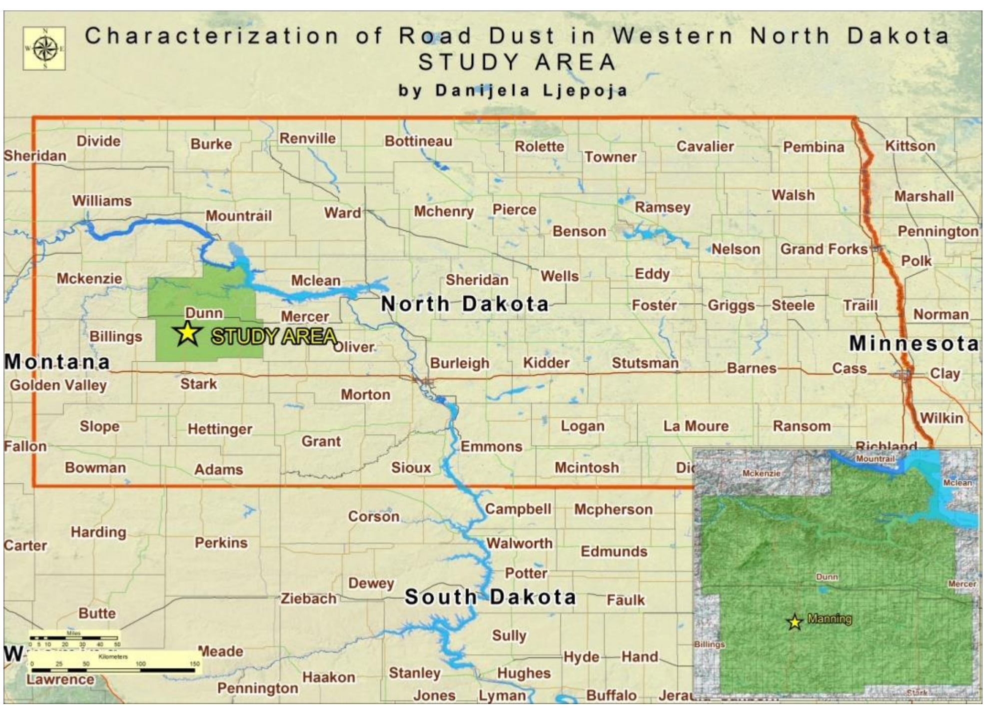


Figure 4. Location of study area. Insert shows Dunn Country. Figure 5 shows details.

3.1.1. Climate and vegetation

North Dakota south and west of the Missouri River is part of the Northwestern Great Plains Ecoregion (EPA, 2013). The topography in the area is gently rolling plains with occasional buttes and badlands. Bedrock material consists of shale, sandstone and siltstone, while the soil units in the study consist mainly of silt loams (NRCS, 2014). The natural vegetation includes a variety of prairie grasses. Most of native grassland has been replaced by alfalfa and spring wheat over the ecoregion.

North Dakota's climate is described as sub-humid continental, excellent for production of small grains and livestock. The average annual temperature in Manning is 42.5°F (5.8°C). The warmest month is July with an average temperature of 69.7°F (20.9°C). The coolest month is January, with an average temperature of 14.8°F (-9.6°C).The average amount of precipitation for the year in Manning is 16.8" (426.7 mm). The month with the most precipitation on average is June with 3.3" (83.8 mm) of precipitation. The month with the least precipitation on average is February with an average of 0.4" (10.2 mm). There is an average of 66.9 days of precipitation, with the most precipitation occurring in June with 9.5 days and the least precipitation occurring in February with 3.7 days (NDAWN, 2014).

3.2. Sampling site descriptions

Sampling was carried out in three locations on and near the Manning Ranch (Figs. 5, 6). For each location, a center point is defined, and subsample locations are defined relative to it (Table 5). All samplers were placed at 1.5 m above the ground.

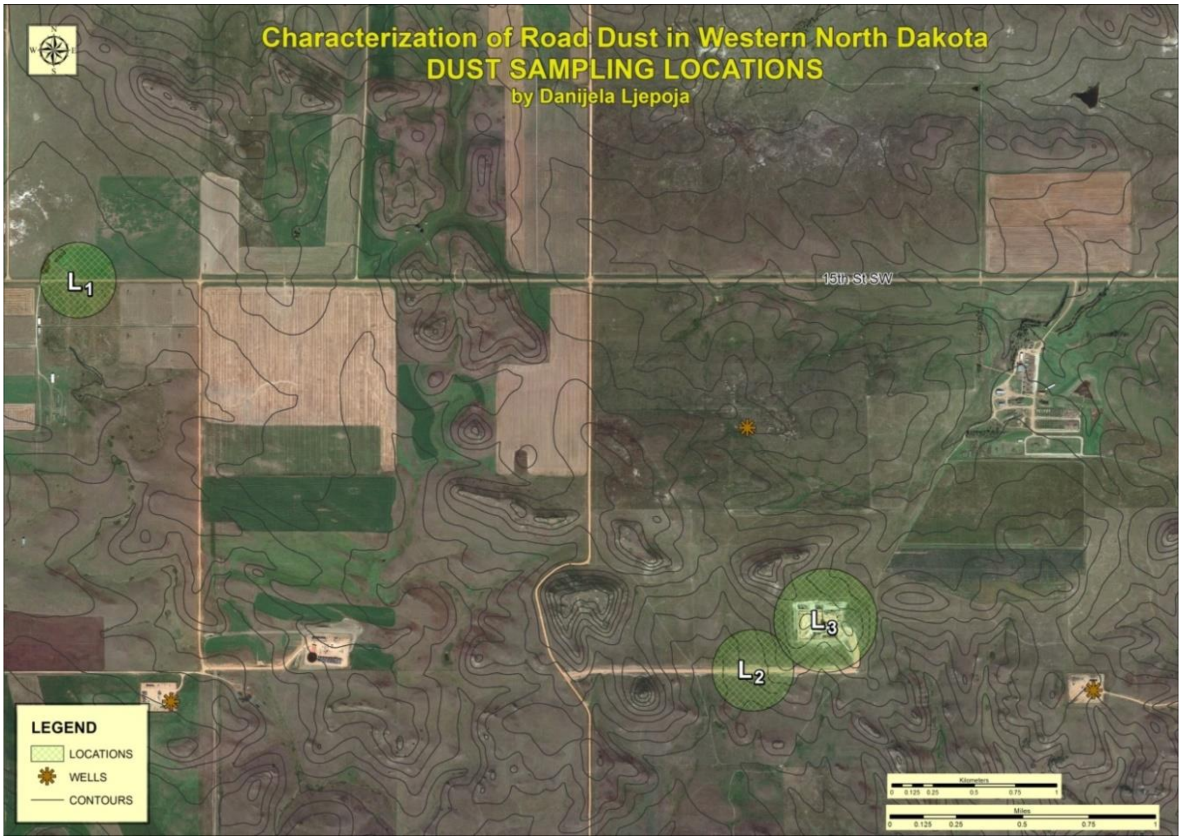


Figure 5. Map of sampling site locations.

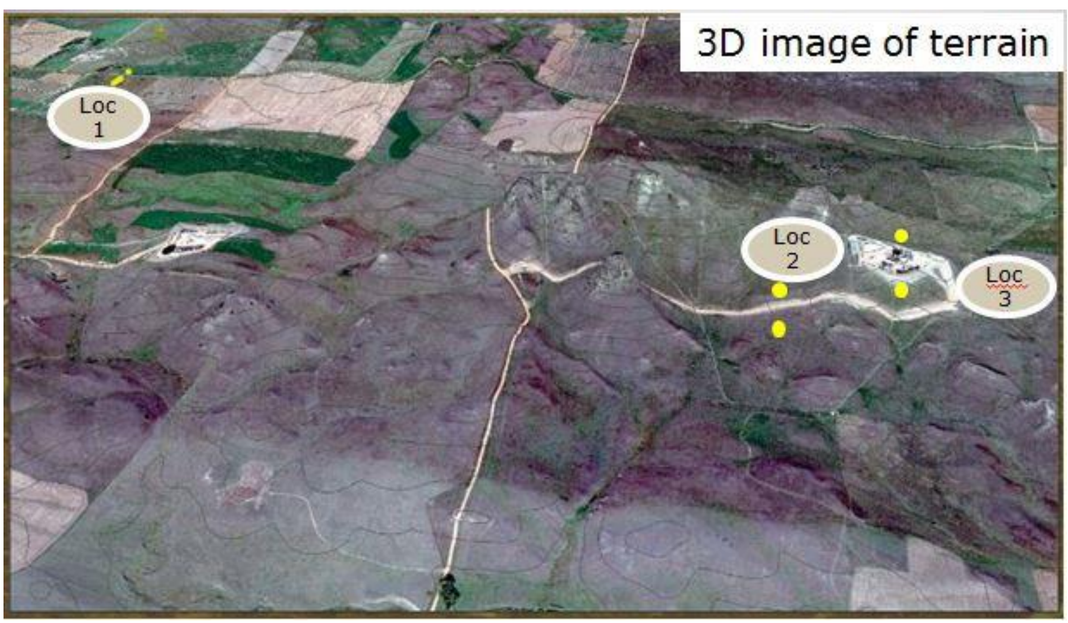


Figure 6. 3D Image of terrain. Image showing sampling locations at Dickinson Research Extension Center Manning Ranch.

Table 5. Location of sampling points.

	Latitude	Longitude	Site ID	Distance from the center
Location1	47° 11' 50.99"	-102° 53' 30.84"	L1-N1 L1-S1 L1-S2 L1-S3	38ft N 38ft S 100ft S 150ft S
Location2	47° 11' 2.39"	-102° 51' 10.79"	L2-N L2-S	78ft N 78ft S
				Distance from the fence that surrounds drill pad
Location3	47° 11' 9.59"	-102° 50' 59.99"	L3-S L3-N	1ft S 1ft N

3.2.1. Sampling Location 1

Samplers were installed on the north and south sides of 15th St. SW (Fig. 7). On the first day of sampling, June 24, 2014, TSP was collected at locations L1-N1 and L1-S1, both 38ft from the road center, and at two sample locations along a service road in the DREC agricultural test fields. These locations, L1-S2 and L1-S3, were 100ft and 150ft, respectively, south of the road center. The second day, June 25, 2014, at Location 1 TSP sampling was carried out only at location L1-N1 and L1-S1.

During the second sampling campaign, July 8, 2014, samplers were set up adjacent to one another at locations L1-N1 and L1-S1 to collect PM_{10} and $PM_{2.5}$ simultaneously.

Figure 7. Photographs at Location 1. Construction work at Location 1 (left); Photo of dust generated by one truck at Location (middle); setting 2 at Location 1 south of the road (right).

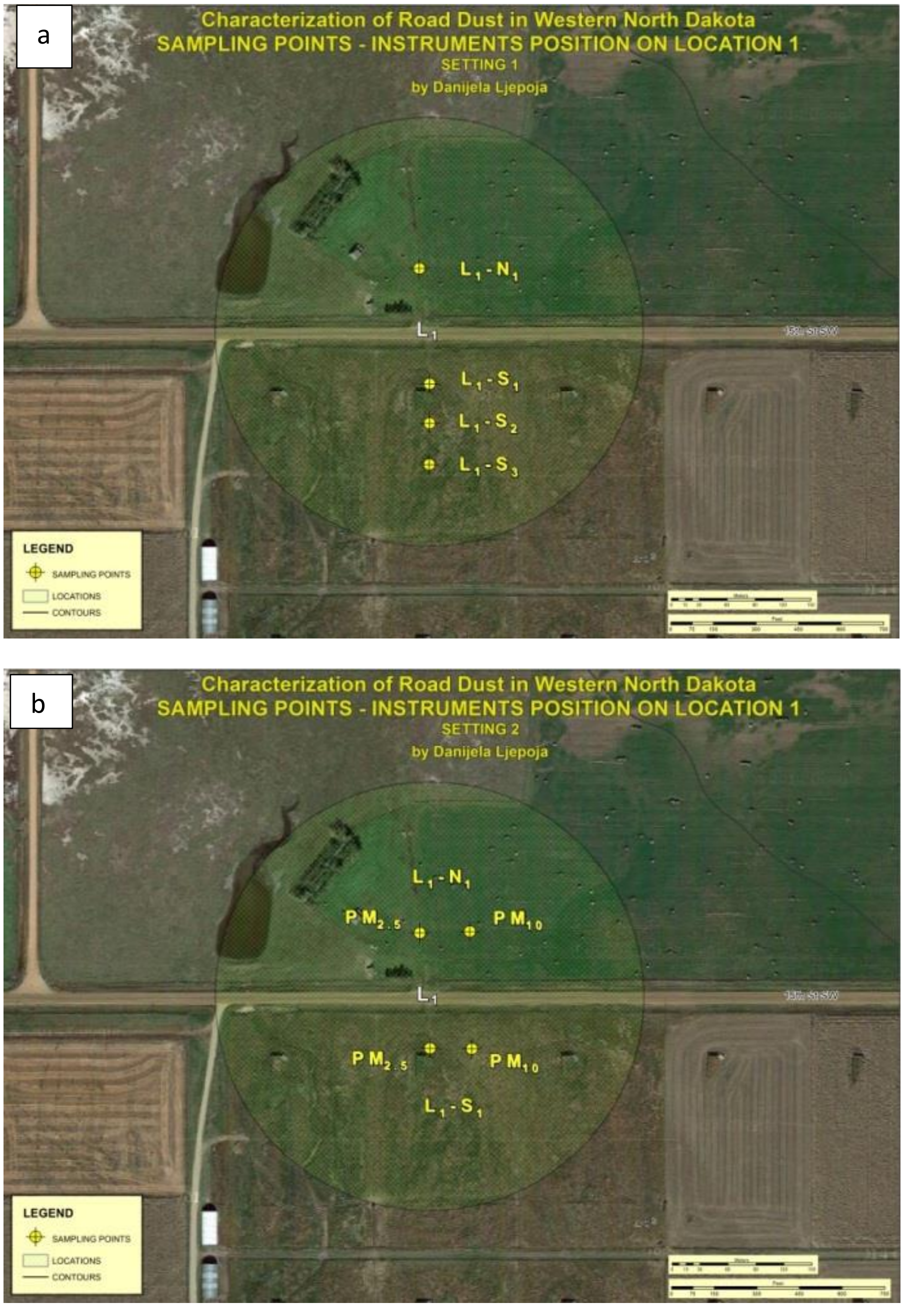


Figure 8. Maps of instrument locations at Location 1. a. Instrument positions at location 1(setting 1); b. Instrument positions at location 1 (setting 2).

3.2.2. Sampling Location 2

Two samplers were installed on June 25, 2014 at a location adjacent to what would become the access road to the drill pad (Fig. 9). Samplers were installed on the North (location L2-N) and South (location L2-S) sides, 78ft from the middle of the projected road location. On June 25, 2014, TSP was collected at both L2-N and L2-S.

On July 9 and August 14, 2014, PM_{10} and $PM_{2.5}$ were collected at adjacent sites at both L2-N and L2-S.

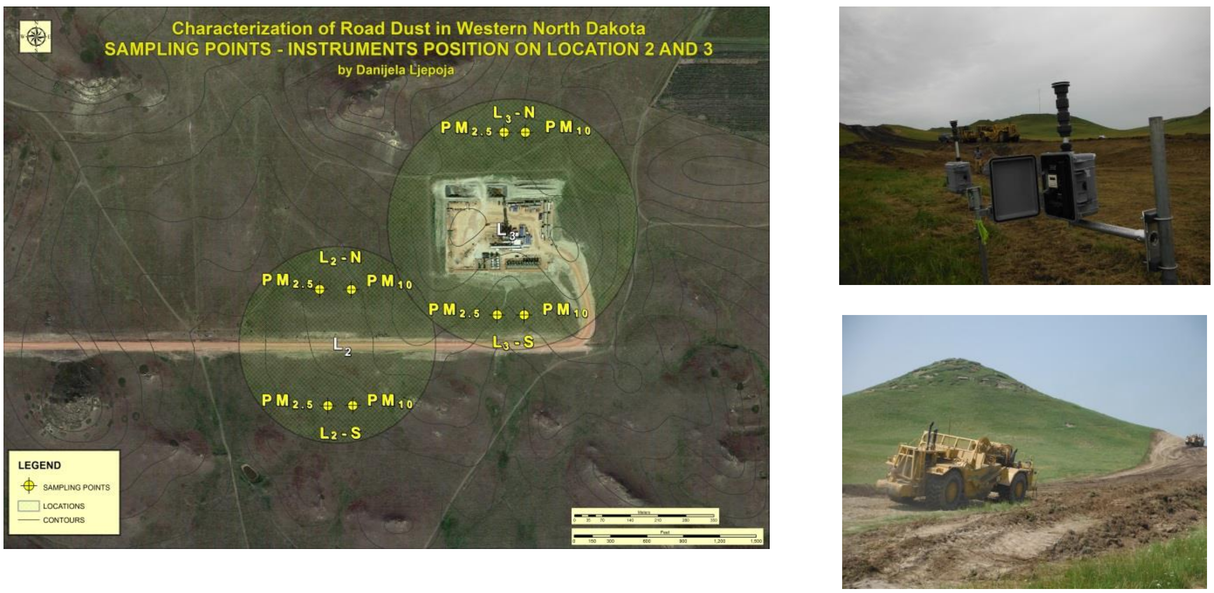


Figure 9. Maps of instrument locations and photographs at Locations 2 and 3. a. Instrument positions at Locations 2 and 3; b. instrument set to collect PM10 and PM2.5 at Location 2; c. Road construction at Location 2.

3.2.3. Sampling Location 3

Four samplers were installed, two each on the N and S sides, of the drill pad to collect PM_{10} and $PM_{2.5}$ (Fig. 10). This location was sampled on August 13, 2014.

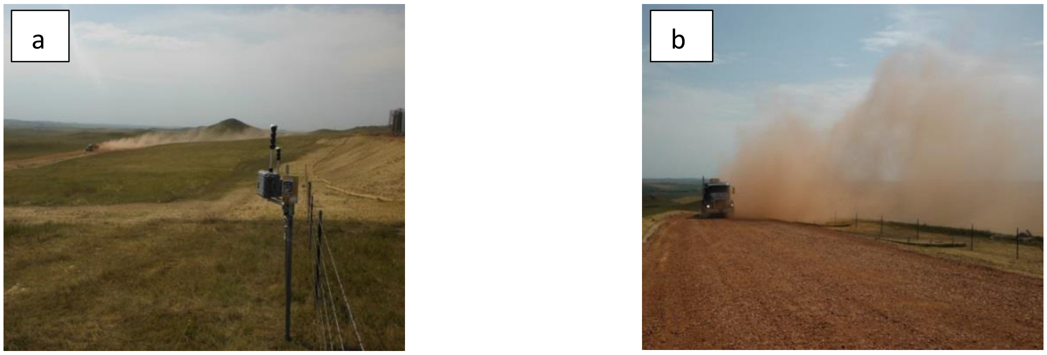


Figure 10. Photographs of Location 3. a. instrument setting at Location 3 on south side of oil well; b. photograph of dust caused by one truck at Location 3.

3.3. Sampling method

The MiniVol™ TAS Sampler is a portable, lightweight and battery operated air sampler for particulate matter. The samplers were checked in the lab, prior taking samples in the field. This involved checking if the instrument is operational, performing a leak check, performing a single point flow check using a calibration set and comparing it with the curve established during calibration. The flow should be between +/-10% of 5lpm at ambient conditions if the instrument operates well.

Figure 11. Photographs of TAS sampler at Location 2 (setting 1, vertical mount).

In the field, instruments were set up vertically mounted to a pole (Fig. 11). A flow rate check was performed before and after each use of sampler; it was 5 liters per minute at ambient conditions at every location. Batteries were fully charged every time before use.

The sampler can be configured to collect in one of three modes: total suspended particulate matter (TSP), PM_{10} and $PM_{2.5}$. Figure 12 is a schematic diagram of how particles are collected.

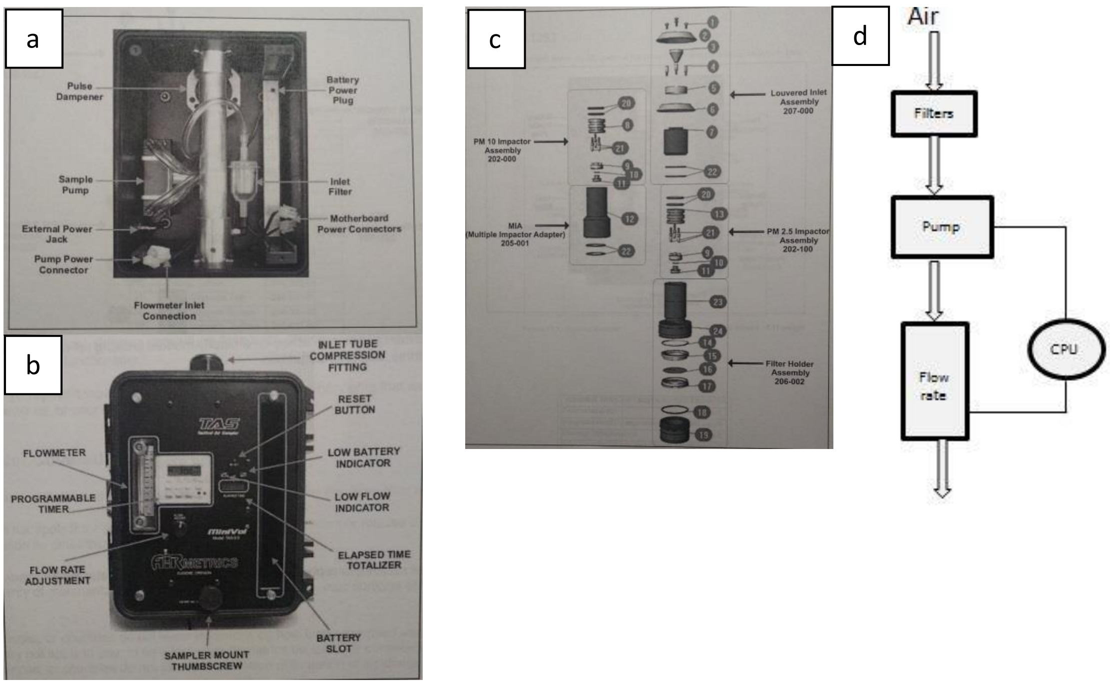


Figure 12. Diagrams of the Airmetrics MiniVol TAS sampler. a. Exterior of sampler, b. Interior of sampler, c. Imactor/filter holder assembly, d. Schematic Diagram of how particles are collected (photos from Airmetrics MiniVol TAS Manual – airmetrics.com).

The collecting mode depends on whether the sampler is operating with or without an impactor. TSP samples are collected without using an impactor. Impactors are available in two sizes. A 10 micron cut point is used for collecting PM_{10} and a 2.5 micron cut point is used for collecting $PM_{2.5}$ samples. Greasing and cleaning of the impactor disk is performed before putting the impactor on the filter holder (Fig.13).

Easy Maintenance Target (EMT) impactor is a removable impactor target developed by Air Metrics to simplify the preparation of the impactor assembly. It can be easily cleaned with paper towel or cloth.

Filters were installed in a protected area (in the car) using gloves

Figure 13. Applying grease to the EMT impactor. Sampling Site 1.

3.3.1. Quartz filters

Whatman High purity Quartz (SiO_2) Fiber circle filters (Grade-QMA, 47mm, CAT No. 1851-047, Lot No.9613165) were used for sampling. Those filters are thin, hard and brittle. Filter size is 47mm diameter.

The cassette separator (Fig.14) was used for insertion and removal of quartz filters from the cassette. Filters were conditioned in a temperature and relative humidity controlled environment for a minimum of 24 hours prior to weighing. Filters were weighed on a Sartorius Microbalance located at Center for Nanoscale Science and Engineering, (CNSE) Research lab at NDSU with sensitivity of ±1µg. Both pre- and post-sampling weighings were carried out on the same balance by the same analyst.

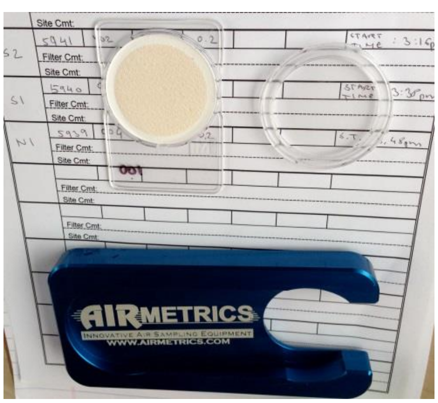


Figure 14. Cassette separator and filter.

To ensure filters maintained constant weight, and to establish an estimation of measurement error, a series of weighing was carried out over 3 weeks before sampling commenced. Results showed a std. dev., between 0.006 and 0.34μg (Appendix A). The post-sampling weighing was carried out within 72 hours after the end of the sampling period.

Filters were transported to the field in protective plastic holders. Filters were kept in horizontal position during transportation back to the lab to prevent loss of material. Every set of 4 plastic holders was transported in a separate plastic box.

3.3.2. Hobo temperature/relative humidity data logger

The Hobo Temperature/Relative Humidity Data Logger (Onset Computer Corporation, Bourne, MA) is a small, battery-powered data logger used for monitoring temperature, relative humidity and pressure on the sampling site (Fig. 15). The Hobo loggers record those conditions in the field, and Hobo ware software and communication device is used for reading conditions data from the Hobo data logger.

Figure 15. Hobo Data Logger at Location 3.

3.4. Analytical methods

3.4.1. Scanning Electron Microscopy

Scanning electron microscopy (SEM) coupled with Energy-Dispersive X-ray analysis (EDS) was used for characterization of atmospheric particulate matter. SEM analysis was carried out on a JEOL JSM-6490LV high-performance variable pressure SEM at the NDSU Electron Microscopy Laboratory.

3.4.1.1. Sample preparation for SEM

A small section (5x5mm) (Fig.16) of the filter that had been exposed to dust was cut out with a razor blade. The cut sections were attached to cylindrical aluminum mounts with double-stick carbon adhesive tape (Ted Pella, Redding CA, USA). A few samples from location 1 were coated with carbon (208 Cressington Carbon Coater, Ted Pella, Redding CA, USA), but other samples were not coated. Examples of scanning electron micrographs of representative samples are shown in Fig. 17.

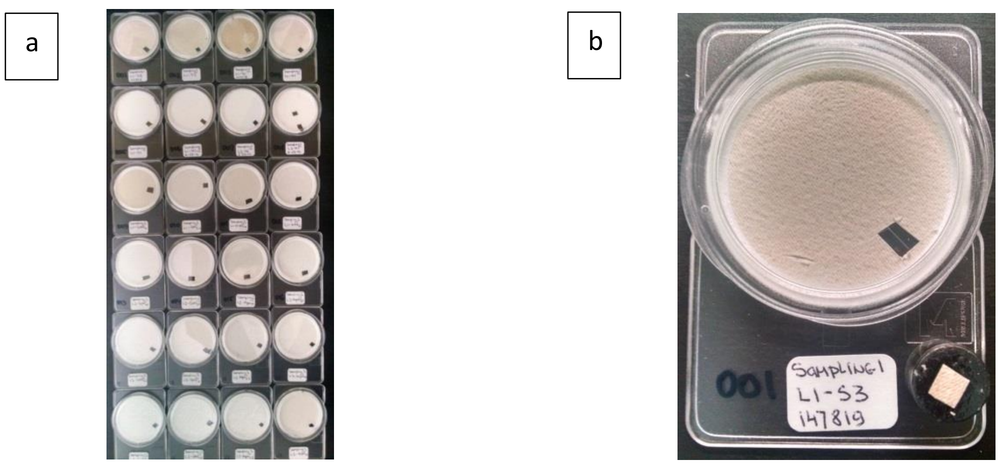


Figure 16. Filters prepared for SEM. a. 5X5mm pieces cut from every filter, b. cut sections were attached to cylindrical aluminum mounts.

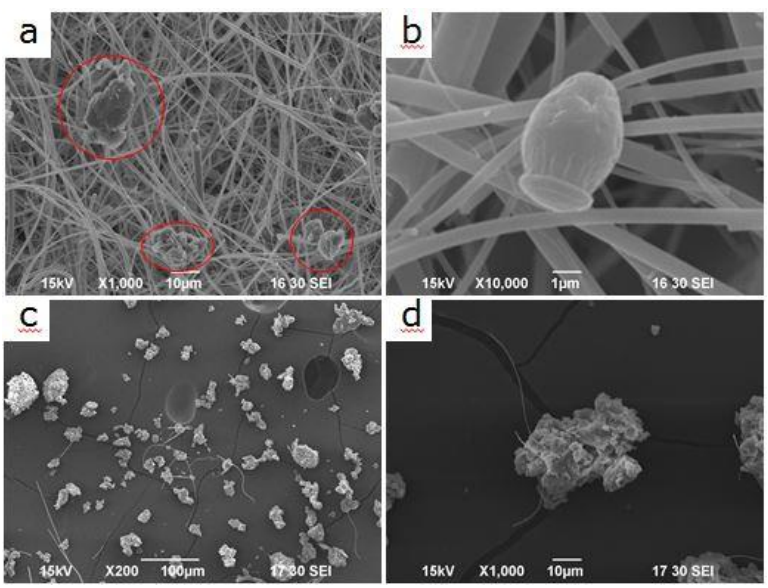


Figure 17. Scanning electron micrographs of dust samples. Samples were collected near Manning Ranch during June, 2014. a) Mineral particles on glass fiber, b) a biogenic particle on glass fiber, c), and d) particles transferred to carbon tape.

Energy-dispersive X-ray information was collected using a Nanotrace EDS detector with a NORVAR light-element window and Noran System Six imaging system (ThermoFisher Scientific, Madison WI, USA) at an accelerating voltage of 15keV for the JSM-6490LV or an Ultra Dry silicon drift X-ray detector and NSS-212e NORAN System 7 X-ray Microanalysis System (Thermo Fisher Scientific, Madison WI, USA).

3.4.2. Methodology to calculate TSP, $PM_{2.5}$ and PM_{10} concentration

Net filter weight, the volume of air that passed through the filter during the sampling period at actual ambient conditions (V_{act}) must be calculated in order to calculate particulate matter concentration.

$$Q_{act} = (m_{vol} \times Q_{ind} + b_{vol}) \times \sqrt{\frac{P_{std}}{P_{act}} \times \frac{T_{act}}{T_{std}}}$$

where:

m_{vol}, b_{vol} = the sampler's calibration slope and intercept

Q_{ind} = Flow Rate (liters/min)

P_{std} = standard atmospheric pressure, 760 mmHg

P_{act} = actual ambient pressure, mmHg

T_{std} = standard temperature, 298K

T_{act}= actual ambient temperature, K

$$V_{act} = (60_{min/hr} X\ Q_{act}\ X_{thr}) / 1000_{l/m3}$$

where:

V_{act} = Volume at ambient condition (m^3)

Q_{act} = Actual Flow Rate (liters/min)

t = sampling period, in hours (hr)

To calculate net mass, the initial weight was subtracted from the post sampling weight (the weight of the particulate matter). To calculate the concentration of particulate matter, net mass of the filter was divided by the volume at ambient condition.

$$PM_{act} = M_{pm} / V_{act}$$

where:

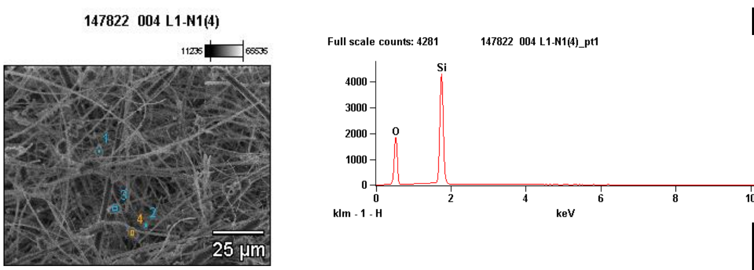
PM_{act} = actual PM concentration, in micrograms per cubic meter (µg/m^3)

M_{pm} = Mass of particulate matter collected on the filter (µg)

The calculation of V_{act} includes consideration of several inputs including instrument specific constants, ambient air temperature and pressure. Details and formulas are provided in MiniVol Portable Air Sampler Manual (airmetrics.com).

3.4.3. Calculating mineral/phase formulas from SEM results

Using SEM/EDS table output presented as % weight it was possible to calculate approximate empirical formulas. In the ideal case, each coefficient for a crystallographic site will be a whole number, and will give an accurate empirical formula. However, it is difficult to identify small mineral particles with complete certainty using only SEM/EDS analysis. The example below is for sample mineral, quartz, SiO_2 (Fig. 18)



	O	Si	
wt. %	53.26	46.74	SEM data
grams/mol	16.0	28.09	Atomic mass
mols	3.33	1.66	
	(normalize)		
mols	2.006	1.000	

Particle Group	Major elements	Minor elements	Possible phase/ group	Formulas from SEM data	Morphology	SEM ID Number
Mineral	O, Si		Quartz	2O 1Si	Nearly spherical	147822 004 L1-N1(4)_pt1

Figure 18. Calculating possible mineral/phase group from SEM data (Quartz).

SEM/EDS outputs data as % weight of atoms (or oxides) present in the sample. These data together with the atomic mass of corresponding elements are used to calculate the empirical formula of the mineral. The procedure is simple for pure phases with sample chemical formula such as quartz (SiO_2).

Starting with the assumption of 100g of the sample, the weight percent of the atoms present in the sample will translate to grams of atom in 100 grams of sample. We can do this as we are interested in the ratio of the weights and not the weights themselves.

	O	Si	
Weight	53.26	46.74	g
Atomic mass	16	28.09	g/mol

We will divide these weights by corresponding atomic mass given in g/mol and get the number of the moles of each atom.

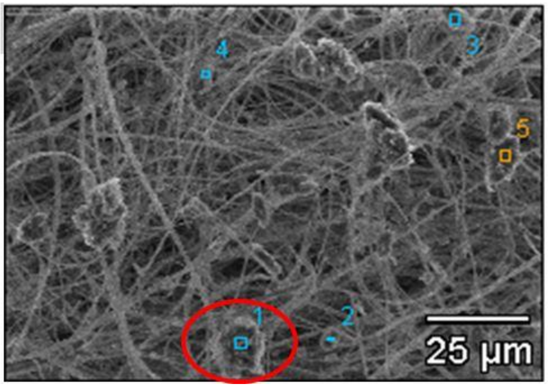
	O	Si	
Number of moles	53.26/16	46.74/28.09	
	3.33	1.66	mol

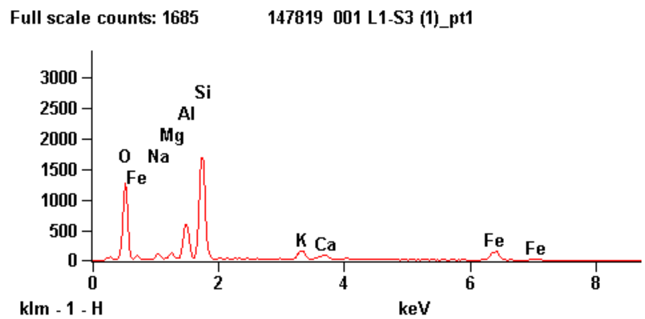
Number of moles should be a whole number. We will divide all the numbers of moles with the smallest of them, and then get number of the moles for each component.

	O	Si	
Number of moles	3.33/1.66	1.66/1.66	
	2.006	1	mol

Finally we have 1 atom of silica and 2 atoms of oxygen which give us SiO_2 .

The procedures are the same if you using oxide weight. In this case molar mass of oxide is used instead of the atomic mass. Calculations are more complex for minerals with the complex formulas and minerals containing impurities, inclusions, etc. If the number of moles could not be brought to a whole number, an approximate empirical formula is calculated. Knowledge of mineral and crystallography can help mineral identification. If the examined material is crystalline, crystal shape can help in identification. For another example, calculation for a clay mineral, with complex chemical formula is given in Fig. 19. The coefficients. do not sum to easily evaluated whole numbers. This discrepancy could be due to a variety of factors: for example, the beam may penetrate a thin particle and generate fluorescence from the SiO_2 filter material.





	O	Na	Mg	Al	Si	K	Ca	Fe	
Weight%	46.84	0.79	0.77	9.17	29.72	5.94	2.62	4.16	SEM data
Gram/mols	15.99	22.99	24.30	26.98	28.08	39.09	40.08	55.84	Atom mass
mols	2.93	0.03	0.03	0.34	1.06	0.15	0.06	0.07	
Normalize	97.64	1	1	11.33	35.33	5	2	2.33	
To get whole numbers, everything is multiply by 3									
293O	3Na	3Mg	34Al	106Si	15K	6Ca	7Fe		

(K,H3O)(Al,Mg,Fe)2(Si,Al)4O10[(OH)2,(H2O)] Chemical formula

$K_{0.6}(H_3O)_{0.4}Al_{1.3}Mg_{0.3}Fe^{2+}_{0.1}Si_{3.5}O_{10}(OH)_2\cdot(H_2O)$ Empirical formula

Particle Group	Major elements	Minor elements	Possible phase/ group	Formulas from SEM data	Morphology	SEM ID Number
Mineral	O, Si, Al, K, Ca, Fe	Na, Mg	Silicates/ Clay	293O 3Na 3Mg 34Al 106Si 15K 6Ca 7Fe	Nearly spherical	147 819 001 L1-S3(1)_pt1

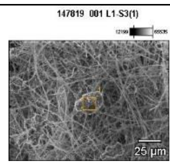
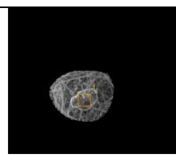
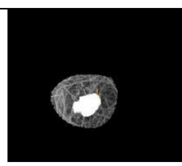
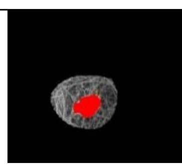
Figure 19. Calculating possible mineral/phase group from SEM data (Silicates).

3.4.4. ImageJ Analysis

Morphology and size distribution of particles was carried out using ImageJ (NIH 2014). This software can measure size of particles, and can help to define morphology of particles.

Every SEM/EDS image has own scale, so calibration was done for each image using the “point” tool. It was possible to measure the scale in pixels, and then to calibrate based on that. Table 6 shows the method of using ImageJ to particle size.

Table 6. ImageJ Software method.

	Original Image (SEM)
	“Free hand tool” the particle surface was selected
	“Edit-Fill tool” used to fill in particle
	Threshold

Important note: number of pixels in the image equal to the scale on the image (10µm, 25µm).

CHAPTER 4. RESULTS

4.1. Particulate matter weight

There was a wide variance in measured particle weight at all three locations (Table 7). Several factors may have contributed to this variation: traffic type and frequency, instrument setup (TSP, $PM_{2.5}$, or PM_{10}), road condition (wet or dry; unpaved road, road construction), and weather (temperature, wind direction, amount of rain). More detail tables are shown in Appendix A (A1-A2-A3). The heaviest samples were collected during sampling campaign 1 (June, 2014) at Location 1. The calculated sample weight was used to calculate the concentration of particulate matter (Appendix A4-A5-A6).

Table 7. Sample weight.

Sampling 1	Net Sample weight
Site ID	(mg)
L1-S3	2.235
L1-S2	2.271
L1-S1	5.466
L1-N1	2.247
L1-S1	0.030
L1-N1	0.320
L2-S1	0.099
L2-N1	0.152
Sampling 2	Sample weight
Site ID	(mg)
L1-S PM_{10}	0.695
L1-S $PM_{2.5}$	0.286
L1-N PM_{10}	0.677
L1-N $PM_{2.5}$	0.266
L2-S PM_{10}	0.276
L2-S $PM_{2.5}$	0.173
L2-N PM_{10}	0.358
L2-N $PM_{2.5}$	0.186
Sampling 3	Sample weight
Site ID	(mg)
L3-S $PM_{2.5}$	0.052
L3-S PM_{10}	0.255
L3-N $PM_{2.5}$	0.062
L3-N PM_{10}	0.188
L2-S $PM_{2.5}$	0.065
L2-S PM_{10}	0.185
L2-N $PM_{2.5}$	0.052
L2-N PM_{10}	0.432

4.2. Particulate matter concentration

Figures 19-21 present the calculated concentrations of particles. The highest measured concentration (911 μg/m^3) was for TSP at Location 1-S1, the sampling site 38ft from the unpaved road, collected on June 24, 2014. During that sampling period, gravel was being spread on the road and the road was being regarded. Temperature was between 25 °C (starting) and 17 °C (ending) and wind was blowing from the NW direction. The temperature next day started 17C and ending at 16C and wind changed direction from NW to SE, blowing dust away from the samplers on the S side of the road. (Appendix A4-A5-A6). That time the lowest measured concentration of 4 μg/m^3 was measured on the S side of the road (Fig. 20).

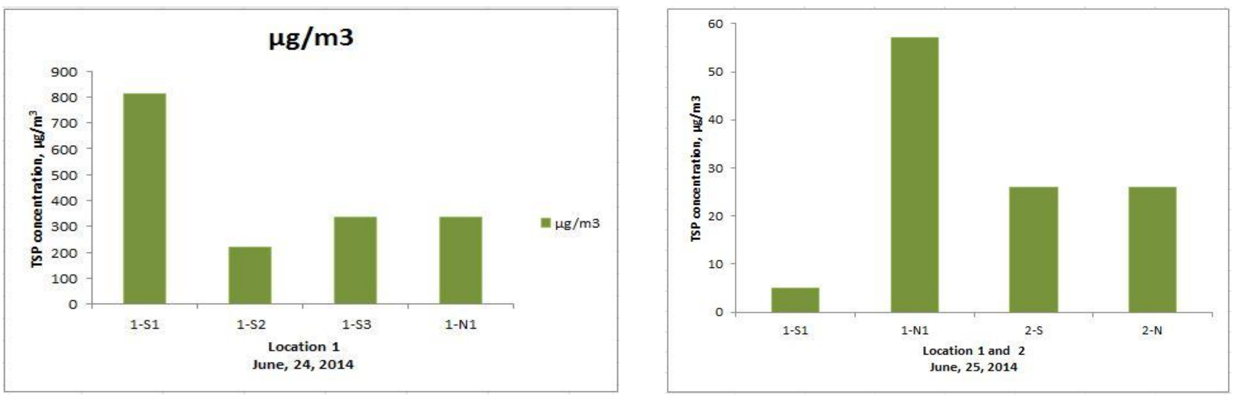


Figure 20. Concentration of TSP collected on June, 2014. Location 1 (left) and Location 2 (right) .

During the second sampling period PM_{10} and $PM_{2.5}$ were collected 38ft from the unpaved road (the same sampling site were TSP were collected on June, 24, 2014) The measured concentration (114 μg/m^3) were for PM_{10} at Location 1-S and concentration of 112 μg/m^3 Location 1-N collected on July 8, 2014. Concentration of $PM_{2.5}$ was lower 47 μg/m^3 on the south side of the road and 44 μg/m^3 on the north side of the road. Temperature was between 27 °C (starting) and 23 °C (ending) and wind was blowing from the NW direction. The next day was, starting temperature was 26 °C and ending temperature was 18 °C. That time, PM_{10} and $PM_{2.5}$ were collected at Location 2, 78ft south and north from the road. PM_{10} concentration on both sides of the road (43 μg/m^3 S and 56 μg/m^3 on north side) was higher compering with $PM_{2.5}$ concentration (27 μg/m^3 and 29 μg/m^3) (Fig. 21).

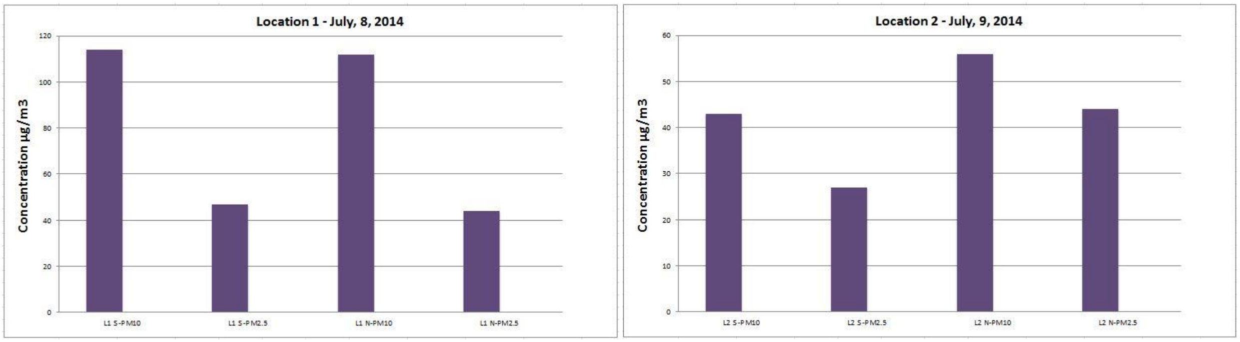


Figure 21. Concentration of $PM_{2.5}$ and PM_{10} collected on July, 2014 .Location 1 (left) and Location 2 (right)

During the sampling period on August, 14, 2014 PM_{10} and $PM_{2.5}$ were collected on Location 2. (Fig. 22)The measured concentration of 29 µg/m^3 were for PM_{10} on the south side of the road and concentration of 68 µg/m^3 on the north side of the road. Concentration of $PM_{2.5}$ was lower 10 µg/m^3 on the south side of the road and 8 µg/m^3 on the north side of the road. Temperature was between 26 °C (starting) and 20 °C (ending) and wind was blowing from the NW direction.

Results showed that measured concentration of PM_{10} particles on Location 2 during July, 8, 2014, and August, 14, 2014, was higher than concentration of $PM_{2.5}$ on the same Location. $PM_{2.5}$.

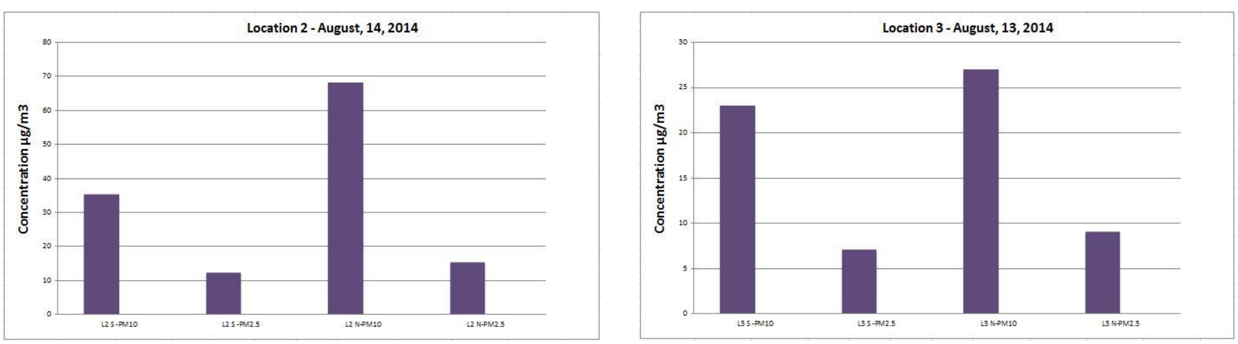


Figure 22. Concentration of $PM_{2.5}$ and PM_{10} collected on August, 2014. Location 2 (left) and Location 3 (right).

4.3. Particulate matter identification

Based on the SEM/EDS data and morphology of particles, particles were classified into two groups: a mineral group (inorganic) and a biogenic group consisting of particles originating from plants and animals.

At Location 1, four TSP samples were collected and 313 particles were analyzed by SEM-EDS and ImageJ; two $PM_{2.5}$ and two PM_{10} samples were collected and 52 particles were analyzed. At Location 2, two TSP samples were collected and 93 particles were analyzed; two $PM_{2.5}$ and two PM_{10} samples were collected and 45 particles were analyzed.

A few samples were carbon coated for SEM analyses (Table 8), all others were not. For these samples, carbon values were excluded from the reported analytical results.

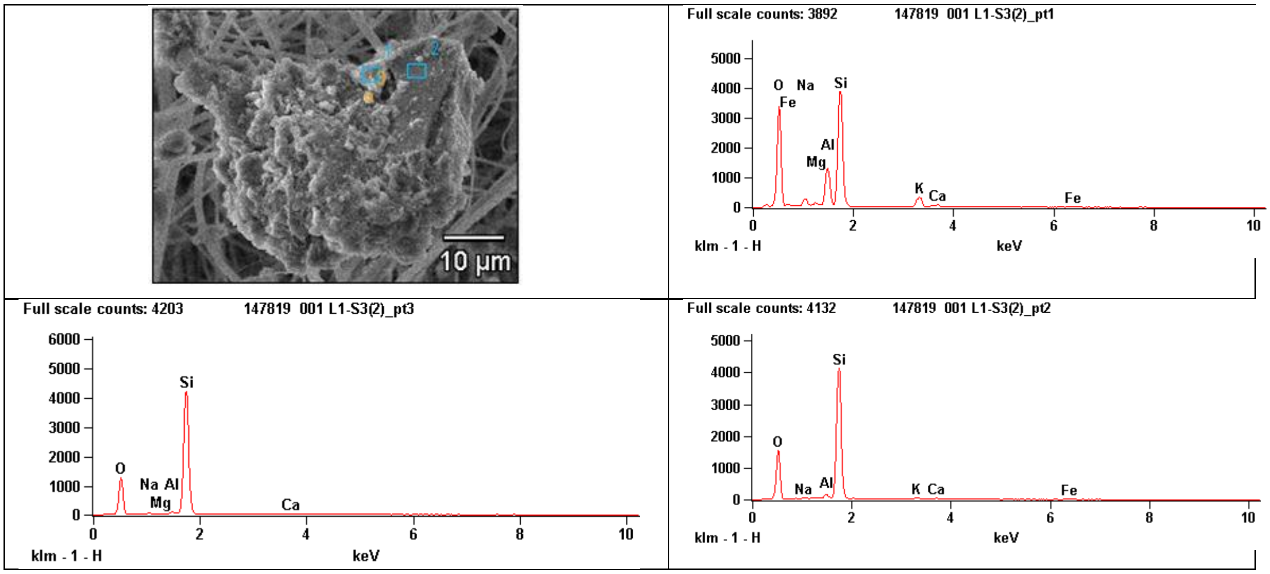
Table 8. Carbon coated samples.

147537	009	L1 - S PM_{10}
147538	010	L1 - S $PM_{2.5}$
147539	011	L1 - N PM_{10}
147540	012	L1 - N $PM_{2.5}$
147541	013	L2 - S PM_{10}
147542	014	L2 - S $PM_{2.5}$
147543	015	L2 - N PM_{10}
147544	016	L2 - N $PM_{2.5}$

4.3.1. Mineral particles

For purposes of classification, mineral particles were further subdivided into quartz, non-quartz silicate, and carbonate minerals.

Quartz (SiO_2) is a significant component of many sedimentary, metamorphic and igneous rocks, and for that reason, quartz is one of the most common minerals found on Earth's surface. Quartz can occur in all different colors, habits and forms. Quartz crystals can be prismatic, tabular or can occur aggregates of crystal. It may also appear in massive form – with no definable shape or form, with crystals or aggregates not visible. Quartz particles are characterized by high content of O and Si summing to 100% with an atomic ratio of 1Si:2O, and by morphology. The particle shown in Figure 23 is an aggregate of at least two minerals: a possible quartz particle with minor amount of elements Al, K, Ca and Fe less than 2 atom%, and another silicate mineral, alkali feldspar (Appendix B).

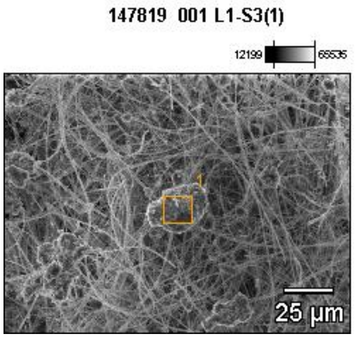


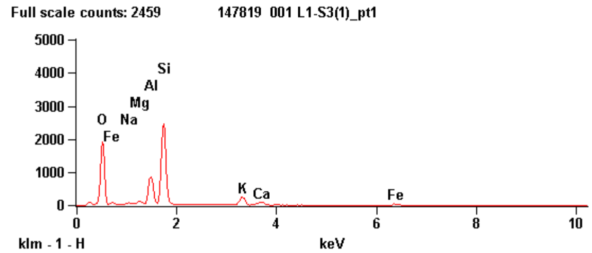
Weight%	O-K	Na-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Fe-K
147819 001 L1-S3(2)_pt1	47.63S	2.94	0.48	8.91	31.66	5.66	1.26	1.44
147819 001 L1-S3(2)_pt2	52.06S	0.31		0.86	43.98	0.51	0.38	1.90
147819 001 L1-S3(2)_pt3	52.65S	0.96	0.30	0.34	45.33		0.41	

Particle Group	Major elements	Minor elements	Possible phase mineral	Formulas from SEM data	Morphology	SEM ID Number
Mineral	O, Si, Al	K, Na, Ca, Mg, Fe	Silicates-Alkali Feldspar	151 O, 6 Na, 1 Mg, 17 Al, 57 Si, 7 K, 2 Ca, 1 Fe	Sub spherical	147819 001 L1-S3(2)_pt1
Mineral	O, Si	Fe, Al, Na, Ca, K	Quartz	343 O, 1 Na, 3 Al, 165 Si, 1 K, 1 Ca, 4 Fe,	Massive-big particle	147819 001 L1-S3(2)_pt2
Mineral	O, Si	Na, Al, Mg, Ca	Quartz	322 O, 4 Na, 1 Mg, 1 Al, 158 Si, 1 Ca,	Sub spherical	147819 001 L1-S3(2)_pt3

Figure 23. Particulate matter identification (Quartz and other silicate minerals).

Non-quartz silicates are identified by high content of Si, Al and O with variable content of Na, Mg, K, Ca, Fe or Ti. Most of the particles in this group showed irregular and sub spherical morphology. Possible phases/minerals are feldspars and clays. Figure 24 shows the classification of a mineral containing high amount of O, Si, Al, and K, and lesser amounts of Ca, Fe, Na and Mg. Although not positively identified, this particle could be a kaolinite aggregate.



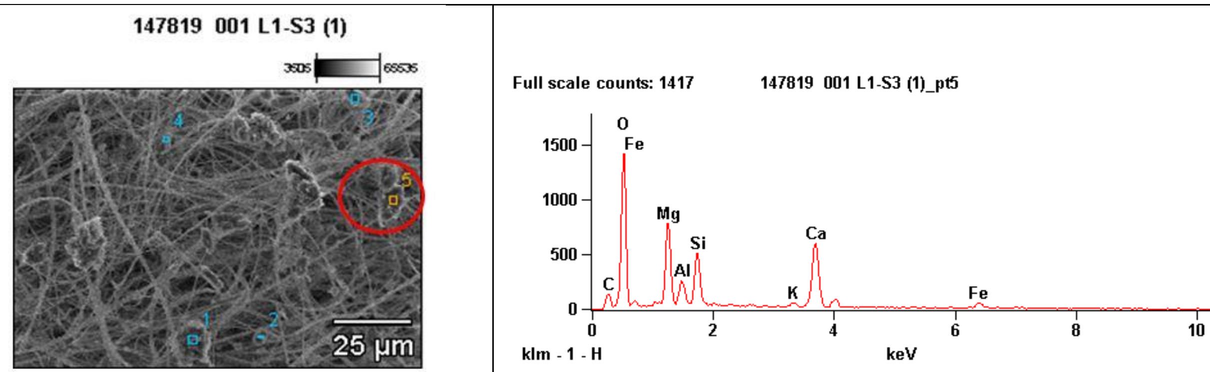


Weight%	O-K	Na-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Fe-K
147819 001 L1-S3(1)_pt1	46.84S	0.79	0.77	9.17	29.72	5.94	2.62	4.16

Particle Group	Major elements	Minor elements	Possible phase/ group	Formulas from SEM data	Morphology	SEM ID Number
Mineral	O, Si, Al, K	Ca, Fe, Na, Mg	Silicates/ Aluminosilicates	92 O, 1 Na, 1 Mg, 11 Al, 33 Si, 5 K, 2 Ca, 2 Fe,	Sub spherical	147819 001 L1-S3 (1)_pt1

Figure 24. Particulate matter identification (Silicate minerals).

Carbonate minerals identified include the possible minerals dolomite ($CaMg(CO_3)_2$) and calcite ($CaCO_3$). In Figure 25, point 5 shows high C content (note this sample was not carbon coated). Taken together with high contents of O, Ca and Mg, this particle likely is dolomite. The Si could be attributed to the quartz fiber substrate.



Weight%	C-K	O-K	Na-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Fe-K
147819 001 L1-S3 (1)_pt5	14.68	55.25		6.65	1.94	4.26	0.57	13.37	3.29

Particle Group	Major elements	Minor elements	Possible phase/ group	Formulas from SEM data	Morphology	SEM ID Number
Mineral	C, O, Mg, Ca, Si	Al, K, Fe,		77 O, 18 Mg, 5 Al, 11 Si, 1 K, 23 Ca, 4 Fe, 14C	Irregular	147819 001 L1-S3 (1)_pt5

Figure 25. Particulate matter identification (Carbonate minerals).

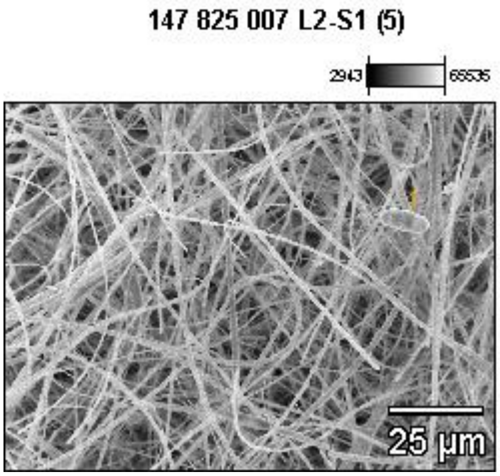
4.3.2. Biogenic particles

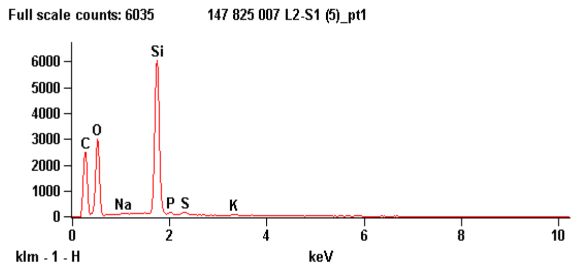
Biological particles could be present in many shapes and sizes. Biological particles contain minor amount of Al, Si, Ca, Zn, Fe, Cl, S, Na, Mg, P and K (usually less than 10%), and major amounts of C and O. These characteristics can be used to separate biological particles from other types of particulate matter (Matthias-Maser and Jaenice, 1994; Matthias-Maser et al., 2000).

In this work biological particles are characterized by using morphology (characteristic forms, spheres, prismatic forms) and elemental composition, where the following rule (Coz et al., 2010) was used

$$(C+O)>75\% \text{ and } 1\%< P, K, Cl < 10\%,$$

keeping in mind that S, Si, Zn and Ca are also tracers of biogenic material. Figures 26 and 27 show examples of identification of biogenic materials on the sample filters.

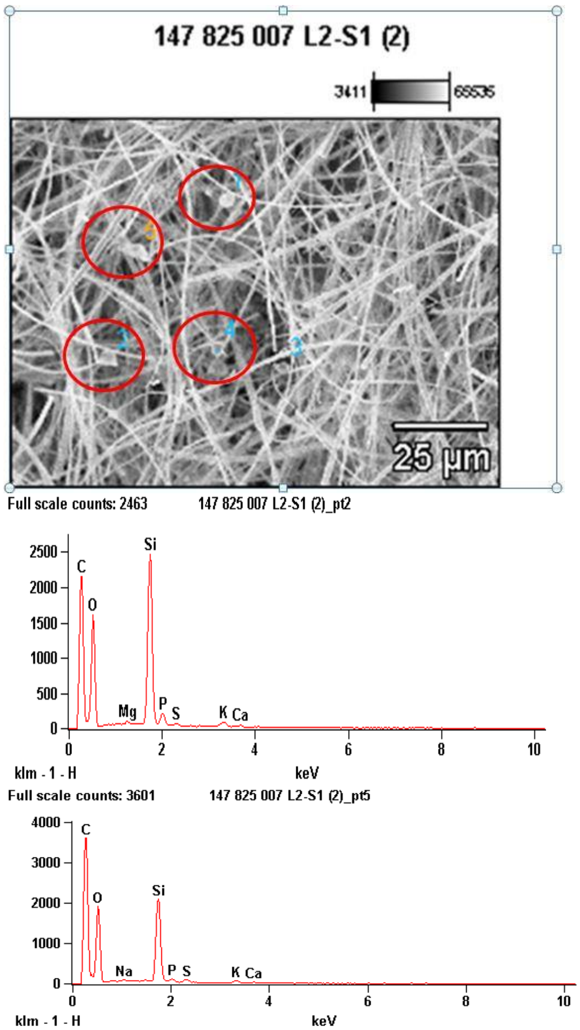




	C-K	O-K	Na-K	Si-K	P-K	S-K	K-K
147 825 007 L2-S1 (5)_pt1	24.02	70.37S	0.04	5.19	0.12	0.19	0.07

Particle group	Major elements	Minor elements	Possible phase/group	Formulas from SEM data	Morphology	SEM ID Number
Biological	O, C, Si	S, P, Na, K		1149 C, 2528 O, 1 Na, 106 Si, 2 P, 3 S, 1 K,	Sub prismatic	147 825 007 L2-S1 (5)_pt1

Figure 26. Particulate matter identification (Biogenic particles).



Weight%	C-K	O-K	Na-K	Mg-K	Al-K	Si-K	P-K	S-K	K-K	Ca-K
147 825 007 L2-S1 (2)_pt1	26.37	72.01S	0.04	0.02	0.02	1.44	0.03	0.02	0.01	0.05
147 825 007 L2-S1 (2)_pt2	25.29	71.19S		0.07		2.87	0.27	0.05	0.21	0.05
147 825 007 L2-S1 (2)_pt4	26.21	71.88S		0.03		1.48	0.18	0.06	0.17	
147 825 007 L2-S1 (2)_pt5	26.17	71.87S	0.05			1.63	0.09	0.1	0.07	0.03

Particle group	Major elements	Minor elements	Possible phase/group	Formulas from SEM data	Morphology	SEM ID Number
Biological	C,O	Si, Na, Mg, Al, P, S, K, Ca		8584 C, 17597 O, 7 Na, 3 Mg, 3 Al, 200 Si, 4 P, 2 S, 1 K, 5 Ca,	Spherical	147 825 007 L2 -S1 (2)_pt1
Biological	C,O	Si, Mg, P ,S, K, Ca		1688 C, 3567 O, 2 Mg, 82 Si, 7 P, 1 S, 4 K, 1 Ca,	Irregular	147 825 007 L2 -S1 (2)_pt2
Biological	C,O	Si, Mg, P, S, K		1768 C, 3640 O, 1 Mg, 43 Si, 5 P, 2 S, 4 K,	Sub Spherical	147 825 007 L2 -S1 (2)_pt4

Figure 27. Particulate matter identification (Biogenic particles).

4.3.3 Relative amounts of measured particles

At Location 1, quartz content was 26% (TSP) and 50% ($PM_{2.5}$ and PM_{10}); for Location 2, 22% (TSP) and 29% ($PM_{2.5}$ and PM_{10}). Biological content was 12% (TSP) and 8% (($PM_{2.5}$ and PM_{10}) at Location 1; for Location 2 it was 68% (TSP) before and 42% ($PM_{2.5}$ and PM_{10}), when road construction started. Silicates go from 58% to 38% at Location 1 and from 5% to 29% at Location 2 when road construction started during the July sampling. Figure 28 presents relative amounts of classified particles at Locations 1 and 2.

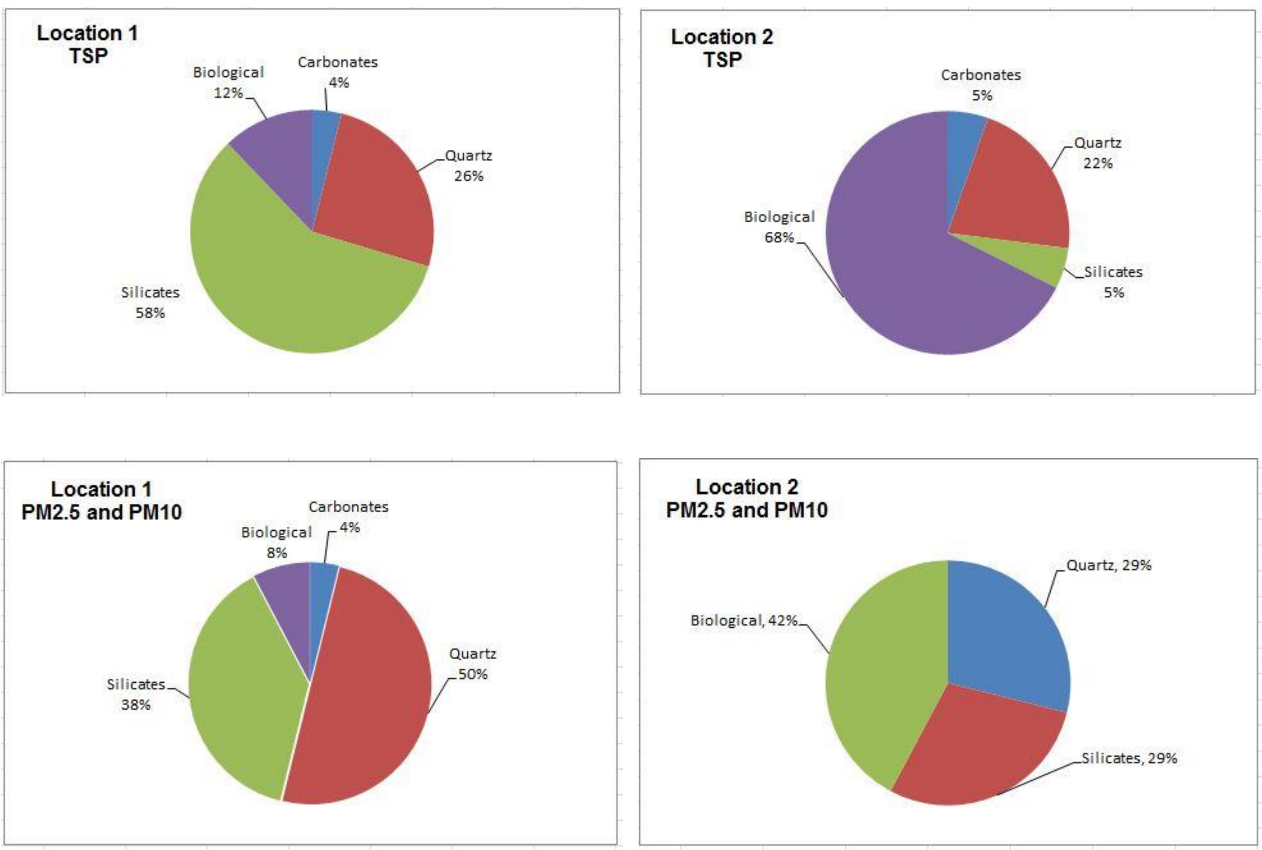


Figure 28. Classification of particles at Locations 1 and 2.

4.4. Particle size distribution and morphology of individual particles

A total of 277 total suspended particulates from Location 1 and 36 from Location 2 collected during sampling in June, 2014 were analyzed with ImageJ software to quantify particle size distribution and morphology. A total of 19 particles ($PM_{2.5}$ and PM_{10}) from Location 1 and 38 from Location 2 collected during sampling in July, 2014 were analyzed with ImageJ software. The formula

$$D = 2\sqrt{\frac{area}{\pi}}$$

where D=particle diameter, was used to estimate particle size. Calculations are presented in Appendix C.

Results showed that particles with sizes between 2.5μm<particle size<10μm (PM_{10}) were most common for analyzed particles for TSP, PM_{10} and $PM_{2.5}$ (Table 9, Fig. 29).

Table 9. Particle size distribution.

Location 1 -TSP Total count 277			Location 1 - PM Total count 19	
PM < 2.5	2..5 < PM < 10	PM > 10	PM < 2.5	PM > 2.5
12	229	36	14	5
Location 2-TSP Total count 36			Location 2 - PM Total count 38	
PM < 2.5	2..5 < PM < 10	PM > 10	PM < 2.5	PM > 2.5
3	29	4	16	22

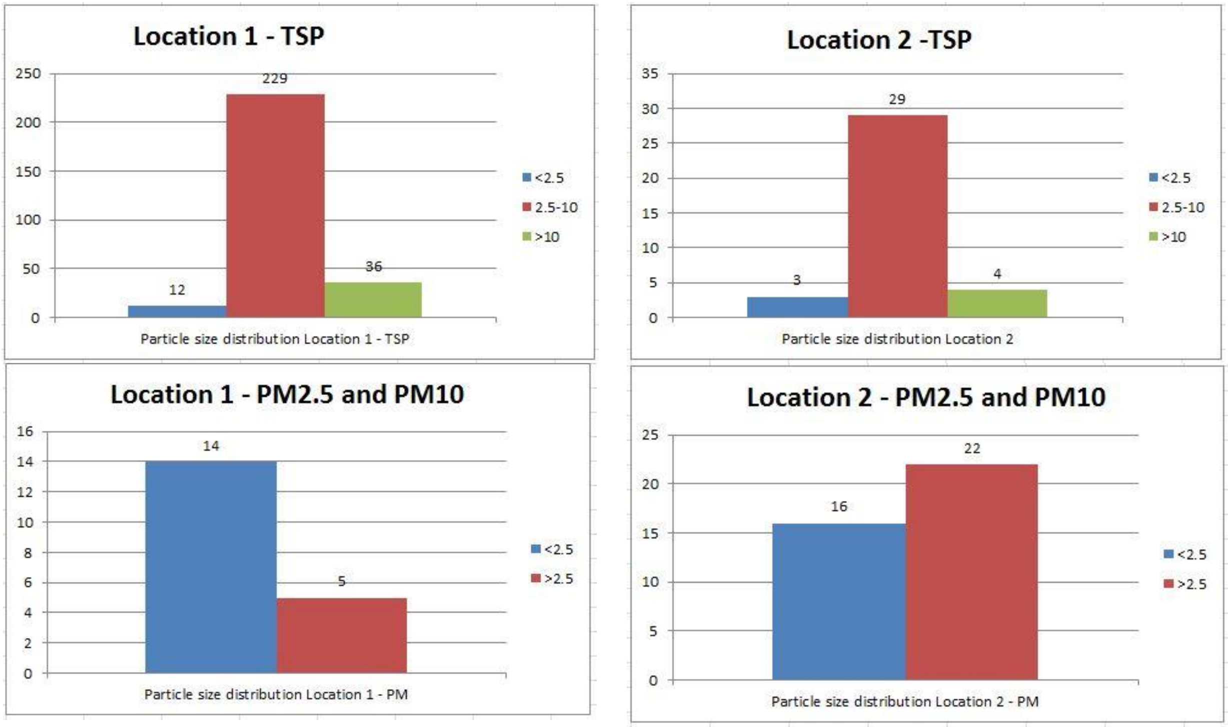


Figure 29. Histograms of particle size distribution.

4.5. Hobo Data Logger

Figure 30 is a comparison between Hobo Data logger data and concentration of particles. Precipitation data were provided by the DREC Manning Ranch (Appendix D).

Figure 30. Temperature/Relative Humidity/Pressure. Data collected with Hobo data logger on sampling site compared with concentrations (Appendix B4, B5, and B6).

CHAPTER 5. DISCUSSION, CONCLUSIONS AND FUTURE WORK

5.1. Discussion and conclusion

The goal of this project was to establish sampling protocols and baseline data for dust concentration related to oil drilling activities in and adjacent to the Dickinson Research Extension Center Manning Ranch. Appendix B summarizes all collected data for measured particulate matter concentrations at all sampling sites for this study. There was a wide variance in measured particle concentration at all three locations. Several factors may have contributed to this variation: instrument setup (TSP, $PM_{2.5}$, or PM_{10}), road condition (wet or dry), traffic type and frequency, road construction, and weather (temperature, wind direction, amount of rain).

For example, the highest measured concentration (814µg/m^3) was for TSP at Location 1-S1, the nearest sampling site to 15th St. SW on its south side, on June 24, 2014. During that sampling period, gravel was being spread on the road and the road was being regraded. This work was in addition to normal road traffic, which continued throughout the day. On the other hand the lowest measured concentration of the study (5µg/m^3) was measured using the TSP setup on the second day of sampling, June 25, 2014, at that same location, L1-S1. On that day, wind direction had shifted to coming from the SE, most likely blowing dust away from that sampler to the north side of the road. In addition, the weather was cooler and slightly rainy. Note the standard deviation of the L1-S1 measurement, 53 µg/m^3, is over 10 times greater than the measurement itself. The north side value at L1-N1 (51+/-241 µg/m^3) also showed a very high standard deviation, rendering this measurement unclear.

The second lowest measured concentrations in this study, in this case for $PM_{2.5}$, occurred on August 14, 2014 at Location 2-N. On this day there was heavy rain, and filters were retrieved from the instrument in wet condition.

Location 2 was sampled three times. During the first sampling (TSP only), the access road to the drill pad had not yet been constructed. Location L2-S1 had TSP concentrations of 15±6 µg/m^3 and L2-N1 showed 24±29 µg/m^3. Because this sampling took place in a relatively undisturbed landscape position, these measurements could be considered as background values for TSP at the DREC Manning Ranch.

A comparison can be made of PM_{10} concentrations at Location 2 but during different months (July and August) (Fig. 27). For July 9, PM_{10} concentration at L2-S was 43±14 µg/m^3 and $PM_{2.5}$ was 27±15 µg/m^3, while at location 2-N, PM_{10} concentration was 56±10 µg/m^3 and $PM_{2.5}$ was 29±8 µg/m^3. These measurements can be compared to those taken at the same locations the following month. At Location 2-S, the August 14 sampling, PM_{10} concentration was 29±19 µg/m^3 and $PM_{2.5}$ was 10±20 µg/m^3. At location 2-N, PM_{10} concentration was 68±23 µg/m^3 and $PM_{2.5}$ was 8±25 µg/m^3.

Element composition, morphology and size distribution of particles were investigated using SEM/EDS and ImageJ Software. The results indicate that for the TSP collection mode, the particle size between 2.5µm<particle size<10µm (PM_{10}) were the most common at Locations 1 and 2. Biological particles contributed about 68% at Location 2 and 12% at Location 1 when TSP was collected, and 42% and 8% when $PM_{2.5}$ and PM_{10} were collected. (Fig. 31)

Figure 31. Concentrations of PM_{10} and $PM_{2.5}$ at Location 2. Data collected during July and August, 2014.

5.2. Future work

The baseline work presented here could be extended in a number of directions in future work. More accurate traffic counts could provide a better correlation between traffic and collected dust. The concept of "Emission Potential" for a road surface as described in Kuhns et al. (2003) could be applied to western North Dakota roads. Emission Potential is a feature of a road itself, independent of the speed or type of vehicle traveling on it. The overall dust distribution across the landscape could be measured using techniques such as Remote Sensing. Meteorological data could be used to predict dust dispersion for given weather conditions. Finally, cost efficient dust abatement methods could be developed and their efficacy determined by comparison to the baseline data presented in this study.

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APPENDIX A

A1. Filter weights before and after sampling (June, 2014).

		Pre									Post		
		06/04/14	06/06/14	06/09/14	06/11/14	06/13/14					06/30/14		Sample weight
#		14:15	9:10	9:06	9:20	13:45	Mean	SDevP	RSTDev		11:00	Site ID	(mg)
1		144.573	144.555	144.563	144.547	144.536	144.5548	0.013	0.009		146.790	L1-S3	2.235
2		146.425	146.357	146.371	146.383	146.321	146.3714	0.034	0.023		148.642	L1-S2	2.271
3		147.005	146.983	146.946	146.97	146.945	146.9698	0.023	0.016		152.436	L1-S1	5.466
4		145.503	145.519	145.516	145.52	145.511	145.5138	0.006	0.004		147.761	L1-N1	2.247
5		144.72	144.666	144.629	144.636	144.557	144.6416	0.053	0.037		144.672	L1-S1	0.030
6		146.082	146.625	146.016	146.009	145.999	146.1462	0.241	0.165		146.466	L1-N1	0.320
7		145.427	145.416	145.414	145.414	145.41	145.4162	0.006	0.004		145.515	L2-S1	0.099
8		146.867	146.812	146.794	146.793	146.788	146.8108	0.029	0.020		146.963	L2-N1	0.152

A2. Filter weights before and after sampling (July, 2014)

		Pre										Post		
		06/04/14	06/06/14	06/09/14	06/11/14	06/13/14	07/07/14					07/14/14		Sample weight
#		14:15	9:10	9:06	9:20	13:45	10:15am	Mean	SDevP	RSTDev		9:55	Site ID	(mg)
9		145.312	145.282	145.267	145.257	145.254	145.273	145.274	0.021	0.015		145.969	L1-S PM_{10}	0.695
10		145.383	145.364	145.356	145.351	145.339	145.362	145.359	0.015	0.010		145.645	L1-S $PM_{2.5}$	0.286
11		144.442	144.397	144.399	144.401	144.387	144.414	144.407	0.019	0.013		145.084	L1- PM_{10}	0.677
12		147.000	146.984	146.943	146.984	146.959	147.006	146.979	0.020	0.014		147.245	L1-N $PM_{2.5}$	0.266
13		145.176	145.151	145.139	145.147	145.137	145.161	145.152	0.014	0.010		145.428	L2- PM_{10}	0.276
14		144.728	144.726	144.707	144.709	144.686	144.746	144.717	0.015	0.011		144.890	L2-S $PM_{2.5}$	0.173
15		145.098	145.087	145.082	145.082	145.068	145.101	145.086	0.010	0.007		145.444	L2-N PM_{10}	0.358
16		145.376	145.375	145.372	145.375	145.356	145.387	145.374	0.008	0.005		145.560	L2-N $PM_{2.5}$	0.186

A3. Filter weights before and after sampling (August, 2014)

		Pre									Post		
		07/21/14	07/23/14	07/30/14	08/04/14	08/08/14					08/19/14		Sample weight
#		10:50	10:15				Mean	SDevP	RSTDev			Site ID	(mg)
17		146.21	146.211	146.195	146.18	146.182	146.1956	0.013	0.009		146.248	L3-S $PM_{2.5}$	0.052
18		145.895	145.852	145.845	145.814	145.82	145.8452	0.029	0.020		146.100	L3-N PM_{10}	0.255
19		145.084	145.063	145.046	145.045	145.04	145.0556	0.016	0.011		145.118	L3-N $PM_{2.5}$	0.062
20		145.804	145.83	145.756	145.751	145.752	145.7786	0.032	0.022		145.967	L3-N PM_{10}	0.188
21		145.856	145.827	145.806	145.814	145.8	145.8206	0.020	0.014		145.886	L2-S $PM_{2.5}$	0.065
22		145.285	145.262	145.245	145.233	145.236	145.2522	0.019	0.013		145.437	L2-S PM_{10}	0.185
23		144.733	144.7	144.673	144.666	144.67	144.6884	0.025	0.017		144.740	L2-N $PM_{2.5}$	0.052
24		145.417	145.352	145.369	145.361	145.359	145.3716	0.023	0.016		145.804	L2-S PM_{10}	0.432

A4. Concentration of TSP (June, 2014).

Date	Starting Time	Ending Time	Site ID	Filter Number	Particle Size	Initial Weight (mg)	Final Weight (mg)	Net mass mg	Net mass µg	Run time hrs	Flow Rate lpm	Volume m^3	Concentration µg/m^3 (std dev)
6/24	0.1	20.5	L1-S3	1	TSP	144.5548	146.79	2.2352	2235.2	20.4	5	6.12	365 (13)
6/24	0.2	20.2	L1-S2	2	TSP	146.3714	148.642	2.2706	2270.6	20	5	6	378 (34)
6/24	23.4	43.4	L1-S1	3	TSP	146.9698	152.436	5.4662	5466.2	20	5	6	911 (23)
6/24	0.2	20.2	L1-N1	4	TSP	145.5138	147.761	2.2472	2247.2	20	5	6	374 (6)
Day 2													
6/25	43.4	64.2	L1-S1	5	TSP	144.6416	144.672	0.0304	30.4	20.8	5	6.24	4 (53)
6/25	20.2	40.9	L1-N1	6	TSP	146.1462	146.466	0.3198	319.8	20.7	5	6.21	51 (241)
6/25	20.2	41.7	L2-S1	7	TSP	145.4162	145.515	0.0988	98.8	21.5	5	6.45	15 (6)
6/25	20.5	42	L2-N1	8	TSP	146.8108	146.963	0.1522	152.2	21.5	5	6.45	24 (29)

A5. Concentration of $PM_{2.5}$ and PM_{10} (July, 2014).

Date	Starting Time	Ending Time	Site ID	Filter Number	Particle Size	Initial Weight (mg)	Final Weight (mg)	Net mass mg	Net mass µg	Run time hrs	Flow Rate lpm	Volume m^3	Concentration µg/m^3 (std dev)
7/8	42	62.3	L1-S	9	PM_{10}	145.274	146.79	0.6948	694.8	20.3	5	6.09	114 (21)
7/8	64.2	84.6	L1-S	10	$PM_{2.5}$	145.359	148.642	0.2858	285.8	20.4	5	6.12	47 (15)
7/8	41.8	61.9	L1-N	11	PM_{10}	144.407	152.436	0.6773	677.3	20.1	5	6.03	112 (19)
7/8	41	61.3	L1-N	12	$PM_{2.5}$	146.979	147.761	0.2657	265.7	20.3	5	6.09	44 (20)
Day 2													
7/9	61.3	82.6	L2-S	13	PM_{10}	145.152	145.428	0.2762	276.2	21.3	5	6.39	43 (14)
7/9	84.6	106	L2-S	14	$PM_{2.5}$	144.717	144.890	0.173	173	21.4	5	6.42	27 (15)
7/9	61.9	83.3	L2-N	15	PM_{10}	145.086	145.444	0.3577	357.7	21.4	5	6.42	56 (10)
7/9	62.3	83.7	L2-N	16	$PM_{2.5}$	145.374	145.560	0.1865	186.5	21.4	5	6.42	29 (8)

A6. Concentration of $PM_{2.5}$ and PM_{10} (August, 2014).

Date	Starting Time	Ending Time	Site ID	Filter Number	Particle Size	Initial Weight (mg)	Final Weight (mg)	Net mass mg	Net mass µm	Run time hrs	Flow Rate lpm	Volume m^3	Concentration µg/m^3 (std dev)
8/13	106	126.3	L3-S	17	$PM_{2.5}$	146.196	146.248	0.052	52	20.3	5	6.09	9 (13)
8/13	83.4	103.7	L3-S	18	PM_{10}	145.845	146.100	0.255	255	20.4	5	6.09	42 (29)
8/13	82.6	102.8	L3-N	19	$PM_{2.5}$	145.056	145.118	0.062	62	20.2	5	6.06	10 (16)
8/13	83.7	103.9	L3-N	20	PM_{10}	145.779	145.967	0.188	188	20.2	5	6.06	31 (32)
Day 2													
8/14	102.8	124	L2-S	21	$PM_{2.5}$	145.821	145.886	0.065	65	21.2	5	6.36	10 (20)
8/14	126.4	147.6	L2-S	22	PM_{10}	145.252	145.437	0.185	185	21.2	5	6.36	29 (19)
8/14	103.8	124.9	L2-N	23	$PM_{2.5}$	144.688	144.740	0.052	52	21.1	5	6.33	8 (25)
8/14	103.9	125.1	L2-N	24	PM_{10}	145.372	145.804	0.432	432	21.2	5	6.36	68 (23)

Standard deviation values used are based on those calculated by repeated weighings of pre-sampling filters. In some cases, the standard deviation is higher than the concentration measured

APPENDIX B

B1. Particle Matter identification.

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147819 001 L1-S3(2)_pt1	Silicates	O, Si, Al	K, Na, Ca, Mg, Fe	151 O, 6 Na, 1 Mg, 17 Al, 57 Si, 7 K, 2 Ca, 1 Fe
147819 001 L1-S3(2)_pt2	Quartz	O, Si	Fe, Al, Na, Ca, K	343 O, 1 Na, 3 Al, 165 Si, 1 K, 1 Ca, 4 Fe,
147819 001 L1-S3(2)_pt3	Quartz	O, Si	Na, Al, Mg, Ca	322 O, 4 Na, 1 Mg, 1 Al, 158 Si, 1 Ca,
147819 001 L1-S3(1)_pt1	Silicates	O, Si, Al, K	Ca, Fe, Na, Mg	92 O, 1 Na, 1 Mg, 11 Al, 33 Si, 5 K, 2 Ca, 2 Fe,
147819 001 L1-S3 (1)_pt1	Silicates	O, Si, Fe, Al	K, Na, Ca, Mg	54 O, 2 Na, 1 Mg, 5 Al, 17 Si, 2 K, 1 Ca, 6 Fe,
147819 001 L1-S3 (1)_pt2	Silicates	O, Si, Al, K	Fe, Mg, Na	173 O, 1 Na, 2 Mg, 18 Al, 69 Si, 6 K, 2 Fe,
147819 001 L1-S3 (1)_pt3	Silicates	O, Si, Na, K	Fe, Ca, Mg	201 O, 8 Na, 1 Mg, 45 Al, 60 Si, 5 K, 2 Ca, 3 Fe,
147819 001 L1-S3 (1)_pt4	Quartz	O, Si	Ca, Fe, Mg, Na, K	112 O, 1 Na, 1 Mg, 5 Al, 49 Si, 1 K, 3 Ca, 2 Fe,
147819 001 L1-S3 (1)_pt5	Silicates	O, Ca, Mg, Si	Al, Fe, K	77 O, 18 Mg, 5 Al, 11 Si, 1 K, 23 Ca, 4 Fe,
147819 001 L1-S3 (2)_pt1	Quartz	O, Si	Al, Fe, Ca	184 O, 2 Al, 89 Si, 1 Ca, 2 Fe,
147819 001 L1-S3 (2)_pt2	Silicates	O, Si, Al	Fe, Na, Mg, K, Ca	261 O, 3 Na, 2 Mg, 14 Al, 115 Si, 2 K, 1 Ca, 3 Fe,
147819 001 L1-S3 (2)_pt3	Silicates	O, Ca, Si	Fe, Al, Mn	69 O, 1 Al, 19 Si, 24 Ca, 1 Mn, 2 Fe,
147819 001 L1-S3 (2)_pt4	Quartz	O, Si	Al, Fe, Ca, K	406 O, 8 Al, 189 Si, 1 K, 2 Ca, 8 Fe,
147819 001 L1-S3 (3)_pt1	Silicates	O, Si, Ca, Fe, Al	Mg, K	161 O, 3 Mg, 10 Al, 40 Si, 1 K, 38 Ca, 17 Fe,
147819 001 L1-S3 (3)_pt2	Silicates	O, Si, Al, Fe	Na, K, Mg	86 O, 1 Na, 1 Mg, 7 Al, 33 Si, 2 K, 4 Fe,
147819 001 L1-S3 (3)_pt3	Silicates	O, Si, Al	K, Mg, Na, Fe	92 O, 1 Na, 2 Mg, 14 Al, 33 Si, 3 K, 1 Fe,
147819 001 L1-S3 (3)_pt4	Silicates	O, Si, Fe	Al, Ca, Mg	195 O, 1 Mg, 4 Al, 67 Si, 1 Ca, 35 Fe,
147819 001 L1-S3 (3)_pt5	Silicates	O, Si, Ca, Al	Fe, Mg, Na, K	165 O, 1 Na, 2 Mg, 7 Al, 62 Si, 1 K, 23 Ca, 3 Fe,
147819 001 L1-S3 (4)_pt1	Silicates	O, Si, Al, Ca, Mg, Fe	K, S, Ti, Ba	1329 O, 41 Mg, 136 Al, 466 Si, 10 S, 13 K, 51 Ca, 4 Ti, 38 Fe, 1 Ba,
147819 001 L1-S3 (4)_pt2	Silicates	O, Ca, Si, Al	Fe, Mg, K	211 O, 6 Mg, 11 Al, 40 Si, 1 K, 99 Ca, 6 Fe,
147819 001 L1-S3 (4)_pt3	Silicates	O, Si, Fe	Al, Ca, Na, K, Mg	241 O, 2 Na, 1 Mg, 8 Al, 103 Si, 1 K, 4 Ca, 10 Fe,
147819 001 L1-S3 (4)_pt4	Silicates	O, Si, Fe, Al	Na, Ca, K, Mg, P	332 O, 13 Na, 3 Mg, 27 Al, 109 Si, 1 P, 4 K, 8 Ca, 34 Fe,
147819 001 L1-S3 (5)_pt1	Silicates	O, Fe, Si, Al	Mg, Ca, P, K	238 O, 3 Mg, 10 Al, 59 SI, 2 P, 1 K, 2 Ca, 64 Fe,
147819 001 L1-S3 (5)_pt2	Silicates	O, Si, Fe, Al, Ca	Mg, K, Ti	127 O, 3 Mg, 11 Al, 34 SI, 2 K, 14 Ca, 1 Ti, 14 Fe,
147819 001 L1-S3 (5)_pt3	Quartz	O, Si	Fe, Al, Mg, Ca, Na	348 O, 1 Na, 2 Mg, 7 Al, 161 SI, 1 Ca, 8 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147819 001 L1-S3 (5)_pt4	Silicates	O, Si, Al, Ca, Fe	K, Mg, Na, Mn	177 O, 2 Na, 3 Mg, 27 Al, 52 SI, 4 K, 16 Ca, 1 Mn, 6 Fe,
147819 001 L1-S3 (5)_pt5	Silicates	O, Si, Al	Ca, K, Mg, Ti	119 O, 1 Mg, 9 Al, 49 SI, 2 K, 4 Ca, 1 Ti,
147820 002 L1-S2 (1)_pt1	Silicates	O, Si, Al, Mg, Fe, K	Na, Ti	118 O, 1 Na, 9 Mg, 15 Al, 35 Si, 5 K, 1 Ti, 8 Fe,
147820 002 L1-S2 (1)_pt2	Silicates	O, Si, Ca, Al, K, Fe	Mg, Na	201 O, 1 Na, 2 Mg, 16 Al, 66 Si, 7 K, 31 Ca, 6 Fe,
147820 002 L1-S2 (1)_pt3	Silicates	O, Si, Fe, Al	Mg, Na, Ca, K	243 O, 3 Na, 5 Mg, 10 Al, 61 Si, 1 K, 2 Ca, 65 Fe,
147820 002 L1-S2 (1)_pt4	Silicates	O, Si, Ca, Na, Al	Fe, Mg	156 O, 9 Na, 1 Mg, 9 Al, 59 Si, 16 Ca, 2 Fe,
147820 002 L1-S2 (2)_pt1	Silicates	O, Si, Al, Fe, Ca	Na, K, Mg	87 O, 2 Na, 1 Mg, 8 Al, 32 Si, 1 K, 3 Ca, 4 Fe,
147820 002 L1-S2 (2)_pt2	Silicates	O, Si, Al, Ca, Fe	K, Mg	60 O, 1 Mg, 6 Al, 20 Si, 1 K, 5 Ca, 3 Fe,
147820 002 L1-S2 (2)_pt3	Silicates	O, Si, Fe, Al	Ca, Mg, K, P	140 O, 3 Mg, 9 Al, 46 Si, 1 P, 1 K, 3 Ca, 17Fe
147820 002 L1-S2 (2)_pt4	Silicates	O, Si, Al, K	Fe, Mg, Na	109 O, 1 Na, 2 Mg, 20 Al, 36 Si, 4 K, 2 Fe,
147820 002 L1-S2 (3)_pt1	Silicates	O, Si, Al, Fe	Mg, K, Ca, Na, Ti	213 O, 2 Na, 4 Mg, 20 Al, 81 Si, 4 K, 2 Ca, 1 Ti, 7 Fe,
147820 002 L1-S2 (3)_pt2	Silicates	O, Si, Al, Na, Fe	Ca, Mg, K	67 O, 3 Na, 1 Mg, 5 Al, 26 Si, 1 K, 1 Ca, 2 Fe,
147820 002 L1-S2 (3)_pt3	Silicates	O, Ca, Si, Al	Fe, Mn, Mg, K	152 O, 2 Mg, 8 Al, 23 Si, 1 K, 83 Ca, 3 Mn, 4 Fe,
147820 002 L1-S2 (3)_pt4	Silicates	O, Si, Al	K, Na, Mg, Fe	68 O, 1 Na, 1 Mg, 7 Al, 27 Si, 2 K, 1 Fe,
147820 002 L1-S2 (3)_pt5	Silicates	O, Si, Fe	Na, Ca, Mg, Al, S	149 O, 3 Na, 2 Mg, 2 Al, 43 Si, 1 S, 3 Ca, 35 Fe,
147820 002 L1-S2 (4)_pt1	Silicates	O, Si, Al, Ca	Fe, Na, Mg, K	374 O, 3 Na, 2 Mg, 18 Al, 164 Si, 1 K, 11 Ca, 3 Fe,
147820 002 L1-S2 (4)_pt2	Quartz	O, Si	Ca, Al, Fe, Na	278 O, 1 Na, 2 Al, 135 Si, 3 Ca, 2 Fe,
147820 002 L1-S2 (5)_pt1	Silicates	O, Si, Al	Fe, Na, K, Ca, Mg	79 O, 2 Na, 1 Mg, 9 Al, 29 Si, 2 K, 1 Ca, 2 Fe,
147820 002 L1-S2 (5)_pt2	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K	106 O, 1 Na, 1 Mg, 8 Al, 41 Si, 1 K, 2 Ca, 5 Fe,
147820 002 L1-S2 (5)_pt3	Silicates	O, Si, Al, Fe, Ca	Na, K, Mg	101 O, 2 Na, 1 Mg, 12 Al, 35 Si, 1 K, 3 Ca, 5 Fe,
147820 002 L1-S2 (6)_pt1	Silicates	O, Si, Al, K	Fe, Ba	280 O, 33 Al, 106 Si, 29 K, 2 Fe, 1 Ba,
147820 002 L1-S2 (6)_pt2	Silicates	O, Si, Al, Fe, Na	K, Ca, Mg	344 O, 7 Na, 1 Mg, 29 Al, 141 Si, 4 K, 3 Ca, 7 Fe,
147820 002 L1-S2 (6)_pt3	Quartz	O, Si	Na, Ca	427 O, 4 Na, 212 Si, 1 Ca,
147820 002 L1-S2 (7)_pt1	Silicates	O, Si, Al, Na	Fe, Ca, K, Mg, Mo, Ba	437 O, 46 Na, 1 Mg, 47 Al, 161 Si, 2 K, 4 Ca, 6 Fe, 1 Mo, 1 Ba,
147820 002 L1-S2 (7)_pt2	Silicates	O, Ca, Si	Br	90 O, 25 Si, 40 Ca, 1 Br,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147820 002 L1-S2 (7)_pt3	Silicates	O, Si, Fe, Ca, Al	Mg, K	100 O, 2 Mg, 7 Al, 24 Si, 1 K, 14 Ca, 17 Fe,
147820 002 L1-S2 (8)_pt1	Silicates	O, Si, Fe, Al	Mg, Ca, Na, K	159 O, 1 Na, 2 Mg, 6 Al, 67 Si, 1 K, 1 Ca, 8 Fe,
147820 002 L1-S2 (8)_pt2	Silicates	O, Si, Al, Na, Fe, K	Ca, Mg, Ti	241 O, 10 Na, 3 Mg, 27 Al, 85 Si, 8 K, 3 Ca, 1 Ti, 9 Fe,
147820 002 L1-S2 (9)_pt1	Silicates	O, Si, Al, Ca, Fe	Na, Mg, K, Ti	1007 O, 14 Na, 11 Mg, 91 Al, 366 Si, 10 K, 46 Ca, 1 Ti, 44 Fe,
147820 002 L1-S2 (9)_pt3	Silicates	O, Si, Al, Fe, Mg	K, Ca	239 O, 10 Mg, 23 Al, 82 Si, 2 K, 1 Ca, 19 Fe,
147820 002 L1-S2 (9)_pt4	Silicates	O, Si, Fe, Al, Ca, Na	Mg, K	90 O, 3 Na, 2 Mg, 9 Al, 24 Si, 1 K, 4 Ca, 13 Fe,
147820 002 L1-S2 (9)_pt5	Silicates	O, Si, Al, Fe	Ca, Mg, K	228 O, 1 Mg, 7 Al, 102 Si, 1 K, 3 Ca, 7 Fe,
147820 002 L1-S2 (9)_pt6	Silicates	O, Ca, Si	Al, Fe	56 O, 1 Al, 14 Si, 25 Ca, 1 Fe,
147820 002 L1-S2 (10)_pt1	Quartz	O, Si	Na, P, Ca, Mg, Al, K	128 O, 3 Na, 1 Mg, 1 Al, 57 Si, 3 P, 1 K, 2 Ca,
147820 002 L1-S2 (11)_pt1	Silicates	O, Si, Al, Fe, Mg, K	Ti	127 O, 9 Mg, 16 Al, 38 Si, 6 K, 1 Ti, 9 Fe,
147820 002 L1-S2 (11)_pt2	Silicates	O, Si, Al, Mg, Ca, Fe	Na, K	144 O, 4 Na, 8 Mg, 18 Al, 46 Si, 1 K, 7 Ca, 5 Fe,
147820 002 L1-S2 (11)_pt3	Quartz	O, Si	Al, Na, Cu	303 O, 2 Na, 2 Al, 149 Si, 1 Cu,
147820 002 L1-S2 (11)_pt4	Silicates	O, Fe, Si, Al	Mg, Ca, K, P	304 O, 5 Mg, 13 Al, 71 Si, 1 P, 1 K, 2 Ca, 87 Fe,
147820 002 L1-S2 (11)_pt5	Silicates	O, Si, Ca, Al	K, Fe, Mg	107 O, 1 Mg, 9 Al, 37 Si, 4 K, 12 Ca, 3 Fe,
147820 002 L1-S2 (12)_pt1	Silicates	O, Si, Al, Fe, Na	K, Mg, Ca, S, P, Ba	173 O, 6 Na, 3 Mg, 20 Al, 55 Si, 1 P, 3 S, 4 K, 3 Ca, 8 Fe, 1 Ba,
147820 002 L1-S2 (12)_pt2	Silicates	O, Si, Al, Fe	Ca, K, Na, Mg	119 O, 1 Na, 1 Mg, 7 Al, 46 Si, 2 K, 4 Ca, 6 Fe,
147820 002 L1-S2 (12)_pt3	Silicates	O, Ca, Si, Mg	Al	168 O, 35 Mg, 1 Al, 40 Si, 51 Ca,
147820 002 L1-S2 (12)_pt4	Silicates	O, Si, Fe	Al, Ca, K	377 O, 3 Al, 177 Si, 1 K, 2 Ca, 12 Fe,
147820 002 L1-S2 (12)_pt5	Silicates	O, Ca,Si	Mg, Na, Fe, Al	91 O, 1 Na, 3 Mg, 1 Al, 10 Si, 64 Ca, 1 Fe,
147820 002 L1-S2 (12)_pt6	Silicates	O, Si, Fe, Ca, Al, K, Ti	Mg	333 O, 1 Mg, 17 Al, 98 Si, 15 K, 20 Ca, 10 Ti, 43 Fe,
147820 002 L1-S2 (13)_pt1	Silicates	O, Si, Ca, Al, Fe	Mg, K, P	221 O, 3 Mg, 19 Al, 71 Si, 1 P, 2 K, 19 Ca, 16 Fe,
147820 002 L1-S2 (13)_pt2	Silicates	O, Si, Al, Fe	Na, K, Ca, Mg	99 O, 2 Na, 1 Mg, 10 Al, 37 Si, 2 K, 2 Ca, 4 Fe,
147820 002 L1-S2 (13)_pt3	Silicates	O, Si	Fe, Mn, Al, Ca, K, Na, Ti	214 O, 1 Na, 2 Al, 97 Si, 2 K, 2 Ca, 1 Ti, 4 Mn, 4 Fe,
147820 002 L1-S2 (13)_pt4	Silicates	O, Si, Al, Fe, K, Mg	Na, Ca, P	212 O, 4 Na, 6 Mg, 30 Al, 70 Si, 1 P, 7 K, 2 Ca, 8 Fe,
147820 002 L1-S2 (14)_pt1	Quartz	O, Si	Na, Ca, P	108 O, 2 Na, 52 Si, 1 P, 1 Ca,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147820 002 L1-S2 (14)_pt2	Quartz	O, Si	Al	219 O, 1 Al, 109 Si,
147820 002 L1-S2 (14)_pt3	Oxide	O, Ca	Si, Al, Fe, Mg	42 O, 1 Mg, 1 Al, 3 Si, 30 Ca, 1 Fe,
147820 002 L1-S2 (15)_pt1	Silicates	O, Si, Al, Fe, Ca	Na, K, Mg	86 O, 2 Na, 1 Mg, 7 Al, 31 Si, 1 K, 3 Ca, 6 Fe,
147820 002 L1-S2 (15)_pt2	Silicates	O, Si, Al, K	Fe, Mg, Na	131 O, 1 Na, 2 Mg, 17 Al, 47 Si, 7 K, 3 Fe,
147820 002 L1-S2 (15)_pt3	Silicates	O, Si, Al	Fe, Ca, Na, K, Mg	160 O, 2 Na, 1 Mg, 7 Al, 70 Si, 1 K, 2 Ca, 3 Fe,
147820 002 L1-S2 (15)_pt4	Silicates	O, Si, Al	Fe, Ca, Mg, K, Na	121 O, 1 Na, 3 Mg, 7 Al, 49 Si, 2 K, 3 Ca, 3 Fe,
147820 002 L1-S2 (15)_pt5	Silicates	O, Si, Fe, Al	Mg, Ca, Na, K	215 O, 2 Na, 3 Mg, 6 Al, 63 Si, 1 K, 2 Ca, 49 Fe,
147820 002 L1-S2 (16)_pt1	Quartz	O, Si	Al, Na	242 O, 1 Na, 1 Al, 120 Si,
147820 002 L1-S2 (16)_pt2	Silicates	O, Si, Ca	Al, Fe, Mg, Na	156 O, 1 Na, 1 Mg, 3 Al, 68 Si, 10 Ca, 2 Fe,
147820 002 L1-S2 (16)_pt3	Silicates	O, Si, Al, Fe, Mg	Ca, Na, K	87 O, 1 Na, 3 Mg, 11 Al, 29 Si, 1 K, 1 Ca, 6 Fe,
147820 002 L1-S2 (16)_pt4	Quartz	O, Si	Al, Ca	341 O, 3 Al, 168 Si, 1 Ca,
147820 002 L1-S2 (16)_pt5	Silicates	O, Ca, Si, Al	Mg, Fe, K	69 O, 2 Mg, 6 Al, 13 Si, 1 K, 30 Ca, 1 Fe,
147820 002 L1-S2 (17)_pt1	Silicates	O, Ca, Si	Al, Mg	108 O, 1 Mg, 2 Al, 20 Si, 65 Ca,
147820 002 L1-S2 (17)_pt2	Silicates	O, Si, Al	K, Fe, Na, Mg, Ca	193 O, 3 Na, 2 Mg, 20 Al, 76 Si, 4 K, 1 Ca, 3 Fe,
147820 002 L1-S2 (18)_pt1	Silicates	O, Si, Al, Na, K	Fe, Mg	223 O, 13 Na, 1 Mg, 27 Al, 82 Si, 13 K, 3 Fe,
147820 002 L1-S2 (18)_pt2	Silicates	O, Si, Fe	Al, Ca, Mg, K	368 O, 1 Mg, 4 Al, 172 Si, 1 K, 1 Ca, 10 Fe,
147820 002 L1-S2 (18)_pt3	Silicates	O, Si, Ca, Al	Fe, Mg, K	66 O, 1 Mg, 7 Al, 19 Si, 1 K, 13 Ca, 2 Fe,
147820 002 L1-S2 (18)_pt4	Quartz	O, Si	Na, Al, Ca, Mg	221 O, 3 Na, 1 Mg, 2 Al, 107 Si, 1 Ca,
147820 002 L1-S2 (18)_pt5	Silicates	O, Si, Fe	Al, Na, Ca, Mg, K	299 O, 3 Na, 2 Mg, 7 Al, 112 Si, 1 K, 2 Ca, 39 Fe,
147821 003 L1-SI(1)_pt1-No Data				No Data
147821 003 L1-SI(1)_pt2	Quartz	O, Si	Al, Fe, Ca, Na, Mg, K	197 O, 2 Na, 1 Mg, 5 Al, 89 Si, 1 K, 3 Ca, 4 Fe,
147821 003 L1-SI(1)_pt3	Silicates	O, Ca, Si, Al	Fe, Na, Mg, K	179 O, 5 Na, 4 Mg, 10 Al, 26 Si, 1 K, 97 Ca, 6 Fe,
147821 003 L1-SI(1)_pt4	Silicates	O, Si, Ca, Fe	Al, S, K, Na, Mg	489 O, 2 Na, 1 Mg, 12 Al, 196 Si, 7 S, 5 K, 23 Ca, 20 Fe,
147821 003 L1-SI(1)_pt5	Silicates	O, Si, Al	Na, Mg, Fe, Ca, K	188 O, 3 Na, 3 Mg, 20 Al, 74 Si, 1 K, 1 Ca, 2 Fe,
147821 003 L1-SI(1)_pt6	Quartz	O, Si	Al, Fe, Ca, Mg, K	385 O, 1 Mg, 5 Al, 184 Si, 1 K, 1 Ca, 5 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147821 003 L1-SI(1)_pt7	Silicates	O, Si, Al	K, Mg, Fe, Na, Ca	117 O, 1 Na, 2 Mg, 13 Al, 44 Si, 4 K, 1 Ca, 2 Fe,
147821 003 L1-SI(1)_pt8	Silicates	O, Si, Al	Fe, Ca, Mg, Na, K	97 O, 1 Na, 1 Mg, 6 Al, 40 Si, 1 K, 1 Ca, 3 Fe,
147821 003 L1-SI(1)_pt9	Silicates	O, Si, Fe	Al, Ca, Mg, Mn	107 O, 1 Mg, 2 Al, 30 Si, 2 Ca, 1 Mn, 27 Fe,
147821 003 L1-SI(1)_pt10	Quartz	O, Si	Al, Fe, Na, K, Ca, Mg	127 O, 2 Na, 1 Mg, 5 Al, 55 Si, 2 K, 2 Ca, 3 Fe,
147821 003 L1-SI(2)_pt1	Silicates	O, Ca, Si	Fe, Al, Mg	116 O, 1 Mg, 2 Al, 34 Si, 41 Ca, 3 Fe,
147821 003 L1-SI(2)_pt2	Silicates	O, Si, Fe, Al	Mg, K, Na, Ca	269 O, 1 Na, 2 Mg, 9 Al, 105 Si, 2 K, 1 Ca, 27 Fe,
147821 003 L1-SI(2)_pt3	Silicates	O, Si, Al, Fe	K, Na, Mg	317 O, 2 Na, 1 Mg, 13 Al, 139 Si, 4 K, 10 Fe,
147821 003 L1-SI(2)_pt4	Silicates	O, Si, Ca, Fe, Al	K, Mg	90 O, 1 Mg, 6 Al, 30 Si, 2 K, 8 Ca, 7 Fe,
147821 003 L1-SI(3)_pt1	Silicates	O, Ca, Si, Al	Fe, Mg, K, Ti	90 O, 3 Mg, 9 Al, 20 Si, 1 K, 25 Ca, 1 Ti, 4 Fe,
147821 003 L1-SI(4)_pt1	Quartz	O, Si	Al	561 O, 1 Al, 280 Si,
147821 003 L1-SI(4)_pt2	Silicates	O, Si, Al, Na	Ca, Fe, K	324 O, 37 Na, 45 Al, 115 Si, 1 K, 6 Ca, 2 Fe,
147821 003 L1-SI(4)_pt3	Silicates	O, Fe, Si, Al	Ca, Mg, K, P	169 O, 2 Mg, 14 Al, 36 Si, 1 P, 1 K, 4 Ca, 44 Fe,
147821 003 L1-SI(5)_pt1	Silicates	O, Si, Al, Fe, Ca	K, Na, Mg	74 O, 1 Na, 1 Mg, 7 Al, 26 Si, 1 K, 3 Ca, 4 Fe,
147821 003 L1-SI(5)_pt2	Silicates	O, Si, Al, Fe	K, Ca, Mg, Na	117 O, 1 Na, 1 Mg, 14 Al, 42 Si, 2 K, 2 Ca, 5 Fe,
147821 003 L1-SI(5)_pt3	Silicates	O, Si, Fe, Al, Ca, Na	S, K, Mg	113 O, 6 Na, 1 Mg, 9 Al, 30 Si, 4 S, 1 K, 7 Ca, 11 Fe,
147821 003 L1-SI(5)_pt4	Quartz	O, Si	Al, Ca, Mg, K	318 O, 1 Mg, 6 Al, 152 Si, 1 K, 4 Ca,
147821 003 L1-SI(5)_pt5	Silicates	O, Si, Fe, Al	Ca, Na, K, Mg	118 O, 2 Na, 1 Mg, 6 Al, 42 Si, 1 K, 3 Ca, 14 Fe,
147821 003 L1-SI(6)_pt1	Quartz	O, Si	Al, K	54 O, 3 Al, 25 Si, 1 K,
147821 003 L1-SI(6)_pt2	Quartz	O, Si	Al, Fe, Ca, Na, Mg, K	328 O, 4 Na, 3 Mg, 9 Al, 149 Si, 1 K, 4 Ca, 4 Fe,
147821 003 L1-SI(6)_pt3	Silicates	O, Si, Al	Na, Ca, Fe, Mg, K	166 O, 3 Na, 1 Mg, 9 Al, 71 Si, 1 K, 3 Ca, 2 Fe,
147821 003 L1-SI(6)_pt4	Silicates	O, Si, Al, K	Na, Mg, Ca, Fe	111 O, 1 Na, 1 Mg, 23 Al, 35 Si, 7 K, 1 Ca, 1 Fe,
147821 003 L1-SI(6)_pt5	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K	84 O, 1 Na, 1 Mg, 8 Al, 31 Si, 1 K, 2 Ca, 4 Fe,
147821 003 L1-SI(7)_pt1	Silicates	O, Si, Fe, Al, Ca	Mg, Na, K, Ti	189 O, 3 Na, 3 Mg, 13 Al, 57 Si, 2 K, 9 Ca, 1 Ti, 26 Fe,
147821 003 L1-SI(7)_pt2	Silicates	O, Si, Al, Na, K	Ca, P	68 O, 4 Na, 8 Al, 24 Si, 1 P, 3 K, 2 Ca,
147821 003 L1-SI(7)_pt3	Silicates	O, Si, Fe, Al, Mg	Ca, Na, K	122 O, 1 Na, 7 Mg, 17 Al, 30 Si, 1 K, 2 Ca, 19 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147821 003 L1-SI(8)_pt1	Silicates	O, Si, Al, Fe, K	Na, Ca, Mg	82 O, 2 Na, 1 Mg, 9 Al, 28 Si, 3 K, 2 Ca, 4 Fe,
147821 003 L1-SI(8)_pt2	Silicates	O, Si, Al, Mg, Fe	Ca	343 O, 48 Mg, 64 Al, 70 Si, 1 Ca, 38 Fe,
147821 003 L1-SI(8)_pt3	Silicates	O, Si, Al	Na, Ca, Ti, Mg, K, Fe	161 O, 5 Na, 1 Mg, 15 Al, 61 Si, 1 K, 5 Ca, 3 Ti, 1 Fe,
147821 003 L1-SI(9)_pt1	Quartz	O, Si	Al, Na, K, P	76 O, 1 Na, 1 Al, 35 Si, 1 P, 1 K,
147821 003 L1-SI(9)_pt2	Silicates	O, Ca, Si, Al, Fe	Mg, Mn, K	106 O, 2 Mg, 8 Al, 24 Si, 1 K, 34 Ca, 1 Mn, 6 Fe,
147821 003 L1-SI(9)_pt3	Silicates	O, Si, Al, K	Mg, Na, Fe	113 O, 1 Na, 2 Mg, 24 Al, 35 Si, 7 K, 1 Fe,
147821 003 L1-SI(10)_pt1	Silicates	O, Si, Al, Fe, Ca	Mg, Na, K	84 O, 1 Na, 2 Mg, 9 Al, 27 Si, 1 K, 3 Ca, 7 Fe,
147821 003 L1-SI(10)_pt2	Quartz	O, Si	Al, Fe, K, Ca, Mg	222 O, 1 Mg, 9 Al, 100 Si, 2 K, 1 Ca, 2 Fe,
147821 003 L1-SI(10)_pt3	Silicates	O, Si, Al, Fe, K, Ca	Mg	104 O, 1 Mg, 15 Al, 31 Si, 7 K, 6 Ca, 7 Fe,
147821 003 L1-SI(10)_pt4	Silicates	O, Si, Al	Fe, K, Na, Ca, Mg	165 O, 2 Na, 1 Mg, 18 Al, 63 Si, 4 K, 1 Ca, 5 Fe,
147821 003 L1-SI(10)_pt5	Quartz	O, Si	Al, Ca, Mg	281 O, 1 Mg, 7 Al, 134 Si, 1 Ca,
147821 003 L1-SI(10)_pt6	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K, S	158 O, 1 Na, 2 Mg, 8 Al, 64 Si, 1 S, 1 K, 2 Ca, 6 Fe,
147821 003 L1-SI(11)_pt1	Silicates	O, Fe, Si	Mn, Mg, Al, Ca	82 O, 2 Mg, 2 Al, 13 Si, 1 Ca, 3 Mn, 32 Fe,
147821 003 L1-SI(11)_pt2	Silicates	O, Si, Al	Fe, Na, K, Ca, Mg	82 O, 2 Na, 1 Mg, 9 Al, 31 Si, 2 K, 1 Ca, 2 Fe,
147821 003 L1-SI(11)_pt3	Silicates	O, Si, Al, Fe, Mg	K, Ca	116 O, 5 Mg, 19 Al, 26 Si, 2 K, 1 Ca, 19 Fe,
147821 003 L1-SI(11)_pt4	Silicates	O, Si, Al, Ca	Fe, Na, K, Mg	54 O, 2 Na, 1 Mg, 7 Al, 16 Si, 1 K, 5 Ca, 2 Fe,
147821 003 L1-SI(11)_pt5	Silicates	O, Si, Al, Fe	K, Ca, Mg, Na, Ti	363 O, 3 Na, 6 Mg, 37 Al, 125 Si, 10 K, 8 Ca, 1 Ti, 23 Fe,
147821 003 L1-SI(12)_pt1	Silicates	O, Si, Al, K	Fe, Ca, Mg, Na	142 O, 1 Na, 2 Mg, 23 Al, 46 Si, 7 K, 2 Ca, 4 Fe,
147821 003 L1-SI(13)_pt1	Silicates	O, Si, Al	K, Fe, Mg, Na, Ca, Ba	433 O, 4 Na, 5 Mg, 50 Al, 164 Si, 13 K, 3 Ca, 8 Fe, 1 Ba,
147821 003 L1-SI(13)_pt2	Silicates	O, Si, Al	Fe, Ca, Mg, Na, K	91 O, 1 Na, 1 Mg, 8 Al, 34 Si, 1 K, 3 Ca, 3 Fe,
147821 003 L1-SI(13)_pt3	Silicates	O, Si, Fe, Al	Na, K, Ca, Mg	130 O, 2 Na, 1 Mg, 8 Al, 50 Si, 2 K, 1 Ca, 10 Fe,
147821 003 L1-SI(13)_pt4	Quartz	O, Si	Al, Ca, Na	216 O, 1 Na, 3 Al, 105 Si, 2 Ca,
147821 003 L1-SI(13)_pt5	Silicates	O, Si, Al	K, Fe, Na, Mg	147 O, 1 Na, 1 Mg, 13 Al, 61 Si, 3 K, 2 Fe,
147822 004 L1-N1(1)_pt1	Silicates	O, Si, Al, Fe, Mg	Ca, K, Na, Ti	345 O, 4 Na, 11 Mg, 39 Al, 113 Si, 5 K, 5 Ca, 1 Ti, 26 Fe,
147822 004 L1-N1(1)_pt2	Silicates	O, Si, Ca	Al, Fe, Mn, Mg, K	286 O, 1 Mg, 8 Al, 109 Si, 1 K, 47 Ca, 2 Mn, 4 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147822 004 L1-N1(1)_pt3	Silicates	O, Si, Ca	Na, Al, Mg, Fe, K	169 O, 5 Na, 2 Mg, 4 Al, 70 Si, 1 K, 15 Ca, 2 Fe,
147822 004 L1-N1(2)_pt1	Quartz	O, Si	P, Na, K, S, Ca, Al, Mg	360 O, 4 Na, 1 Mg, 2 Al, 161 Si, 8 P, 3 S, 4 K, 3 Ca,
147822 004 L1-N1(2)_pt2	Silicates	O, Si, Fe	Al, Ca, Na, Ti, Mg, K	327 O, 3 Na, 2 Mg, 7 Al, 135 Si, 1 K, 6 Ca, 3 Ti, 20 Fe,
147822 004 L1-N1(2)_pt3	Silicates	O, Si, Fe, Al	Na, Mg, Mn, Ca, K	154 O, 3 Na, 2 Mg, 8 Al, 47 Si, 1 K, 1 Ca, 2 Mn, 27 Fe,
147822 004 L1-N1(2)_pt4	Silicates	O, Si, Al	Na, K, Ca	79 O, 3 Na, 5 Al, 34 Si, 1 K, 1 Ca,
147822 004 L1-N1(2)_pt5	Quartz	O, Si	Fe, Al	151 O, 1 Al, 71 Si, 5 Fe,
147822 004 L1-N1(3)_pt1	Silicates	O, Si, Ca, Al, Fe, Na	Mg, K	257 O, 10 Na, 5 Mg, 16 Al, 95 Si, 1 K, 17 Ca, 11 Fe,
147822 004 L1-N1(3)_pt2	Silicates	O, Si, Al	Fe, Na, K, Mg	94 O, 2 Na, 1 Mg, 6 Al, 40 Si, 2 K, 2 Fe,
147822 004 L1-N1(3)_pt3	Quartz	O, Si	Na, Ca, Al	556 O, 4 Na, 1 Al, 275 Si, 3 Ca,
147822 004 L1-N1(3)_pt4	Silicates	O, Si, Al	Fe, Mg, Na, K	55 O, 1 Na, 1 Mg, 7 Al, 20 Si, 1 K, 1 Fe,
147822 004 L1-N1(3)_pt5	Silicates	O, Si, Al, Fe	Ca, Mg, K	148 O, 1 Mg, 6 Al, 64 Si, 1 K, 1 Ca, 6 Fe,
147822 004 L1-N1(4)_pt1	Quartz	O, Si		2 O, 1 Si,
147822 004 L1-N1(4)_pt2	Quartz	O, Si	Ca, Al	344 O, 1 Al, 170 Si, 2 Ca,
147822 004 L1-N1(4)_pt3	Silicates	O, Ca, Si, Fe, Al	Mg, K	178 O, 3 Mg, 7 Al, 46 Si, 1 K, 56 Ca, 9 Fe,
147822 004 L1-N1(4)_pt4	Quartz	O, Si	Ca	289 O, 144 Si, 1 Ca,
147822 004 L1-N1(5)_pt1	Silicates	O, Si, Al	Fe, Ca, Mg, K	202 O, 1 Mg, 9 Al, 88 Si, 1 K, 2 Ca, 6 Fe,
147822 004 L1-N1(5)_pt2	Quartz	O, Si	Al, Na, Fe, Ca, Mg	466 O, 5 Na, 1 Mg, 6 Al, 223 Si, 2 Ca, 4 Fe,
147822 004 L1-N1(5)_pt3	Silicates	O, Si, Al, K	Fe, Na, Ca, Mg, S	89 O, 2 Na, 1 Mg, 10 Al, 29 Si, 2 S, 4 K, 2 Ca, 3 Fe,
147822 004 L1-N1(5)_pt4	Silicates	O, Si, Al, Fe, Ca	Mg, Na, K	99 O, 1 Na, 2 Mg, 8 Al, 37 Si, 1 K, 4 Ca, 4 Fe,
147822 004 L1-N1(6)_pt1	Silicates	O, Si, Fe, Ca, Al	Mg, Na, K	120 O, 1 Na, 2 Mg, 5 Al, 48 Si, 1 K, 5 Ca, 6 Fe,
147822 004 L1-N1(6)_pt2	Quartz	O, Si	Fe, Al, Na, Ca, Mg, K	479 O, 5 Na, 2 Mg, 8 Al, 221 Si, 1 K, 2 Ca, 12 Fe,
147822 004 L1-N1(6)_pt3	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K	106 O, 1 Na, 2 Mg, 8 Al, 41 Si, 1 K, 3 Ca, 4 Fe,
147822 004 L1-N1(6)_pt4	Quartz	O, Si	Al, Ca, Fe, Na, P, K	321 O, 4 Na, 6 Al, 146 Si, 3 P, 1 K, 6 Ca, 4 Fe,
147823 005 L1-S1(17)_pt1	Bio	O, Si, P	Ca, S, Mg, K, Cl	108 O, 1 Mg, 41 Si, 6 P, 2 S, 1 Cl, 1 K, 2 Ca,
147822 004 L1-N1(6)_pt5	Quartz	O, Si	Al, Ca	380 O, 3 Al, 187 Si, 1 Ca,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147822 004 L1-N1(7)_pt1	Quartz	O, Si	Fe, Al, Ca, Mg, Na, K	469 O, 3 Na, 3 Mg, 9 Al, 209 Si, 1 K, 17 Ca, 10 Fe,
147822 004 L1-N1(8)_pt1	Silicates	O, Si, Al	Fe, Mg, Na, K, Ca	307 O, 2 Na, 2 Mg, 13 Al, 140 Si, 2 K, 1 Ca, 3 Fe,
147822 004 L1-N1(8)_pt2	Quartz	O, Si		2 O, 1 Si,
147822 004 L1-N1(8)_pt3	Quartz	O, Si	Al, Na	271 O, 1 Na, 1 Al, 134 Si,
147822 004 L1-N1(9)_pt1	Silicates	O, Si, Al, Na, Ca	Fe, Mg, K	161 O, 9 Na, 1 Mg, 17 Al, 59 Si, 1 K, 7 Ca, 2 Fe,
147822 004 L1-N1(9)_pt2	Silicates	O, Si, Al, Na	Fe, Ca, Mg, K	108 O, 5 Na, 1 Mg, 12 Al, 40 Si, 1 K, 1 Ca, 4 Fe,
147822 004 L1-N1(9)_pt3	Quartz	O, Si	Al, Fe, K, Ca, Mg, Ti	407 O, 3 Mg, 11 Al, 182 Si, 4 K, 3 Ca, 1 Ti, 11 Fe,
147822 004 L1-N1(9)_pt4	Silicates	O, Si, Al, K	Ca, Fe, Mg, Na	169 O, 1 Na, 2 Mg, 32 Al, 53 Si, 9 K, 3 Ca, 3 Fe,
147822 004 L1-N1(9)_pt5	Silicates	O, Ca, Si	Al, Fe, Mg, Na, K	179 O, 2 Na, 2 Mg, 5 Al, 45 Si, 1 K, 73 Ca, 4 Fe,
147822 004 L1-N1(9)_pt6	Silicates	O, Si, Al	Fe, Mg, Na, K	128 O, 1 Na, 4 Mg, 10 Al, 50 Si, 1 K, 5 Fe,
147822 004 L1-N1(9)_pt7	Silicates	O, Si, Al, Ca, Fe	Mg, Mn, K	147 O, 2 Mg, 17 Al, 45 Si, 1 K, 14 Ca, 1 Mn, 8 Fe,
147822 004 L1-N1(9)_pt8	Silicates	O, Si, Al, Fe	K, Mg, Na, Ca	104 O, 1 Na, 2 Mg, 14 Al, 36 Si, 3 K, 1 Ca, 4 Fe,
147822 004 L1-N1(10)_pt1	Silicates	O, Si, Al	K, Fe, Ca, Na, Mg	213 O, 2 Na, 1 Mg, 18 Al, 87 Si, 7 K, 2 Ca, 3 Fe,
147822 004 L1-N1(10)_pt2	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K	54 O, 1 Na, 1 Mg, 6 Al, 18 Si, 1 K, 1 Ca, 3 Fe,
147822 004 L1-N1(10)_pt3	Quartz	O, Si	Al, K	418 O, 3 Al, 207 Si, 1 K,
147822 004 L1-N1(10)_pt4	Quartz	O, Si	Fe, Al, Ca, Mn	327 O, 1 Al, 160 Si, 1 Ca, 1 Mn, 2 Fe,
147822 004 L1-N1(10)_pt5	Silicates	O, Si, Ca, Al, Fe	Mg, Na, K, S	133 O, 1 Na, 1 Mg, 6 Al, 50 Si, 1 S, 1 K, 12 Ca, 5 Fe,
147822 004 L1-N1(11)_pt1	Quartz	O, Si	Al, Ca	214 O, 2 Al, 105 Si, 1 Ca,
147822 004 L1-N1(11)_pt2	Quartz	O, Si		2 O, 1 Si,
147822 004 L1-N1(12)_pt1	Quartz	O, Si	Al, Mg	323 O, 1 Mg, 2 Al, 160 Si,
147822 004 L1-N1(12)_pt2	Silicates	O, Ca, Si	Al, Fe, Mg	52 O, 1 Mg, 2 Al, 13 Si, 21 Ca, 1 Fe,
147822 004 L1-N1(12)_pt3	Quartz	O, Si	Na, Ca, Al	318 O, 3 Na, 1 Al, 157 Si, 1 Ca,
147822 004 L1-N1(12)_pt4	Silicates	O, Si, Ca, Al, Fe	Mg, K, Ti	160 O, 2 Mg, 8 Al, 45 Si, 1 K, 45 Ca, 1 Ti, 5 Fe,
147822 004 L1-N1(13)_pt1	Silicates	O, Si, Fe, Al, Na	Mg, Ca, K	182 O, 6 Na, 3 Mg, 13 Al, 62 Si, 1 K, 2 Ca, 19 Fe,
147822 004 L1-N1(13)_pt2	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K	163 O, 1 Na, 3 Mg, 14 Al, 58 Si, 1 K, 5 Ca, 11 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147822 004 L1-N1(14)_pt1	Silicates	O, Si, Al	Fe, Ca, Mg, K, Na	120 O, 1 Na, 2 Mg, 9 Al, 48 Si, 2 K, 2 Ca, 3 Fe,
147822 004 L1-N1(14)_pt2	Silicates	O, Si, Al	K, Na, Fe, Ca, Mg	232 O, 5 Na, 1 Mg, 31 Al, 87 Si, 6 K, 1 Ca, 3 Fe,
147822 004 L1-N1(14)_pt3	Quartz	O, Si	Fe, Al, Na, K	316 O, 3 Na, 4 Al, 149 Si, 1 K, 5 Fe,
147822 004 L1-N1(14)_pt4	Silicates	O, Si, Ca, Al	Fe, Na, K, Mg	121 O, 2 Na, 1 Mg, 6 Al, 50 Si, 1 K, 7 Ca, 2 Fe,
147822 004 L1-N1(14)_pt5	Quartz	O, Si		2 O, 1 Si,
147822 004 L1-N1(14)_pt6	Quartz	O, Si	Fe, Al, Ca, Mg, Mn	308 O, 1 Mg, 1 Al, 143 Si, 1 Ca, 1 Mn, 11 Fe,
147822 004 L1-N1(6)_pt5	Quartz	O, Si	Al, Ca	380 O, 3 Al, 187 Si, 1 Ca,
147822 004 L1-N1(7)_pt1	Quartz	O, Si	Fe, Al, Ca, Mg, Na, K	469 O, 3 Na, 3 Mg, 9 Al, 209 Si, 1 K, 17 Ca, 10 Fe,
147823 005 L1-S1(16)_pt2	Silicates	O, Si, Ca	Mg, Fe, Na	149 O, 1 Na, 2 Mg, 57 Si, 31 Ca, 1 Fe,
147823 005 L1-S1(16)_pt3	Quartz	O, Si	Ca	360 O, 179 Si, 1 Ca,
147822 004 L1-N1(15)_pt1	Bio?	O, Si	Na, Ca, S	152 O, 2 Na, 73 Si, 1 S, 1 Ca,
147822 004 L1-N1(15)_pt2	Silicates	O, Si, Al, Fe, K	Ca, Mg, Na	80 O, 1 Na, 1 Mg, 8 Al, 29 Si, 3 K, 1 Ca, 4 Fe,
147822 004 L1-N1(15)_pt3	Bio	O, Si	K, P, S	115 O, 53 Si, 2 P, 1 S, 2 K,
147822 004 L1-N1(16)_pt1	Bio	O, Ca, Si, Al, Fe	Na, Mg, K, S	164 O, 3 Na, 2 Mg, 6 Al, 45 Si, 1 S, 1 K, 50 Ca, 5 Fe,
147822 004 L1-N1(16)_pt2	Silicates	O, Si, Mg, Fe, Al	Ca, K	471 O, 28 Mg, 27 Al, 179 Si, 1 K, 2 Ca, 28 Fe,
147822 004 L1-N1(16)_pt3	Silicates	O, Si, Al, K	Fe, Mg, Na	92 O, 1 Na, 1 Mg, 15 Al, 32 Si, 5 K, 1 Fe,
147822 004 L1-N1(16)_pt4	Quartz	O, Si	Al, Fe, K, Mg	206 O, 1 Mg, 7 Al, 94 Si, 2 K, 3 Fe,
147822 004 L1-N1(16)_pt5	Silicates	O, Ca, Si, Al, Fe	Na, Mg, K	175 O, 3 Na, 2 Mg, 9 Al, 43 Si, 1 K, 61 Ca, 7 Fe,
147823 005 L1-S1(1)_pt1	Quartz	O, Si	Ca, Na, Cl	113 O, 1 Na, 55 Si, 1 Cl, 2 Ca,
147823 005 L1-S1(1)_pt2	Bio?	O, Si	P, Na, K, Ca, Mo	287 O, 2 Na, 137 Si, 3 P, 2 K, 1 Ca, 1 Mo,
147823 005 L1-S1(2)_pt1	Silicates	O, Si, Al	K, Fe, Mg, Na	126 O, 1 Na, 1 Mg, 15 Al, 49 Si, 3 K, 2 Fe,
147823 005 L1-S1(2)_pt2	Quartz	O, Si	Na, P, Cl, K, Ca, Mg, S	174 O, 3 Na, 1 Mg, 79 Si, 3 P, 1 S, 2 Cl, 2 K, 1 Ca,
147823 005 L1-S1(2)_pt3	Bio	O, Si	Na, P, K	228 O, 7 Na, 107 Si, 4 P, 1 K,
147823 005 L1-S1(2)_pt4	Bio	O, Si, K, P	S, Cl, Na, Mg, Al	525 O, 5 Na, 3 Mg, 1 Al, 205 Si, 26 P, 10 S, 8 Cl, 28 K,
147823 005 L1-S1(3)_pt1	Silicates	O, Si, Al, Fe	Na, Mg, Ca, K	90 O, 2 Na, 2 Mg, 12 Al, 31 Si, 1 K, 1 Ca, 5 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147823 005 L1-S1(3)_pt2	Bio	O, Si	P, K, Na, S, Cl	297 O, 3 Na, 135 Si, 7 P, 2 S, 1 Cl, 4 K,
147823 005 L1-S1(3)_pt3	Silicates	O, Si, Al	K, Fe, Na, Mg	176 O, 1 Na, 1 Mg, 12 Al, 76 Si, 3 K, 2 Fe,
147823 005 L1-S1(3)_pt4	Bio	O, Si, P	Na, K, Mg, S, Cl	235 O, 4 Na, 2 Mg, 99 Si, 10 P, 1 S, 1 Cl, 4 K,
147823 005 L1-S1(4)_pt1	Bio	O, Si	Na, K, P, Br	170 O, 6 Na, 80 Si, 2 P, 2 K, 1 Br,
147823 005 L1-S1(5)_pt1	Bio	O, Si, K, P	S, Cl, Mg	103 O, 1 Mg, 41 Si, 4 P, 2 S, 2 Cl, 5 K,
147823 005 L1-S1(5)_pt2	Quartz	O, Si	Na	246 O, 1 Na, 123 Si,
147823 005 L1-S1(6)_pt1	Silicates	O, Si, Al	Fe, Mg, Ca, Na, K	97 O, 1 Na, 2 Mg, 7 Al, 39 Si, 1 K, 1 Ca, 2 Fe,
147823 005 L1-S1(7)_pt1	Bio	O, Si	P, S, Na, K	112 O, 1 Na, 52 Si, 2 P, 1 S, 1 K,
147823 005 L1-S1(7)_pt2	Bio	O, Si, Al	Fe, Na, K, Mg, P	199 O, 3 Na, 2 Mg, 11 Al, 85 Si, 1 P, 2 K, 4 Fe,
147823 005 L1-S1(7)_pt3	Quartz	O, Si	Na, Al	526 O, 3 Na, 1 Al, 262 Si,
147823 005 L1-S1(7)_pt4	Silicates	O, Si, Al	Fe, Na, Mg, K, Ca, S	259 O, 4 Na, 3 Mg, 13 Al, 111 Si, 1 S, 3 K, 2 Ca, 5 Fe,
147823 005 L1-S1(8)_pt1	Bio	O, Si, Al, K	Na, Fe, Mg, Ti	125 O, 2 Na, 1 Mg, 18 Al, 44 Si, 4 K, 1 Ti, 2 Fe,
147823 005 L1-S1(8)_pt2	Quartz	O, Si	Al, K	26 O, 1 Al, 12 Si, 1 K,
147823 005 L1-S1(8)_pt3	Bio	O, Si	P, Na, K, S	230 O, 2 Na, 108 Si, 4 P, 1 S, 2 K,
147823 005 L1-S1(9)_pt1	Quartz	O, Si	Al, Na	84 O, 1 Na, 1 Al, 41 Si,
147823 005 L1-S1(9)_pt2	Bio	O, Si, Al, S	Na, Fe, Ca, Mg, K	137 O, 4 Na, 1 Mg, 5 Al, 53 Si, 5 S, 1 K, 2 Ca, 3 Fe,
147823 005 L1-S1(9)_pt3	Quartz	O, Si	Al, Na, Fe, Ca, Mg, K	373 O, 4 Na, 1 Mg, 8 Al, 177 Si, 1 K, 1 Ca, 2 Fe,
147823 005 L1-S1(9)_pt4	Silicates	O, Ca, Si	Al, Fe, Mn, Na, Mg	136 O, 2 Na, 1 Mg, 2 Al, 37 Si, 53 Ca, 2 Mn, 2 Fe,
147823 005 L1-S1(9)_pt5	Quartz	O, Si	Na	206 O, 1 Na, 103 Si,
147823 005 L1-S1(9)_pt6	Bio	O, Si	Na, Mg, Ca, Al, P	422 O, 7 Na, 2 Mg, 1 Al, 206 Si, 1 P, 1 Ca,
147823 005 L1-S1(10)_pt1	Silicates	O, Ca, Si	Mg, Al	81 O, 2 Mg, 1 Al, 13 Si, 51 Ca,
147823 005 L1-S1(11)_pt1	Bio	O, Si	P, K, Mg, S	205 O, 1 Mg, 94 Si, 5 P, 1 S, 3 K,
147823 005 L1-S1(12)_pt1	Bio	O, Si, P, K	Na, Mg, Mo, Cl	158 O, 2 Na, 2 Mg, 58 Si, 12 P, 1 Cl, 8 K, 1 Mo,
147823 005 L1-S1(12)_pt2	Bio	O, Si, S, Ca	Na, P, Al	235 O, 3 Na, 1 Al, 60 Si, 2 P, 28 S, 26 Ca,
147823 005 L1-S1(13)_pt1	Bio	O, Si, Ca, Fe, S	Na, Al, Mg, P	170 O, 3 Na, 1 Mg, 2 Al, 54 Si, 1 P, 6 S, 24 Ca, 6 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147823 005 L1-S1(13)_pt2	Silicates	O, Si, Ca	Al, Fe, Mg	146 O, 1 Mg, 4 Al, 55 Si, 26 Ca, 2 Fe,
147823 005 L1-S1(14)_pt1	Silicates	O, Si, Fe	Al, Na, Mg, P	153 O, 2 Na, 1 Mg, 3 Al, 61 Si, 1 P, 14 Fe,
147823 005 L1-S1(15)_pt1	Quartz	O, Si		2 O, 1 Si,
147823 005 L1-S1(16)_pt1	Silicates	O, Si, Fe	Na, Br, Ti	231O,3Na,100Si,Ti,18Fe,3Br,
147823 005 L1-S1(17)_pt2	Quartz	O, Si		2 O, 1 Si,
147823 005 L1-S1(18)_pt1	Bio	O, Si, P, Ca, S	Mg, K, Cl	33 O, 1 Mg, 6 Si, 5 P, 2 S, 1 Cl, 1 K, 2 Ca,
147 824 006 L1-N1 (1)_pt1	Bio	C,O, Si	Fe, Al, Mg	159 C, 816 O, 1 Mg, 2 Al, 244 Si, 3 Fe,
147 824 006 L1-N1 (1)_pt2	Bio	C, O, Si, Al, Fe	Na, K, Mg, Ca	55 C, 406 O, 7 Na, 2 Mg, 15 Al, 122 Si, 2 K, 1 Ca, 15 Fe,
147 824 006 L1-N1 (2)_pt1	Bio	O, C, Si, Fe, Al	Ca, Mg, Na, K	150 C, 634 O, 4 Na, 5 Mg, 17 Al, 93 Si, 1 K, 6 Ca, 73 Fe,
147 824 006 L1-N1 (2)_pt2	Bio	O, Si	Na, K, P, S	1133 C, 2383 O, 2 Na, 54 Si, 2 P, 1 S, 2 K,
147 824 006 L1-N1 (2)_pt3	Bio	O, Si	Fe, Al	64 C, 476 O, 1 Al, 168 Si, 6 Fe,
147 824 006 L1-N1 (2)_pt4	Bio	O, Si		1 C, 10 O, 4 Si,
147 824 006 L1-N1 (2)_pt5	Bio	O, Si	Al, Fe, Na, Ca, Mg, K	44 C, 269 O, 3 Na, 1 Mg, 7 Al, 80 Si, 1 K, 2 Ca, 3 Fe,
147 824 006 L1-N1 (3)_pt1	Bio	O, Si, Al	K, Fe, Na, Mg	40 C, 294 O, 1 Na, 1 Mg, 9 Al, 98 Si, 2 K, 1 Fe,
147 824 006 L1-N1 (3)_pt2	Bio	O, Si, Al, Na, Fe	Ca, K, Mg, P, S	33 C, 246 O, 8 Na, 2 Mg, 14 Al, 66 Si, 2 P, 1 S, 2 K, 4 Ca, 6 Fe,
147 824 006 L1-N1 (3)_pt3	Bio	O, Si	Al, Na, Ca	28 C, 250 O, 2 Na, 3 Al, 93 Si, 1 Ca,
147 824 006 L1-N1 (4)_pt1	Bio	O, Si	Al, Na, Ca, Ti, Fe, Mg, K	60 C, 780 O, 6 Na, 2 Mg, 9 Al, 312 Si, 1 K, 4 Ca, 4 Ti, 4 Fe,
147 824 006 L1-N1 (5)_pt1	Quartz	O, Si		1 C, 11 O, 4 Si,
147 824 006 L1-N1 (6)_pt1	Bio	O, Si	P, Na, K, S, Al	2706 C, 5934 O, 4 Na, 1 Al, 246 Si, 7 P, 3 S, 4 K,
147 824 006 L1-N1 (6)_pt2	Bio	O, Si	P, K, Na, S	386 C, 843 O, 1 Na, 28 Si, 3 P, 1 S, 2 K,
147 824 006 L1-N1 (6)_pt3	Bio	O, Si	P, S, K, Na	423 C, 937 O, 1 Na, 41 Si, 2 P, 1 S, 1 K,
147 824 006 L1-N1 (6)_pt4	Bio	O, Si	Na, P, K, S, Mg, Al	1914 C, 4012 O, 7 Na, 1 Mg, 1 Al, 79 Si, 6 P, 1 S, 2 K,
147 824 006 L1-N1 (6)_pt5	Bio	O, Si	Ca, Na	74 C, 312 O, 1 Na, 81 Si, 1 Ca,
147 824 006 L1-N1 (7)_pt1	Bio	O, Si	Na, Mg, Al	73 C, 597 O, 4 Na, 1 Mg, 1 Al, 224 Si,
147 824 006 L1-N1 (8)_pt1	Bio	O, Si, N	Na, P, K, S, Al	2506 C, 117 N, 5907 O, 6 Na, 1 Al, 288 Si, 6 P, 3 S, 4 K,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147 824 006 L1-N1 (8)_pt2	Bio	O, Si	Na, P, K	1571 C, 3441 O, 4 Na, 145 Si, 2 P, 1 K,
147 824 006 L1-N1 (8)_pt3		O, Si	Fe, Al	20 C, 170 O, 1 Al, 61 Si, 5 Fe,
147 824 006 L1-N1 (9)_pt1	Bio	O, Si	P, Na, K, S, Al	5589 C, 11963 O, 9 Na, 1 Al, 360 Si, 17 P, 6 S, 6 K,
147 824 006 L1-N1 (9)_pt2	Bio	O, Si	P, Na, K, S	1319 C, 2839 O, 3 Na, 94 Si, 3 P, 1 S, 1 K,
147 824 006 L1-N1 (10)_pt1	Bio	O, Si, Al, Fe, Ca	Mg, Na, K	37 C, 153 O, 1 Na, 2 Mg, 13 Al, 23 Si, 1 K, 3 Ca, 5 Fe,
147 825 007 L2-S1 (1)_pt1	Bio	O, Si	P, K, Na, S, Cl	3616 C, 7821 O, 8 Na, 259 Si, 19 P, 5 S, 1 Cl, 12 K,
147 825 007 L2-S1 (1)_pt2	Bio	O, Si, Al, Na	Fe, Ca, Mg, K	132 C, 695 O, 22 Na, 3 Mg, 26 Al, 184 Si, 1 K, 4 Ca, 4 Fe,
147 825 007 L2-S1 (2)_pt1	Bio	O, Si	Na, Ca, P, Mg, Al, S, K	8584 C, 17597 O, 7 Na, 3 Mg, 3 Al, 200 Si, 4 P, 2 S, 1 K, 5 Ca,
147 825 007 L2-S1 (2)_pt2	Bio	O, Si	P, K, Mg, Ca, S	1688 C, 3567 O, 2 Mg, 82 Si, 7 P, 1 S, 4 K, 1 Ca,
147 825 007 L2-S1 (2)_pt3	Carbonates	O, Ca, Mg,	Al	68 C, 192 O, 15 Mg, 1 Al, 11 Si, 17 Ca,
147 825 007 L2-S1 (2)_pt4	Bio	O, Si, P, K	S, Mg	1768 C, 3640 O, 1 Mg, 43 Si, 5 P, 2 S, 4 K,
147 825 007 L2-S1 (2)_pt5	Bio	O, Si	P, S, Na, K, Ca	2911 C, 6001 O, 3 Na, 78 Si, 4 P, 4 S, 2 K, 1 Ca,
147 825 007 L2-S1 (3)_pt1	Bio	O, Si, P	K, Mg, Mo	1693 C, 3561 O, 2 Mg, 74 Si, 8 P, 4 K, 1 Mo,
147 825 007 L2-S1 (3)_pt2	Bio	O, Si	Na, Ca, Mg, Al, P, S	3398 C, 6970 O, 3 Na, 1 Mg, 1 Al, 81 Si, 1 P, 1 S, 2 Ca,
147 825 007 L2-S1 (3)_pt3	Bio	O, Si	Na, P, K, S, Br	1688 C, 3556 O, 5 Na, 79 Si, 5 P, 2 S, 3 K, 1 Br,
147 825 007 L2-S1 (3)_pt4	Quartz	O, Si	Al, Fe, Na, Mg, Ca, K	75 C,419 O,2 Na,2 Mg, 10 Al,119Si,1K,1Ca,7 Fe
147 825 007 L2-S1 (3)_pt5	Quartz	O, Si	Na, Ca, Mg, Al, Fe	30 C, 233 O, 2 Na, 1 Mg, 1 Al, 82 Si, 2 Ca, 1 Fe,
147 825 007 L2-S1 (4)_pt1	Silicates	O, Si, Al, Fe, Na, Ca	Mg, K, Mn, P	130 C, 533 O, 14 Na, 5 Mg, 34 Al, 87 Si, 1 P, 3 K, 10 Ca, 1 Mn, 14 Fe,
147 825 007 L2-S1 (4)_pt2	Quartz	O, Si	Na, Al	2221 C, 5675 O, 6 Na, 1 Al, 615 Si,
147 825 007 L2-S1 (5)_pt1	Quartz	O, Si	S, P, Na, K	1149 C, 2528 O, 1 Na, 106 Si, 2 P, 3 S, 1 K,
147 825 007 L2-S1 (6)_pt1	Quartz	O, Si	Na, Mg, Ca, Al	64 C, 669 O, 8 Na, 2 Mg, 1 Al, 266 Si, 2 Ca,
147 825 007 L2-S1 (6)_pt2	Silicates	O, Si, Al	Fe, K, Ca, Mg, Na, S	40 C, 271 O, 2 Na, 3 Mg, 17 Al, 72 Si, 1 S, 4 K, 3 Ca, 5 Fe,
147 825 007 L2-S1 (6)_pt3	Quartz	O, Si	Na, Ca	101 C, 527 O, 5 Na, 160 Si, 1 Ca,
147 825 007 L2-S1 (7)_pt1	Bio	O, Si	Na, S, P, Ca, K, Cl, Mg	2388 C, 5206 O, 4 Na, 1 Mg, 202 Si, 3 P, 4 S, 1 Cl, 2 K, 3 Ca,
147 825 007 L2-S1 (8)_pt1	Quartz	O, Si	Na, Al	1259 C, 2918 O, 2 Na, 1 Al, 198 Si,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147 825 007 L2-S1 (9)_pt1	Bio	O, Si	Na, S, K, P	1545 C, 3402 O, 2 Na, 151 Si, 1 P, 2 S, 1 K,
147 826 008 L2-N1 (1)_pt1	Quartz	O, Si	Na, Mg, Al	183 C, 1374 O, 10 Na, 2 Mg, 1 Al, 500 Si,
147 826 008 L2-N1 (1)_pt2	Bio	O, Si, P	Na, K, S, Mg	2681 C, 5477 O, 3 Na, 1 Mg, 42 Si, 8 P, 2 S, 3 K,
147 826 008 L2-N1 (1)_pt3	Bio	O, Si, Al	Na, Fe, Mg, K, P, Ca, Mo	65 C, 390 O, 8 Na, 4 Mg, 25 Al, 96 Si, 2 P, 3 K, 1 Ca, 7 Fe, 1 Mo,
147 826 008 L2-N1 (2)_pt1	Bio	O, Si	Na, Ca, P, S, Mg	5223 C, 10874 O, 12 Na, 1 Mg, 197 Si, 5 P, 3 S, 6 Ca,
147 826 008 L2-N1 (2)_pt2	Bio	O, Si, Na	P, S, Ca, Al	1473 C, 3030 O, 6 Na, 1 Al, 32 Si, 3 P, 2 S, 1 Ca,
147 826 008 L2-N1 (3)_pt1	Quartz	O, Si	Ca, Al	145 C, 1358 O, 1 Al, 532 Si, 3 Ca,
147 826 008 L2-N1 (4)_pt1	Quartz	O, Si	Na, Ba	231 C, 1640 O, 6 Na, 587 Si, 1 Ba,
147 826 008 L2-N1 (5)_pt1	Bio	O, Si, Al	Fe, Na, Mg, K, P, Ca, Ti	433 C, 1419 O, 11 Na, 6 Mg, 33 Al, 226 Si, 3 P, 4 K, 2 Ca, 1 Ti, 16 Fe,
147 826 008 L2-N1 (5)_pt2	Bio	O, Si, Ca, Al, Na	Fe, S, Mg, K, P	1293 C, 2704 O, 4 Na, 1 Mg, 4 Al, 47 Si, 1 P, 2 S, 1 K, 5 Ca, 2 Fe,
147 826 008 L2-N1 (6)_pt1	Carbonates	O, S, Ca, Si	Al	89 C, 543 O, 1 Al, 26 Si, 81 S, 69 Ca,
147 826 008 L2-N1 (6)_pt2	Bio	O, Si	Na, P, S, Na, K	1546 C, 3426 O, 6 Na, 1 Mg, 158 Si, 3 P, 2 S, 1 K,
147 826 008 L2-N1 (6)_pt3	Bio	O, Si, Al	Fe, Na, Mg, Ca, K, S	452 C, 1097 O, 3 Na, 3 Mg, 11 Al, 79 Si, 1 S, 1 K, 2 Ca, 5 Fe,
147 826 008 L2-N1 (7)_pt1	Bio	O, Si	P, Na, K, S, Al	2543 C, 5844 O, 6 Na, 1 Al, 361 Si, 8 P, 4 S, 5 K,
147 826 008 L2-N1 (7)_pt2	Bio	O, Si, Fe, Al	Na, Mg, Ca, K	66 C, 348 O, 3 Na, 2 Mg, 10 Al, 71 Si, 1 K, 1 Ca, 36 Fe,
147 826 008 L2-N1 (7)_pt3	Bio	O, Si, Ca	Al, Fe, Mg, S	436 C, 1153 O, 1 Mg, 2 Al, 108 Si, 1 S, 56 Ca, 1 Fe,
147 826 008 L2-N1 (8)_pt1	Bio	O, Si	P, K, Na, S	929 C, 2020 O, 1 Na, 76 Si, 3 P, 1 S, 2 K,
147 826 008 L2-N1 (9)_pt1	Bio	O, P, Si, Na, S, K	Mg	1806 C, 3658 O, 6 Na, 1 Mg, 6 Si, 9 P, 3 S, 3 K,
147537 009 L1-S PM_{10} (1)_pt1	Quartz	O, Si	Na, Al	470 O, 4 Na, 1 Al, 233 Si
147537 009 L1-S PM_{10} (2)_pt1	Silicates	O, Si, Al, Fe	Ca, Mg, Na, K	139 O, 3 Na, 3 Mg, 10 Al, 48 Si, 1 K, 8 Ca, 10 Fe,
147537 009 L1-S PM_{10} (2)_pt2	Silicates	O, Si, Al	Fe, Mg, Ca, Na, K	331 O, 2 Na, 3 Mg, 12 Al, 151 Si, 1 K, 2 Ca, 4 Fe,
147537 009 L1-S PM_{10} (3)_pt1	Bio	O, Si, Fe, Ti, Al	Na, Ca, Mg, K	228 O, 2 Na, 2 Mg, 7 Al, 80 Si, 1 K, 2 Ca, 9 Ti, 22 Fe,
147537 009 L1-S PM_{10} (3)_pt2	Silicates	O, Si, Al, Ca, Fe	Mg, K	220 O, 8 Mg, 22 Al, 76 Si, 1 K, 11 Ca, 11 Fe,
147537 009 L1-S PM_{10} (3)_pt3	Silicates	O, Si, Al, Na	F, K, Ca, Mg	295 O, 4 F, 9 Na, 1 Mg, 15 Al, 132 Si, 3 K, 2 Ca,
147537 009 L1-S PM_{10} (4)_pt1	Silicates	O, Si, Al, Na	Fe, Ca, Mg, K, P	358 O, 20 Na, 5 Mg, 34 Al, 137 Si, 1 P, 5 K, 5 Ca, 7 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147537 009 L1-S PM_{10} (4)_pt2	Silicates	O, Si	Al, Ca, Na, Mg, Fe, S	151 O, 2 Na, 1 Mg, 6 Al, 67 Si, 1 S, 6 Ca, 1 Fe,
147537 009 L1-S PM_{10} (5)_pt1	Silicates	O, Si, Fe, Al, Ca, Na	Mg, K, Ti	386 O, 14 Na, 7 Mg, 31 Al, 122 Si, 4 K, 19 Ca, 1 Ti, 39 Fe,
147537 009 L1-S PM_{10} (5)_pt2	Silicates	O, Ca, Si, Al	Mg, Na, Fe, K, S	196 O, 4 Na, 5 Mg, 10 Al, 38 Si, 1 S, 1 K, 93 Ca, 4 Fe,
147537 009 L1-S PM_{10} (5)_pt3	Quartz	O, Si	Na, Ca, Al	404 O, 3 Na, 1 Al, 199 Si, 3 Ca,
147537 009 L1-S PM_{10} (5)_pt4	Quartz	O, Si	Al, Fe	57 O, 1 Al, 27 Si, 1 Fe,
147537 009 L1-S PM_{10} (6)_pt1	Silicates	O, Si, Al, Fe	Mg, Ca, K, Na, S	171 O, 2 Na, 3 Mg, 15 Al, 59 Si, 1 S, 2 K, 2 Ca, 15 Fe,
147537 009 L1-S PM_{10} (6)_pt2	Silicates	O, Si, Al, Fe, Mg	Na, K, Ca, Ti, Ba	455 O, 8 Na, 10 Mg, 28 Al, 187 Si, 7 K, 4 Ca, 1 Ti, 11 Fe, 1 Ba,
147537 009 L1-S PM 10(7)_pt1	Silicates	O, Si, Al	K, Na, Mg, Fe	123 O, 1 Na, 1 Mg, 15 Al, 48 Si, 5 K, 1 Fe,
147537 009 L1-S PM_{10} (8)_pt1	Quartz	O, Si	Al	149 O, 1 Al, 74 Si,
147537 009 L1-S PM_{10} (8)_pt2	Quartz	O, Si	Na, Al	172 O, 2 Na, 1 Al, 85 Si,
147537 009 L1-S PM_{10} (9)_pt1	Silicates	O, Si, Fe, Al	Mg, K, Na, Ca	269 O, 2 Na, 5 Mg, 11 Al, 110 Si, 3 K, 1 Ca, 16 Fe,
147537 009 L1-S PM_{10} (9)_pt2-No Data.				No Data
147538 010 L1-S $PM_{2.5}$ (1)_pt1	Bio	O, Si,C	Na	48 C, 238 O, 1 Na, 70 Si,
147538 010 L1-S $PM_{2.5}$ (2)_pt1	Bio	O, Si,C	Na, Al	762 C, 3396 O, 10 Na, 1 Al, 933 Si,
147538 010 L1-S $PM_{2.5}$ (2)_pt2	Bio	O, Si,C	Na	50 C, 218 O, 1 Na, 58 Si,
147538 010 L1-S $PM_{2.5}$ (3)_pt1	Bio	O, Si, Na,C	Ca, Mg, Al	71 C, 277 O, 8 Na, 1 Mg, 1 Al, 63 Si, 2 Ca,
147538 010 L1-S $PM_{2.5}$ (3)_pt2	Quartz	O, Si, C		1 C, 5 O, 1 Si,
147538 010 L1-S $PM_{2.5}$ (3)_pt3		O, Si,C	Na, Al, Ca, Mg	199 C, 636 O, 5 Na, 1 Mg, 2 Al, 115 Si, 1 Ca,
147538 010 L1-S $PM_{2.5}$ (3)_pt4	Quartz	O, Si		1 C, 7 O, 3 Si,
147538 010 L1-S $PM_{2.5}$ (3)_pt5	Bio	O, Si	Na, Ca	307 C, 1114 O, 4 Na, 248 Si, 1 Ca,
147538 010 L1-S $PM_{2.5}$ (4)_pt1	Bio	O, Si	Fe, Al, Na	69 C, 401 O, 1 Na, 1 Al, 124 Si, 8 Fe,
147538 010 L1-S $PM_{2.5}$ (4)_pt2	Bio	O, Si	Na	192 C, 485 O, 1 Na, 50 Si,
147538 010 L1-S $PM_{2.5}$ (5)_pt1	Bio	O, Si	Na, Ca, Al	343 C, 1461 O, 4 Na, 1 Al, 384 Si, 4 Ca,
147538 010 L1-S $PM_{2.5}$ (5)_pt2	Bio	O, Si	Na, Ca, Al	495 C, 1756 O, 7 Na, 1 Al, 380 Si, 2 Ca,
147538 010 L1-S $PM_{2.5}$ (5)_pt3	Bio	O, Si	Na, Al	25 C, 91 O, 2 Na, 1 Al, 19 Si,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147538 010 L1-S $PM_{2.5}$ (6)_pt1	Bio	O, Si	Na, Al, Fe, Mg, Ca	120 C, 396 O, 5 Na, 3 Mg, 5 Al, 68 Si, 1 Ca, 4 Fe,
147538 010 L1-S $PM_{2.5}$ (6)_pt2	Bio	O, Si	Na	23 C, 182 O, 1 Na, 68 Si,
147538 010 L1-S $PM_{2.5}$ (7)_pt1	Bio	O, Si, Al, Fe	Ti, Mg, Na, K, P, S	268 C, 786 O, 3 Na, 4 Mg, 14 Al, 91 Si, 2 P, 1 S, 2 K, 9 Ti, 10 Fe,
147538 010 L1-S $PM_{2.5}$ (7)_pt2	Bio	O, Si, Al, Fe	Mg, Na, K	185 C, 562 O, 4 Na, 7 Mg, 12 Al, 75 Si, 1 K, 9 Fe,
147538 010 L1-S $PM_{2.5}$ (8)_pt1	Bio	O, Si	Na, Al	611 C, 2119 O, 8 Na, 1 Al, 446 Si,
147538 010 L1-S $PM_{2.5}$ (9)_pt1	Bio	O, Si, Al	Na, Fe, K, Mg, Ca	239 C, 779 O, 5 Na, 4 Mg, 10 Al, 135 Si, 4 K, 1 Ca, 4 Fe,
147538 010 L1-S $PM_{2.5}$(9)_pt2	Bio	O, Si	Na. Ca	309 C, 1113 O, 7 Na, 246 Si, 1 Ca,
147539 011 L1-N PM_{10} (1)_pt1	Quartz	O, Si		2 O, 1 Si,
147539 011 L1-N PM_{10} (2)_pt1	Silicates	O, Si, Al	Na, Fe, Mg, Ca, K	215 O, 4 Na, 1 Mg, 11 Al, 96 Si, 1 K, 1 Ca, 2 Fe,
147539 011 L1-N PM_{10} (3)_pt1	Silicates	O, Si, Al	Fe,Ca, Mg, K	54 O, 1 Mg, 8 Al, 19 Si, 1 K, 1 Ca, 2 Fe,
147539 011 L1-N PM_{10} (4)_pt1	Silicates	O, Si, Al, Fe	Ca, Na, K, Mg	184 O, 3 Na, 1 Mg, 11 Al, 74 Si, 1 K, 4 Ca, 8 Fe,
147539 011 L1-N PM_{10} (4)_pt2-No Data.				No Data
147539 011 L1-N PM_{10} (5)_pt1	silicates	O, Si, Al	Fe, Mg, Na, K, Ca	295 O, 2 Na, 6 Mg, 13 Al, 129 Si, 2 K, 1 Ca, 6 Fe,
147539 011 L1-N PM_{10} (5)_pt2-No Data.				No Data
147539 011 L1-N PM 10(6)_pt1	Quartz	O, Si		2 O, 1 Si,
147539 011 L1-N PM 10(7)_pt1	Silicates	O, Si, Fe	Al, Mg, Ca, K	491 O, 4 Mg, 8 Al, 157 Si, 1 K, 4 Ca, 105 Fe,
147537 009 L1-S PM 10(8)_pt1	Quartz	O, Si	Al	149 O, 1 Al, 74 Si,
147537 009 L1-S PM 10(8)_pt2	Quartz	O, Si	Na, Al	172 O, 2 Na, 1 Al, 85 Si,
147540 012 L1-N PM_{10} (1)_pt1	Bio	O, Si	Fe, Ca, Na, Al, Mg	72 C, 455 O, 3 Na, 1 Mg, 2 Al, 150 Si, 3 Ca, 3 Fe,
147540 012 L1-N PM_{10} (2)_pt1	Bio	O, Si	Na, Mg, Al	338 C, 1459 O, 8 Na, 2 Mg, 1 Al, 388 Si,
147540 012 L1-N PM_{10} (3)_pt1	Bio	O, Si, Ti, Fe	Na, Ca, Mg, Al	112 C, 421 O, 1 Na, 1 Mg, 1 Al, 69 Si, 1 Ca, 17 Ti, 13 Fe,
147540 012 L1-N PM_{10} (4)_pt1	Bio	O, Si	Ti, Fe, Al, Na	143 C, 482 O, 1 Na, 1 Al, 95 Si, 1 Ti, 1 Fe,
147540 012 L1-N PM_{10} (5)_pt1	Bio	O,Si	Fe, Na	47 C, 242 O, 1 Na, 72 Si, 2 Fe,
147541 013 L2-S PM_{10} (1)_pt1	Bio	O, Si	Na, Ca, Mg, Al	92 C, 517 O, 7 Na, 1 Mg, 1 Al, 163 Si, 1 Ca,
147541 013 L2-S PM_{10} (1)_pt2	Bio	O, Si	Fe, Na, Al, Ca, Mg	202 C, 640 O, 3 Na, 1 Mg, 2 Al, 111 Si, 1 Ca, 4 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147541 013 L2-S PM_{10} (2)_pt1	Bio	O, Si, S	Al, Na, Ca, Fe, Mg	2600 C, 5436 O, 4 Na, 1 Mg, 7 Al, 68 Si, 26 S, 4 Ca, 2 Fe,
147541 013 L2-Spm10(3)_pt1	Bio	O, Si, Al, Ca, Mg, Fe, K	Na, Ti	1303 C, 3259 O, 6 Na, 18 Mg, 70 Al, 225 Si, 14 K, 40 Ca, 1 Ti, 17 Fe,
147541 013 L2-S PM_{10} (3)_pt2	Bio	O, Si	Na, Mg, Al	231 C, 1240 O, 10 Na, 1 Mg, 1 Al, 385 Si,
147541 013 L2-S PM_{10} (3)_pt3	Bio	O, Si, Al	K, Fe, Ca, Mg, Na, Ti, P	384 C, 1113 O, 3 Na, 3 Mg, 53 Al, 120 Si, 1 P, 6 K, 5 Ca, 1 Ti, 5 Fe,
147541 013 L2-S PM_{10} (4)_pt1	Bio	O, Ca, Si	Al, Fe, Mg, K	1004 C, 2295 O, 3 Mg, 8 Al, 80 Si, 1 K, 105 Ca, 5 Fe,
147541 013 L2-S PM_{10} (5)_pt1	Biogenic	C, O, Fe, Si	Na, Al	46 C, 217 O, 1 Na, 1 Al, 28 Si, 43 Fe,
147541 013 L2-S PM_{10} (5)_pt2	Biogenic	C,O, Si, Al	Na, K, Mg, Fe, Ca, P	185 C, 682 O, 6 Na, 4 Mg, 36 Al, 118 Si, 1 P, 5 K, 3 Ca, 4 Fe,
147541 013 L2-S PM_{10} (6)_pt1	Biogenic	C,O, Si	Na, Ca, Al	284 C, 1045 O, 7 Na, 1 Al, 235 Si, 2 Ca,
147542 014 L2-S $PM_{2.5}$ (1)_pt1	Biogenic	C,O, Si	Na, S, Al	2569 C, 5859 O, 13 Na, 1 Al, 354 Si, 2 S,
147542 014 L2-S $PM_{2.5}$ (2)_pt1	Biogenic	C,O. Si	Na	72 C, 311 O, 1 Na, 83 Si,
147542 014 L2-S $PM_{2.5}$ (3)_pt1	Biogenic	C,O, Si	Na	84 C, 318 O, 1 Na, 75 Si,
147542 014 L2-S $PM_{2.5}$ (4)_pt1	Biogenic	C,O, Si, Na	Ca, Mg, Al, K, Mo	399 C, 1570 O, 31 Na, 7 Mg, 5 Al, 366 Si, 1 K, 9 Ca, 1 Mo,
147543 015 L2-S PM_{10} (1)_pt1	Biogenic	C,O, Si, Al	Na, K, Mg, Ca, Fe	294 C, 932 O, 6 Na, 1 Mg, 10 Al, 160 Si, 2 K, 1 Ca, 1 Fe,
147543 015 L2-S PM_{10} (2)_pt1	Biogenic	C,O, Si, Al, Ca, Fe	Mg, P, K, S, Cl, Ti	851 C, 2097 O, 6 Mg, 60 Al, 124 Si, 4 P, 2 S, 1 Cl, 3 K, 15 Ca, 1 Ti, 12 Fe,
147543 015 L2-S PM_{10} (2)_pt2	Biogenic	C,O, Si,	Al, Na, Mg, Fe, K	116 C, 741 O, 3 Na, 2 Mg, 4 Al, 248 Si, 1 K, 2 Fe,
147543 015 L2-S PM_{10} (3)_pt1	Quartz	O, Si		1 C, 5 O, 1 Si,
147543 015 L2-S PM_{10} (3)_pt2	Biogenic	O, Si	Na	29 C, 178 O, 1 Na, 60 Si,
147543 015 L2-S PM_{10} (4)_pt1	Biogenic	C,O, Si, Ca, Al, Fe	Mg, K, Na, Ba, P, S	241 C, 773 O, 1 Na, 3 Mg, 12 Al, 102 Si, 1 P, 1 S, 2 K, 45 Ca, 9 Fe, 1 Ba,
147543 015 L2-S PM_{10} (5)_pt1	Biogenic	C,O, Si, Al	Na, Ca, S, Mg, K, Fe, P	119 C, 352 O, 2 Na, 1 Mg, 6 Al, 46 Si, 1 P, 2 S, 1 K, 2 Ca, 1 Fe,
147543 015 L2-S PM_{10} (6)_pt1	Biogenic	C,O, Si, Al, Fe, Ca, Mg	K, Na, Ba, S	369 C, 1033 O, 4 Na, 8 Mg, 34 Al, 100 Si, 1 S, 5 K, 9 Ca, 13 Fe, 1 Ba,
147543 015 L2-S PM_{10} (6)_pt2	Biogenic	C,O, Si, Al	Na, Ca, Fe, Mg, K	154 C,417O,2Na,1 Mg, 7 Al, 45 Si,1 K, 2 Ca, 2 Fe,
147543 015 L2-S PM_{10} (7)_pt1	Bio	O, Si, Al	Ca, Mg, Na, K, Fe	104 C, 331 O, 1 Na, 2 Mg, 21 Al, 41 Si, 1 K, 3 Ca, 1 Fe,
147543 015 L2-S PM_{10}(8)_pt1	Bio	O, Si, Al	K, Na, Fe, Mg	90 C, 308 O, 2 Na, 1 Mg, 19 Al, 47 Si, 3 K, 2 Fe,

B1. Particle Matter identification (Continued).

SEM ID Number	Mineral Group	Major elements	Minor elements	Formulas from SEM data
147544 016 L2-N $PM_{2.5}$ (1)_pt1	Bio	O, Si	Na, Al, Ca	188 C, 987 O, 3 Na, 2 Al, 303 Si, 1 Ca,
147544 016 L2-N $PM_{2.5}$ (2)_pt1	Bio	O, Si, Fe, Al	Na, Mg, Ca, P, K, S	163 C, 653 O, 6 Na, 3 Mg, 9 Al, 136 Si, 2 P, 1 S, 1 K, 2 Ca, 16 Fe,
147544 016 L2-N $PM_{2.5}$ (3)_pt1	Bio	O, Si	Al, Na, K, Mg, Ca, Mo	303 C, 1741 O, 7 Na, 3 Mg, 13 Al, 552 Si, 5 K, 2 Ca, 1 Mo,
147544 016 L2-N $PM_{2.5}$ (4)_pt1	Bio	O, Si, Fe, Al	Mg, Na, Ca, K	676 C, 1925 O, 3 Na, 5 Mg, 38 Al, 221 Si, 1 K, 3 Ca, 42 Fe,
147544 016 L2-N $PM_{2.5}$ (5)_pt1	Quartz	O, Si	Na, S	154 C, 643 O, 3 Na, 165 Si, 1 S,
147544 016 L2-N $PM_{2.5}$ (6)_pt1	Bio	O, Si	P, Ca, Na, Mg	92 C, 551 O, 2 Na, 1 Mg, 175 Si, 5 P, 3 Ca,
147544 016 L2-N $PM_{2.5}$ (7)_pt1	Quartz	O, Si		1 C, 6 O, 2 Si,
147544 016 L2-N $PM_{2.5}$ (8)_pt1	Bio	O, Si, Fe, Al	S, Na, K, Ca, Mg, P	49 C, 202 O, 2 Na, 1 Mg, 5 Al, 35 Si, 1 P, 3 S, 2 K, 1 Ca, 7 Fe,
147544 016 L2-N $PM_{2.5}$ (9)_pt1	Silicates	O, Si, Fe	Na, Al	386 C, 2361 O, 11 Na, 1 Al, 736 Si, 73 Fe,
147544 016 L2-N $PM_{2.5}$ (10)_pt1	Bio	O, Si, Fe	Na, P, Mg, Al, Ca, Mn, S	188 C, 820 O, 6 Na, 2 Mg, 2 Al, 190 Si, 3 P, 1 S, 2 Ca, 2 Mn, 30 Fe,
147544 016 L2-N $PM_{2.5}$ (11)_pt1	Bio	O, Si, Mg, Fe	Na, Ca, Al, P, S	222 C, 756 O, 3 Na, 26 Mg, 1 Al, 125 Si, 1 P, 1 S, 1 Ca, 17 Fe,
147544 016 L2-N $PM_{2.5}$(12)_pt1	Bio	O, Si, Fe, Al	Na, Ca, Mg, P, K, S	229 C, 671 O, 5 Na, 2 Mg, 8 Al, 86 Si, 2 P, 1 S, 1 K, 3 Ca, 9 Fe,
147 827 017 (1)_pt1		O, Si	Al, Na, Ca, K, Mg, K	
147 827 017 (2)_pt1	Bio	O, Si, Al	Na, Fe, Ca, Mg, K	49 C, 408 O, 3 Na, 1 Mg, 17 Al, 137 Si, 1 K, 1 Ca, 3 Fe,

APPENDIX C

C1. Particle size and morphology of the particles (calculated using ImageJ software).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147819 001 L1-S3 (2)	1	1375.986	sub spherical	41
	2		same particle	
147819 001 L1-S3	1	564.777	sub spherical	26
147819 001 L1-S3 (1)	3	58.302	irregular	8
	4	23.153	irregular	5
	5	76.155	irregular	9
	1	121.903	irregular	12
	2	15.621	sub spherical	4
147819 001 L1-S3 (2)	3	2.583	sub spherical	1
	2	2.009	irregular	1
	4	91.548	irregular	10
	1	9.184	sub oval	3
147819 001 L1-S3 (3)	5	7.175	sub spherical	3
	1	13.201	sub spherical	4
	3	464.63	oval	24
	4	10.618	sub spherical	3
	2	6.888	sub spherical	2
147819 001 L1-S3 (4)	3	10.044	sub spherical	3
	1	10.618	sub spherical	3
	4	29.56	sub spherical	6
	2	18.654	sub spherical	4
147819 001 L1-S3 (5)	4	39.891	sub spherical	7
	5	1176.641	sub spherical	38
	1	17.506	sub angular	4
	2	63.998	oval	9
	3	15.21	spherical	4
147820 002 L1-S2 (1)	1	108.19	oval	11
	4	21.578	spherical	5
	3	55.744	spherical	8
	2	74.325	oval	9
147820 002 L1-S2 (2)	4	30.569	sub spherical	6
	2	18.281	sub spherical	4
	1	7.492	sub spherical	3
	3	22.477	sub spherical	5
147820 002 L1-S2 (3)	1	9.89	spherical	3
	4	19.181	sub angular	4

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147820 002 L1-S2 (3)	5	5.095	sub spherical	2
	3	16.783	sub spherical	4
	2	43.156	oval	7
147820 002 L1-S2 (4)	1	23.676	sub spherical	5
	2	91.407	oval	10
147820 002 L1-S2 (5)	1	22.178	sub spherical	5
	3	29.071	sub spherical	6
	2	17.682	sub spherical	4
147820 002 L1-S2 (6)	2	14.985	sub spherical	4
	3	29.071	sub spherical	6
	1	48.551	sub spherical	7
147820 002 L1-S2 (7)	2	13.486	oval	4
	3	114.484	spherical	12
	1	32.367	spherical	6
147820 002 L1-S2 (8)	2	13.187	spherical	4
	1	39.26	oval	7
147820 002 L1-S2 (9)	5	29.37	sub spherical	6
	4	289.207	sub angular	19
	3	8.092	sub spherical	3
	2	4.196	spherical	2
	6	41.358	spherical	7
	1	41.358	angular	7
147820 002 L1-S2 (10)	1	41.658	spherical	7
147820 002 L1-S2 (11)	1	224.473	angular	16
	3	7.792	angular	3
	2	55.444	sub angular	8
	4	59.939	sub oval	8
	5	62.637	oval	8
147820 002 L1-S2 (12)	1	30.869	oval	6
	4	21.278	sub spherical	5
	3	12.887	spherical	4
	2	23.376	sub angular	5
	3	27.572	sub spherical	5
	5	32.967	oval	6
147820 002 L1-S2 (13)	1	22.477	angular	5
	3	57.542	sub angular	8

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147820 002 L1-S2 (13)	2	12.587	sub spherical	4
	4	12.887	oval	4
147820 002 L1-S2 (14)	3	26.673	oval	5
	2	29.67	sub spherical	6
	1	61.737	oval	8
147820 002 L1-S2 (15)	4	10.19	spherical	3
	5	5.395	spherical	2
	1	22.477	sub spherical	5
	3	4.795	spherical	2
	2	24.875	oval	6
147820 002 L1-S2 (16)	1	28.471	sub spherical	6
	5	39.86	sub spherical	7
	4	24.275	oval	6
	2	6.893	spherical	3
	3	14.985	oval	4
147820 002 L1-S2 (17)	2	14.985	spherical	4
	3	354.241	irregular	21
147820 002 L1-S2 (18)	4	83.915	sub spherical	10
	3	9.59	sub spherical	3
	5	4.795	oval	2
	1	64.435	sub spherical	9
	2	52.147	spherical	8
147821 003 L1-S1 (1)	2	274.822	irregular	19
	7	37.162	sub spherical	7
	8	26.973	oval	6
	5	24.275	sub spherical	6
	6	12.887	spherical	4
	4	6.593	sub spherical	3
	1	51.248	irregular	8
	3	36.263	irregular	7
	19	9.89	sub spherical	4
	10	116.282	irregular	12
147821 003 L1-S1 (2)	2	19.78	sub spherical	5
	1	4.795	sub spherical	2
	3	21.578	sub spherical	5
	4	18.581	sub angular	5

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147821 003 L1-S1 (3)	1	72.527	sub spherical	10
147821 003 L1-S1 (4)	3	29.67	spherical	6
	1	101.897	sub prismatic	11
	2	29.67	sub spherical	6
147821 003 L1-S1 (5)	1	29.67	sub spherical	6
	2	6.294	sub spherical	3
	5	14.385	irregular	4
	4	15.884	sub spherical	4
	3	18.881	irregular	5
147821 003 L1-S1 (6)	5	186.111	irregular	15
	1	20.08	spherical	5
	2	102.796	sub spherical	11
	4	88.71	irregular	11
	3	20.979	sub oval	5
147821 003 L1-S1 (7)	3	36.563	irregular	7
	1	142.955	sub spherical	13
	2	78.82	irregular	10
147821 003 L1-S1 (8)	2	58.141	irregular	9
	1	35.664	irregular	7
	3	14.086	irregular	4
147821 003 L1-S1 (9)	3	85.413	spherical	10
	2	54.844	spherical	8
	1	29.97	sub spherical	6
147821 003 L1-S1 (10)	1	186.111	irregular	15
	2	19.78	sub spherical	5
	3	18.281	oval	5
	6	6.294	oval	3
	5	19.48	sub oval	5
	7	17.682	sub spherical	5
	4	110.588	irregular	12
147821 003 L1-S1 (11)	2	25.474	irregular	6
	3	62.037	oval	9
	1	14.385	irregular	4
	4	34.765	sub spherical	7
	5	14.685	irregular	4
147821 003 L1-S1 (12)	1	84.514	irregular	10

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147821 003 L1-S1 (13)	5	29.37	oval	6
	2	12.887	irregular	4
	1	8.092	oval	3
	3	3.896	oval	2
	4	58.441	irregular	9
147822 004 L1-N1 (1)	3	12.288	oval	4
	1	35.664	sub oval	7
	2	46.753	irregular	8
147822 004 L1-N1 (2)	3	19.181	sub spherical	5
	5	59.939	irregular	9
	4	21.878	sub prismatic	5
	1	26.973	sub prismatic	6
	2	20.379	irregular	5
147822 004 L1-N1 (3)	3	4.495	sub spherical	2
	1	20.979	sub spherical	5
	2	6.593	spherical	3
	5	6.294	oval	3
	4	34.165	sub spherical	7
147822 004 L1-N1 (4)	1	27.272	sub spherical	6
	3	29.071	oval	6
	2	9.59	spherical	3
	4	20.379	oval	5
147822 004 L1-N1 (5)	4	9.89	spherical	4
	1	3.596	spherical	2
	2	38.361	sub spherical	7
	3	12.587	irregular	4
147822 004 L1-N1 (6)	2	9.291	sub spherical	3
	1	5.395	spherical	3
	3	108.19	irregular	12
	5	13.486	spherical	4
	4	5.095	sub spherical	3
147822 004 L1-N1 (7)	1	24.575	spherical	6
147822 004 L1-N1 (8)	1	108.49	irregular	12
	3	11.089	sub oval	4
	2	53.346	prismatic	8
147822 004 L1-N1 (9)	7	55.144	irregular	8

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147822 004 L1-N1 (9)	1	83.016	irregular	10
	2	20.979	sub oval	5
	3	19.48	sub oval	5
	6	19.78	irregular	5
	5	29.37	oval	6
	4	81.817	sub spherical	10
	8	54.844	sub prismatic	8
147822 004 L1-N1 (10)	2	65.334	sub oval	9
	1	26.373	irregular	6
	4	18.281	oval	5
	3	89.909	sub spherical	11
	5	6.893	irregular	3
147822 004 L1-N1 (11)	1	19.48	irregular	5
	2	32.068	sub prismatic	6
147822 004 L1-N1 (12)	4	23.077	sub oval	5
	2	24.575	spherical	5
	3	16.483	sub oval	4
	1		too big	
147822 004 L1-N1 (13)	2	7.792	sub spherical	3
	1	7.193	spherical	3
147822 004 L1-N1 (14)	4	6.893	sub spherical	3
	3	9.291	sub spherical	3
	5	23.676	sub oval	5
	1	65.633	spherical	9
	2	49.45	irregular	8
	6	17.382	oval	5
147822 004 L1-N1 (15)	1	483.11	irregular	25
	3	18.281	sub spherical	5
	2	31.168	sub spherical	6
147822 004 L1-N1 (16)	1	18.881	irregular	5
	4	22.777	sub spherical	5
	5	37.162	sub oval	7
	3	68.331	sub oval	9
	2	28.471	sub oval	6
147823 005 L1-S1 (1)	1	537.056	sub angular	26
	2	20.08	spherical	5

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147823 005 L1-S1 (2)	4	18.281	sub spherical	5
	2	26.074	sub prismatic	5
	3	12.288	sub spherical	4
	1	24.575	sub spherical	6
147823 005 L1-S1 (3)	4	23.376	irregular	5
	3	31.768	sub oval	6
	1	31.168	sub spherical	6
	2	17.682	spherical	5
147823 005 L1-S1 (4)	1	15.285	sub spherical	4
147823 005 L1-S1 (5)	2	29.67	sub spherical	6
	1	118.38	oval	12
147823 005 L1-S1 (6)	1	12.887	sub spherical	4
147823 005 L1-S1 (7)	3	20.679	sub prismatic	5
	4	3.596	spherical	2
	1	6.593	sub spherical	3
	2	6.593	sub spherical	3
147823 005 L1-S1 (8)	2	7.492	irregular	3
	1	337.758	irregular	21
	3	8.991	oval	3
147823 005 L1-S1 (9)	2	8.991	irregular	3
	1	17.982	sub prismatic	5
	4	11.089	sub oval	4
	6	10.789	sub spherical	4
	5	8.691	irregular	3
	3	8.391	sub oval	3
147823 005 L1-S1 (10)	1	15.285	sub spherical	4
147823 005 L1-S1 (11)	1	6.593	sub spherical	3
147823 005 L1-S1 (12)	2	8.391	spherical	3
	1	22.777	sub spherical	5
147823 005 L1-S1 (13)	2	19.773	spherical	5
	1	6.591	spherical	3
147823 005 L1-S1 (14)	1	5.692	sub spherical	3
147823 005 L1-S1 (15)	1	24.866	sub prismatic	6
147823 005 L1-S1 (16)	1	2.397	irregular	2
	2	6.291	irregular	3
	3	4.793	irregular	2

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147823 005 L1-S1 (17)	1	59.318	sub oval	9
	2	33.254	irregular	7
147823 005 L1-S1 (18)	1	68.006	oval	9
147824 006 L1-N1 (1)	2	12.583	sub spherical	4
	1	25.764	spherical	6
147824 006 L1-N1 (2)	1	17.975	sub spherical	5
	5	6.291	sub spherical	3
	3	16.777	spherical	5
	4	22.469	sub prismatic	5
	2	10.785	irregular	4
147824 006 L1-N1 (3)	2	12.882	sub spherical	4
	1	29.36	irregular	6
	3	9.587	irregular	3
147824 006 L1-N1 (4)	1	7.19	sub spherical	3
147824 006 L1-N1 (5)	1	477.242	irregular	25
147824 006 L1-N1 (6)	5	25.465	irregular	6
	1	30.558	sub oval	6
	2	52.428	sub prismatic	8
	4	14.081	sub oval	4
	3	17.975	sub prismatic	5
147824 006 L1-N1 (7)	1	11.684	sub spherical	4
147824 006 L1-N1 (8)	1	11.085	irregular	4
	3	9.886	irregular	4
	2	8.988	irregular	3
147824 006 L1-N1 (9)	2	9.587	sub spherical	3
	1	9.886	spherical	4
147824 006 L1-N1 (10)	1	177.655	irregular	15
147825 007 L2-S1 (1)	1	14.38	oval	4
	2	18.574	irregular	5
147825 007 L2-S1 (2)	1	13.182	spherical	4
	5	35.052	irregular	7
	2	19.473	irregular	5
	4	11.384	sub spherical	4
	3	8.089	sub oval	3
147825 007 L2-S1 (3)	5	4.494	spherical	2
	4	15.878	irregular	4

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147825 007 L2-S1 (3)	3	16.178	irregular	5
	2	4.194	spherical	2
	1	10.785	sub oval	4
147825 007 L2-S1 (5)	1	59.019	sub prismatic	9
147825 007 L2-S1 (6)	2	8.688	irregular	3
	1	7.789	spherical	3
	3	23.368	irregular	5
147825 007 L2-S1 (7)	1	36.55	sub prismatic	7
147825 007 L2-S1 (8)	1	114.143	sub prismatic	12
147825 007 L2-S1 (9)	1	15.878	sub prismatic	4
147826 008 L2-N1 (1)	1	41.043	sub prismatic	7
	3	10.486	sub spherical	4
	2	14.38	sub spherical	4
147826 008 L2-N1 (2)	2	14.081	spherical	4
	1	14.68	sub spherical	4
147826 008 L2-N1 (3)	1	80.289	oval	10
147826 008 L2-N1 (4)	1	362.5	oval	21
147826 008 L2-N1 (5)	2	124.329	irregular	13
	1	9.287	angular	3
147826 008 L2-N1 (6)	2	14.38	spherical	4
	1	21.87	irregular	5
	3	4.793	spherical	2
147826 008 L2-N1 (7)	2	8.988	irregular	3
	3	6.291	angular	3
	1	8.388	spherical	3
147826 008 L2-N1 (8)	1	19.773	sub prismatic	5
147826 008 L2-N1 (9)	1	65.01	irregular	9
147537 009 L1-S PM_{10}(1)	1	31.236	spherical	6
147537 009 L1-S PM_{10} (2)	1	76.087	irregular	10
	2		same particle	
147537 009 L1-S PM_{10} (3)	3	14.272	irregular	4
	1	3.358	subspherical	2
	2	33.531	irregular	7
147537 009 L1-S PM_{10} (4)	1	34.188	irregular	7
	2	25.904	irregular	6
147537 009 L1- PM_{10} (5)	4	23.03	irregular	5

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147537 009 L1- PM_{10} (5)	2	27.981	irregular	6
	1	14.923	irregular	4
	3	5.309	irregular	3
147537 009 L1-S PM_{10} (6)	1	97.809	irregular	11
	2	35.082	subtriangular	7
147537 009 L1-S PM_{10} (7)	1	64.888	irregular	9
147537 009 L1-S PM_{10} (8)	2	35.941	subspherical	7
	1	87.812	irregular	11
147537 009 L1-S PM_{10} (9)	2	36.591	suboval	7
	1	7.299	irregular	3
147538 010 L1-S $PM_{2.5}$ (1)	1	4.96	subspherical	3
147538 010 L1-S $PM_{2.5}$ (2)	2	5.76	suboval	3
	1	5.12	irregular	3
147538 010 L1-S $PM_{2.5}$ (3)	2	4.32	subspherical	2
	5	3.52	subspherical	2
	4	2.56	spherical	2
	1	12	prismatic	4
	3	4.32	irregular	2
147538 010 L1-S $PM_{2.5}$ (4)	1	17.28	irregular	4
	2	3.36	subspherical	2
147538 010 L1-S $PM_{2.5}$ (5)	2	4.96	subspherical	3
	1	2.24	irregular	2
	3	6.88	irregular	3
147538 010 L1-S $PM_{2.5}$ (6)	1	6.4	irregular	3
	2	4	irregular	2
147538 010 L1-SPM25(7)	1	4.96	irregular	3
	2	5.76	irregular	3
	3	4.64	irregular	2
147538 010 L1-S $PM_{2.5}$ (8)	1	3.84	irregular	2
147538 010 L1-S $PM_{2.5}$ (9)	2	5.6	irregular	3
	1	5.12	irregular	3
147539 011 L1-N PM_{10} (1)	1	131.001	irregular	13
147539 011 L1-N PM_{10} (2)	1	48.718	irregular	8
147539 011 L1-N PM_{10} (3)	1	87.558	irregular	11
147539 011 L1-N PM_{10} (4)	2	46.847	irregular	8
	1	27.234	subspherical	6

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147539 011 L1-N PM_{10} (5)	2	29.15	suboval	6
	1	43.886	irregular	8
147539 011 L1-N PM_{10} (6)	1	22.593	subspherical	5
147539 011 L1-N PM_{10} (7)	1	7.42	subspherical	3
147539 011 L1-N PM_{10} (8)	2	39.508	subspherical	7
	1	84.753	irregular	10
147540 012 L1-N $PM_{2.5}$ (1)	1	3.411	subspherical	2
147540 012 L1-N $PM_{2.5}$ (2)	1	2.873	subspherical	2
147540 012 L1-N $PM_{2.5}$ (3)	1	5.745	subspherical	3
147540 012 L1-N $PM_{2.5}$ (4)	1	3.052	subspherical	2
147540 012 L1-N $PM_{2.5}$ (5)	1	3.346	subspherical	2
147541 013 L2-S PM_{10} (1)	2	34.131	irregular	7
	1	9.905	suboval	4
147541 013 L2-S PM_{10} (2)	1	41.627	subspherical	7
147541 013 L2-S PM_{10} (3)	1	57.375	suboval	9
	3	12.149	suboval	4
	2	6.014	irregular	3
147541 013 L2-S PM_{10} (4)	1	5.755	suboval	3
147541 013 L2-S PM_{10} (5)	1	3.882	spherical	2
147541 013 L2-S PM_{10} (6)	2	11.243	prismatic	4
	1	19.943	subprismatic	5
147542 014 L2-S $PM_{2.5}$ (1)	1	2.701	subspherical	2
147542 014 L2-S $PM_{2.5}$ (2)	1	1.775	subspherical	2
147542 014 L2-S $PM_{2.5}$ (3)	1	2.006	subspherical	2
147542 014 L2-S $PM_{2.5}$ (4)	1	7.688	subspherical	3
147542 014 L2-S $PM_{2.5}$ (5)	1	1.752	irregular	1
147543 015 L2-N PM_{10} (1)	1	45.118	suboval	8
147543 015 L2-N PM_{10} (2)	1	50.805	oval	8
	2	70.802	oval	9
147543 015 L2-N PM_{10} (3)	1	10.936	subspherical	4
	2	18.497	spherical	5
147543 015 L2-N PM_{10} (4)	1	5.644	spherical	3
147543 015 L2-N PM_{10} (5)	1	6.812	irregular	3
147543 015 L2-N PM_{10} (6)	1	11.483	spherical	4
	2	3.99	irregular	2
147543 015 L2-N PM_{10} (7)	1	25.983	irregular	6

C1. Particle size and morphology of the particles (calculated using ImageJ software) (Continued).

	pt	Area (µm)	Morphology	Size (diameter) of particles (µm)
147543 015 L2-N PM_{10} (8)	1	65.639	irregular	9
147544 016 L2-N $PM_{2.5}$ (1)	1	5.031	irregular	3
147544 016 L2-N $PM_{2.5}$ (2)	1	3.405	irregular	2
147544 016 L2-N $PM_{2.5}$ (3)	1	1.678	spherical	1
147544 016 L2-N $PM_{2.5}$ (4)	1	5.562	prismatic	3
147544 016 L2-N $PM_{2.5}$ (5)	1	2.242	angular	2
147544 016 L2-N $PM_{2.5}$ (6)	1	2.409	subtriangular	2
147544 016 L2-N $PM_{2.5}$ (7)	1	0.568	subspherical	1
147544 016 L2-N $PM_{2.5}$ (8)	1	2.528	angular	2
147544 016 L2-N $PM_{2.5}$ (9)	1	0.922	subspherical	1
147544 016 L2-N $PM_{2.5}$ (10)	1	0.472	irregular	1
147544 016 L2-N $PM_{2.5}$ (11)	1	2.319	prismatic	2
147544 016 L2-N $PM_{2.5}$(12)	1	1.111	subspherical	1

APPENDIX D

D1. Information collected with HOBO data logger on the sampling site. Wind direction from NDAWN.

Sampling Date	Time		Temp. (C)		RH%		mmHg		Wind direction
	Starting	Ending	Starting	Ending	Starting	Ending	Starting	Ending	
06/24-06/25	14:17	11:17	25	16.65	52.335	79.6	734	735	NW
06/25-06/26	12:17	9:17	16.98	16.46	77.43	95.64	735	736	S-SE
07/08-07/09	14:31	10:31	27.45	22.89	50.37	60.18	702	699	W-NW
07/09-07/10	11:31	9:31	26.13	17.84	54.29	86.29	699	699	W-SW
08/13-08/14	13:21	10:21	25.94	25.19	43.95	69.55	699	695	SE
08/14-08/15	10:21	9:21	25.19	19.51	69.55	98.64	695.42	696	W-SW

D2. Temperature/rain data (Dickinson Ranch HQ).

Sampling Date	Temperature (°F)		Rain, melted snow, etc.
	MAX	MIN	
06/24/2014	75	58	0
06/25/2014	68	42	0.03
07/08/2014	73	54	0.09
07/09/2014	75	51	0
08/13/2014	89	55	0
08/14/2014	90	64	0