Health Consultation

Exposure Investigation

Outdoor Air Exposures to Crystalline Silica Dust and Particulate Matter
in Wedron, Illinois

WEDRON ILLINOIS SILICA EXPOSURE INVESTIGATION
WEDRON, ILLINOIS

October 22, 2019

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a health consultation may lead to specific actions such as restricting use of or replacing water supplies, intensifying environmental sampling, restricting site access, or removing the contaminated material.

In addition, health consultations may recommend additional public health actions such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes, conducting biological indicators of exposure studies to assess exposure, or providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by the
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List of Acronyms and Abbreviations

AQG	air quality guideline
ATSDR	Agency for Toxic Substances and Disease Registry
CA OEHHA	California Office of Environmental Health Hazard Assessment
°C	degrees Celsius
CFR	Code of Federal Regulations
COV	coefficient of variation
CV	comparison value
DQO	data quality objective
E-BAM	environmental beta attenuation monitor
EI	exposure investigation
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
°F	degrees Fahrenheit
LPM	liters per minute
m^3	cubic meter
µg	Micrograms
$\mu g/m^3$	micrograms per cubic meter
µm	Micrometer
Mg	Milligram
mmHg	millimeter of mercury
NAAQS	National Ambient Air Quality Standards
NIOSH	National Institute for Occupational Health and Safety
NIST	National Institute of Standards and Technology
PM	particulate matter
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or smaller
PM_4 crystalline silica	respirable crystalline silica particles with an aerodynamic diameter of 4 micrometers or smaller
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or smaller
QA/QC	quality assurance/quality control
REL	Reference Exposure Level
RPD	relative percent difference

RTD	resistance temperature detector
RTI	Research Triangle Institute
RTP	Research Triangle Park
UCL	upper confidence limit of the mean
WHO	World Health Organization
XRD	x-ray diffraction

Executive Summary

Background

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted an exposure investigation (EI) in Wedron, Illinois to determine if residents living near Fairmount Santrol are exposed to harmful levels of silica and particulate matter in outdoor air. Fairmount Santrol ("Fairmount") is a sand mining and processing facility located in a mixed rural, residential, and industrial area of Wedron, an unincorporated community in LaSalle County, Illinois. Fugitive sand from the facility has been observed on the sides of streets and on residential properties. Residents have reported that the sand blows into their homes through their windows, fills their gutters, and covers their cars. ATSDR conducted this EI in response to residents' concerns about their exposure to silica and its potential health effects.

During this EI, ATSDR measured respirable fraction of crystalline silica particles with an aerodynamic diameter of 4 micrometers or smaller (PM_4 crystalline silica), particulate matter with an aerodynamic diameter of 2.5 micrometers or smaller ($PM_{2.5}$), and PM_{10} (particulate matter with an aerodynamic diameter of 10 micrometers or smaller) in Wedron, Illinois. Outdoor air concentrations of these pollutants were measured at locations near potential sources of silica (i.e. silica plant and rail/truck routes) within the residential area. Air monitoring was conducted over an 8-week period from October 5, 2016 to December 3, 2016. In the subsequent months, PM_4 samples underwent laboratory analysis for crystalline silica. ATSDR then worked with our contractor Eastern Research Group (ERG) to validate data and perform statistical analyses. ATSDR examined the data for public health implications considering the magnitude, frequency, duration, and location of exposure as well as meteorological conditions that influence these exposures. ATSDR calculated 24-hour averages at each site to assess acute exposures, and the average of the daily concentrations was used to assess chronic exposures.

ATSDR notes that sampling periods (up to eight weeks) are much shorter than those generally used to estimate chronic exposure (greater than a year). However, the EI findings are comparable to a previous year-long study conducted by the U.S. Environmental Protection Agency (EPA) in 2016. The results of this EI are expected to be consistent with long-term exposures.

Air pollutant concentrations were compared to contaminant-specific, health-based comparison values (CVs) from the World Health Organization (WHO) and the California Office of Environmental Health Hazard Assessment (CA OEHHA). CVs are used in screening the air monitoring data and to decide whether further study was needed to determine if there is a potential public health hazard. ATSDR has no CVs for $PM_{2.5}$, PM_{10}, or PM_4 crystalline silica. ATSDR prepared this health consultation as an in-depth public health evaluation of the pollutant concentrations measured during the EI. After a careful evaluation of the measured pollutant concentrations, ATSDR has come to the following conclusions:

Conclusion 1

Long-term and short-term exposure to PM_{10} and $PM_{2.5}$ in Wedron and the surrounding area is not likely to result in harmful health effects to the general population.

Basis for Conclusion 1

- The 8-week average concentrations for PM_{10} and $PM_{2.5}$ were approximately equal to long-term health-based guidelines from the WHO. The highest PM_{10} concentration (95% upper confidence limit on the mean) was 22 micrograms per cubic meter (µg/m^3). $PM_{2.5}$ at the one site with data was 10 µg/m^3. WHO's annual Air Quality Guidelines (AQGs) for long-term exposures are 20 and 10 µg/m^3, respectively.

- None of the 24-hour average PM_{10} or $PM_{2.5}$ concentrations exceeded the WHO's 24-hour AQG for short-term exposures.
- Reported literature indicates that exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6-13% per 10 micrograms per cubic meter ($\mu g/m^3$) of $PM_{2.5}$ and susceptible groups are particularly vulnerable [WHO 2006]. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur. The AQGs are aimed to achieve the lowest concentrations of PM possible. However, no significant health effects are expected in healthy individuals among the general public.

Conclusion 2

Long-term exposure, and to a lesser extent short-term exposure, to PM_{10} and $PM_{2.5}$ in Wedron and the surrounding area may contribute to harmful health effects in sensitive populations: the elderly, children, and individuals with preexisting heart and lung disease.

Basis for Conclusion 2

- Prolonged, long-term, exposure to PM, especially $PM_{2.5}$, above the AQGs may slightly increase the likelihood of harm to individuals with pre-existing health conditions, such as lung and heart diseases, the elderly, and children.
- Although short-term exposures were below the AQG, current science does support evidence that in some instances, small increases in risk are possible for highly sensitive populations at concentrations below the AQGs. AQGs do not define "safe" levels, but rather are targets set for regulators to achieve the lowest feasible concentrations or particulate matter.
- EPA recently evaluated data from 2000 air monitoring stations in the U.S. and found that more than half of had $PM_{2.5}$ and PM_{10} annual average concentrations greater than the AQGs, indicating that PM is a widespread issue.

Conclusion 3

Concentrations of PM_4 crystalline silica in outdoor air are not likely to cause harmful health effects to people in the residential areas of Wedron.

Basis for Conclusion 3

- The highest average concentration for the 8-week EI period is below the CA OEHHA Reference Exposure Level (REL) of 3.0 $\mu g/m^3$. These short-term results are consistent with a previous 1-year monitoring study that EPA required Fairmount to conduct.

- Study sites were near the sand processing operations, as well as truck and train car loading, sand coating, and along the truck transit routes offsite of Fairmount. By monitoring at five distinct locations, with varying distances from different facility operations, ATSDR was able to document that silica was below the CV throughout the Wedron community.

Limitations

ATSDR acknowledges that all scientific investigations, such as the Wedron EI, have limitations. These include:

- Monitoring was conducted at fixed, stationary locations; however, people move around, and do not remain in one place all day long. Therefore, the data collected at the fixed locations are not directly equivalent to actual exposures that may have occurred.
- The monitoring only measured some of the potential contaminants associated with large surface sand mining, processing, and transportation of the final product. ATSDR's choice of contaminants was based on community concerns and careful review of current scientific knowledge about potential hazards in Wedron. ATSDR did not evaluate exposures to volatile and semi-volatile organic contaminants from Fairmount, such as vehicle emissions and the resin coating operations.
- The data collected during this program represent air quality conditions from October 5, 2016 to December 3, 2016. While this 8-week time period represents just a snapshot of time, PM and silica results are consistent with previous long-term monitoring and may be representative of community exposures throughout the year. Both the previous year-long EPA study and the new ATSDR investigation captured dates where the prevailing wind direction was from the south, i.e. from the silica sand processing operations at Fairmount.
- Collocated $PM_{2.5}$ measurements were not collected, thus there were no measurements available to assess monitoring precision of the Environmental Beta Attenuation Monitor (E-BAM) results for this pollutant. However, collected measurements were available for PM_4 crystalline silica and PM_{10}
- $PM_{2.5}$ was only measured at one site, Site 2, which is the station that recorded the highest PM_{10} concentration. $PM_{2.5}$ was not measured at Site 4, which observed the highest PM_4 crystalline silica levels.

The EI program met most, but not all, of its intended data quality objectives (DQOs). PM_{10} measurement precision, which is quantified by comparing two side-by-side monitors, was not within the specified bounds. The DQO was for the two monitors to report data with a less than 20% coefficient of variation (COV) between them. In this study, the side-by-side monitors at Site 3 had a 40% COV. Although the DQO was not met, the ultimate difference between the two PM_{10} monitor long-term averages was 1.5 ug/m^3. This level of uncertainty, i.e. if other PM_{10} monitor means were potentially off by 1 to 2 ug/m^3, is not likely to have impacted the EI conclusions.

Recommendations

Following its review of available information, ATSDR recommends:

1. Fairmount should implement best practices to limit point and fugitive emissions of particulate matter throughout their site operations. Particle emissions should be well controlled at all stages of production: extraction, transportation to the facility, processing and production, handling and storage of intermediate, byproducts and waste, and shipping of final products. Trucks that drive through the community should be covered and cleaned off before leaving the facility.
2. If Fairmount workers are concerned about occupational exposures to PM_4 crystalline silica dust and potential health effects, they may request that a Health Hazard Evaluation should be performed by the National Institute for Occupational Safety and Health (NIOSH). Any actions to reduce silica dust emissions

will benefit workers and the community alike, because crystalline silica dust generated from Fairmount activities migrate offsite to nearby residents.

Public Health Actions Planned

1. ATSDR will share results of this investigation at a public meeting in Wedron. ATSDR should educate the community on actions that the elderly, children, and individuals with heart and lung disease can take to protect themselves against particulate matter exposures. Fairmount will be invited and given the opportunity to tell the community what they are doing to control PM emissions from sand processing and transportation activities.
2. ATSDR will also invite other stakeholders including EPA Region 5, State Agencies, and local agencies to communicate the findings and public health options available to reduce community exposures to PM_4 crystalline silica, $PM_{2.5}$ and PM_{10}. ATSDR will also follow-up with all partners to assure that the recommendations or public health actions were taken.

Purpose and Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted an exposure investigation (EI) from October 5, 2016 to December 3, 2016 in Wedron IL to assess community exposures to crystalline silica dust in outdoor air near the operations of Fairmount Santrol ("Fairmount"), an industrial site comprised of Wedron Silica Company and Technisand. Residents of Wedron have expressed concern about exposure to airborne crystalline silica dust from the nearby silica sand mining, processing, and transportation operations.

Mining activities that break up soil and rock layers can release particulate matter (PM) into the air that are invisible to the naked eye. The U.S. Environmental Protection Agency (EPA) and World Health Organization (WHO) have established air quality standards for two categories of particulate matter. Inhalation of particles with aerodynamic diameters that are 10 micrometers (µm) and smaller (PM_{10}); and fine inhalable particles, with diameters that are 2.5 µm and smaller ($PM_{2.5}$) are associated with increased respiratory and cardiovascular effects and mortality [EPA 2009, 2012].

In occupational settings, particles that are 4 µm or less are considered the respirable particle fraction for crystalline silica[1]. Respirable crystalline silica or PM_4 crystalline silica has long been known to cause silicosis and is associated with increased risk for lung cancer [NTP 2016]. Inhalation of respirable crystalline silica has also been associated with other respiratory diseases such as chronic obstructive pulmonary disease, bronchitis, and emphysema, as well as kidney and immune system diseases [ATSDR 2017]. ATSDR conducted this EI to determine if community exposures to airborne PM are a health concern in Wedron, Illinois. Outdoor air concentrations of $PM_{2.5}$ and PM_{10} mass, as well as PM_4 crystalline silica, were measured in residential areas surrounding Fairmount. ATSDR examined the data for public health implications considering the magnitude, frequency, duration, and location of exposure as well as meteorological conditions that influenced the exposures.

The EI was designed to evaluate community exposures to the above selected pollutants and evaluate potential health impacts. EI results cannot determine facility compliance with local, state and federal regulations. Nor can they be used to determine whether outdoor air is in attainment of National Ambient Air Quality Standards (NAAQS). State and federal environmental enforcement agencies are responsible for evaluating facility adherence to existing rules and regulations. While the information was not collected for a regulatory purpose, the results could be used by EPA to inform potential actions.

Background

The residential community of Wedron is adjacent to silica sand mining, processing, and transportation operations. Fugitive sand has been observed on the sides of streets and on residential properties. Residents have

[1]Recommended exposure limits for crystalline silica (quartz, cristobalite, tridymite) apply to particles of respirable size fraction, which occupational hygiene methods define as particles with aerodynamic diameters of 4 micrometers or less with a 50% probability of penetration to the alveolar region of the lung. This is where the most critical toxic effects for crystalline silica—silicosis and cancer—are believed to occur [Cal EPA 2005]. The U.S. Environmental Protection Agency's definition of inhalable coarse particles are those with nominal mean aerodynamic diameters greater than 2.5 and less than or equal to 10 micrometers, and inhalable fine particles as those less than or equal to 2.5 micrometers in diameter [EPA 2009].

reported that the sand blows into their houses, fills their gutters, and covers their cars. They have been concerned about their levels of exposure to silica dust and the potential associated health effects.

In 2013, in response to community concerns, EPA required Wedron Silica to collect one year of outdoor air monitoring data for particulate matter with an aerodynamic diameter of 10 µm or smaller (PM_{10}) and respirable crystalline silica particles with an aerodynamic diameter of 4 µm or smaller (PM_4 crystalline silica) in the Wedron community. Between February 2015 and March 2016, Wedron Silica operated ambient air samplers at two locations: a background location on the southern boundary of the mining area, and another on the north side of the facility in front of the main Wedron administrative office. Wedron Silica collected 121 filter-based measurements of PM_4 crystalline silica and reported that:

- At the north monitor, the average crystalline silica concentration of all samples collected over the duration of the study was 1.5 micrograms per cubic meter (µg/m^3). Approximately 37 percent of the samples had crystalline silica concentrations below the level that the laboratory method can detect and measuring, which is 0.3 µg/m^3. These “nondetects” were assigned a value of 50 percent of the detection level (0.15 µg/m^3) for the purposes of calculating the long-term average.
- At the south monitor (background location), around 85 percent of the samples had crystalline silica concentrations below the detection level (0.3 µg/m^3). The samples above detection all had silica concentrations less than 0.7 µg/m^3

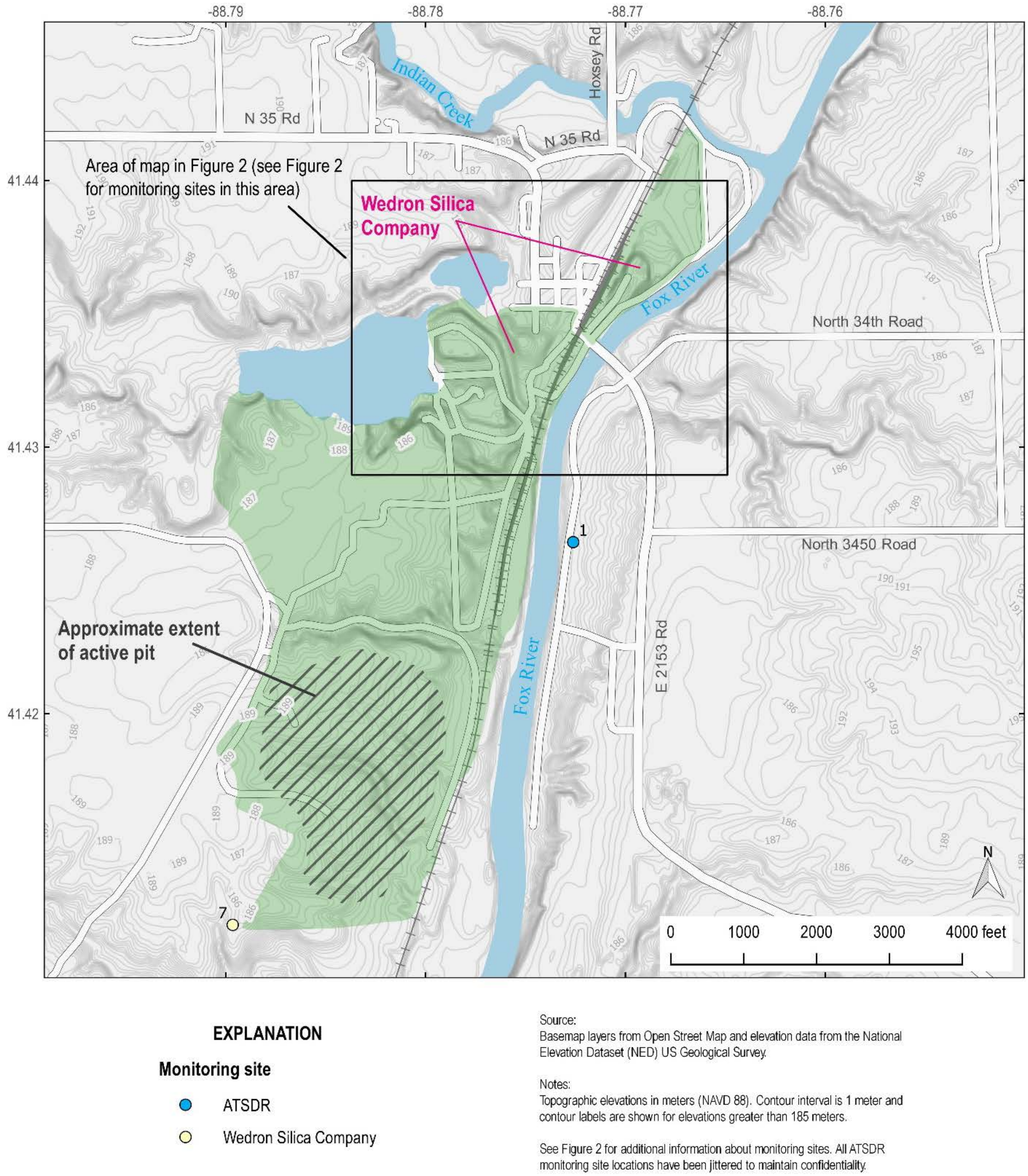
The results of Wedron’s year-long air monitoring were posted on the EPA website (https://www.epa.gov/il/air-monitoring-wedron-illinois).

The 1-year EPA monitoring program was designed to capture emissions from their various processing facilities adjacent to residential areas. Since emissions from transportation of processed silica sand via trucks that pass through town or loading of rail cars were unlikely to be captured with monitors located at the administrative building, there was a lack of information on silica exposures in other residential areas. Thus, ATSDR monitored contaminants (PM_4 crystalline silica, $PM_{2.5}$, and PM_{10}) at residential locations near the processing facility to determine the public health impact of exposure to emissions from all the mining operations and transportation of silica within the community.

Site Description

Wedron is an unincorporated community comprised of about 40 homes in LaSalle County, Illinois. The industrial operations of Fairmount are directly south of Wedron and on the west bank of the Fox River. The areas surrounding Wedron and Fairmount operations are predominately agricultural or undeveloped land. A major rail line, owned by Illinois Railway Company, runs through Wedron. The majority of rail traffic on this line transports raw or coated silica. An overview map, which includes the background sites established for the Fairmount and ATSDR air monitoring studies, is presented in Figure 1.

Figure 1. Topographic Map of Wedron, Surrounding Area, and Background Monitor Sites



Sand has been mined in Wedron since the early 1900s. Fairmount Minerals Ltd. was formed in 1986, when Wedron Silica Company merged with the Best Sand Corporation. Fairmount Santrol was then formed in 1991 when Fairmount purchased Technisand Inc. and Santrol from British Industrial Sand. Fairmount Santrol operates two facilities: Wedron Silica Company, an industrial sand plant that produces high-purity sand (~99.9% pure silica sand), and Technisand, Inc., which makes resin-coated silica sand. Wedron Silica owns and operates a sand mining facility, sand mining pits, and ancillary operations for processing silica sand. The main Wedron Silica processing facility is south of County Highway 21 and Technisand, Inc. is to the north. Both

Wedron Silica and Technisand operate rail and truck loading facilities to distribute their respective products. Markets served by these companies include foundry, glass, sport and recreation, specialty products, building products, water, and the oil and gas industry.

The Fairmount complex operates 24-hours per day, 7 days per week, and 52 weeks per year. Wedron Silica and Technisand are considered a single source for purposes of air pollution control permitting programs, because they are adjacent to each other. One plant supplies the raw material for the other, and they have the same parent company. Additionally, Fairmount owns and operates sand facility-related maintenance, storage, and administrative properties.

Methods

Exposure Investigation (EI) Design

The goal of the EI was for ATSDR to obtain representative community-based air concentrations of PM_4 crystalline silica, $PM_{2.5}$, and PM_{10}, as well as meteorological measurements, from residential locations in Wedron. The EI was designed to evaluate community exposures to the above selected pollutants and to assess potential health impacts of these exposures. The complete EI Protocol is provided in Appendix A.

To determine the concentrations of target pollutants in air, ATSDR selected EI monitoring locations where community exposures were most likely to occur. ATSDR documented these locations by longitude and latitude using a hand held global positioning system. Written consent agreements were obtained from participating property owners before beginning the program. The final number and placement of locations was dependent on actual site conditions at the time of equipment deployment, siting constraints (e.g., availability of electrical power, ability to secure equipment), and the ability to identify willing participants.

ATSDR established a total of five fixed monitoring locations at and near residential areas. A primary monitoring system was placed at five locations (Sites 1, 2, 3, 4, and 5) and a *collocated*[2] system was established at two sites (Site 1 for PM_4 crystalline silica sampling and at Site 3 for PM_{10} monitoring) (Table 1). The locations and types of measurements are presented in Figure 2. The sites included four residential properties and one commercial location—all of which were outdoors and near local roads within a half-mile of Fairmount. Air monitors at these sites are expected to capture both direct industrial emissions and road dust, some of which is re-entrained particles from local mining operations.

EI field staff from ATSDR and ERG transported and set up all monitoring equipment and measurement systems at the established sites. Once installations were completed, all measurement systems were tested to ensure that damage had not occurred during transport.

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[2] *Collocated* measurements are collected simultaneously using two independent collection systems at the same location and at the same time. Analysis of collocated measurements provides information on the potential for variability (or precision) expected between different collection systems.

Table 1. Measurements Collected for Each Air Monitoring Site

Site ID*	Particulate Matter (PM) measurement type
Site 1-Primary	PM_4 crystalline silica (primary), PM_{10}
Site 1-Collocated	PM_4 crystalline silica (collocated)
Site 2	$PM_{2.5}$, PM_4 crystalline silica, PM_{10}
Site 3-Primary	PM_4 crystalline silica, PM_{10} (primary), meteorology
Site 3-Collocated	PM_{10} (collocated)
Site 4	PM_4 crystalline silica, PM_{10}
Site 5	PM_4 crystalline silica, PM_{10}
* Collocated instruments were set up at Site 1 for PM_4 crystalline silica and at Site 3 for PM_{10}	

Monitoring at each EI site commenced after that location's measurement systems were determined to be operating correctly. Throughout the monitoring event, at least one field staff member visited each site daily to assess the functional status of the equipment and correct any problems identified. During the EI, daily observations in the field were noted. Figure 2 below shows the monitoring locations downwind of the facility and the pollutant(s) measured at each site. Table 2 summarizes the type of measurement, the device used, method detection limit and bibliographic source of additional information.

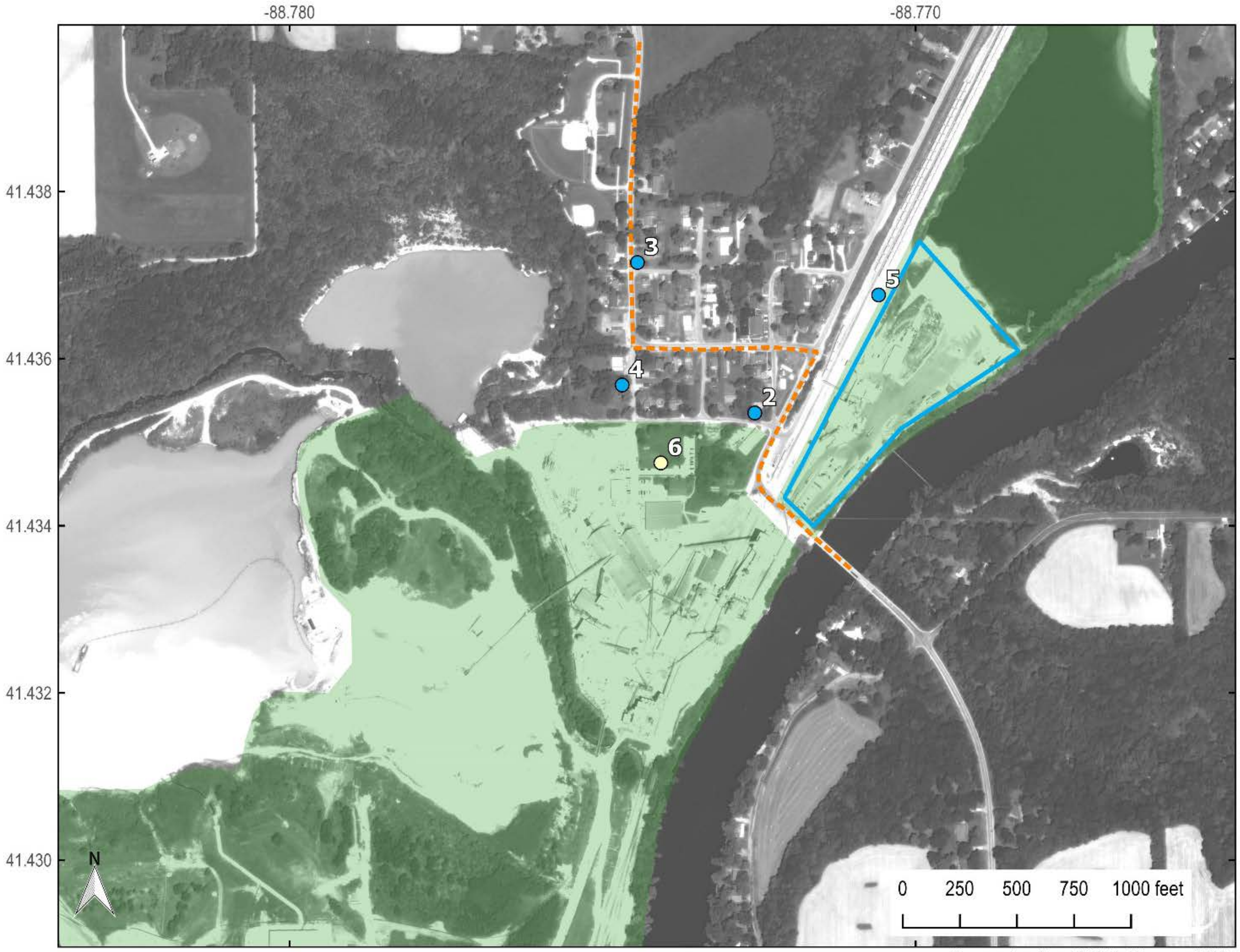
Data Quality Objectives

ATSDR established data quality objectives (DQOs) to help determine if data were of sufficient quality to achieve the project's specific technical goals and objectives. Appendix B presents some parts of the DQO report. All the final data were stored in a Microsoft Access database (available upon request).

Data Analysis

For specific details on the analysis of data, see Appendix C. In general, ATSDR calculated 24-hour averages from the data at each site for all pollutants. Maximum 24-hour concentrations were used as estimates of acute exposure. The 95% upper confidence level (UCL, a conservative estimate of the average) of the mean over the duration of the EI was used as an estimate of chronic exposure. Polar plots comparing measured contaminant concentrations to wind direction and speed were also developed for each monitor (see page 23 for additional information).

Figure 2. Map of Monitoring Network in Wedron Residential Area – an insert of the area shown on Figure 1



Basemap layer from ESRI World Imagery (2016) converted to grayscale.

EXPLANATION

Monitoring site

- ATSDR (station ID 1-5)
- Wedron Silica Company (station ID 6-7)

Other features

- Approximate route of trucks
- Wedron Silica Company
- Technisand Inc.

Site ID	Pollutant measurement type
1	PM_4, PM_{10}
2	$PM_{2.5}$, PM_4, PM_{10}
3	PM_4, PM_{10}, meteorology
4	PM_4, PM_{10}
5	PM_4, PM_{10}
6	PM_4, PM_{10}
7	PM_4, PM_{10}, meteorology

Note: Site 1 and 7 not shown in this map—see Figure 1 for approximate location. All ATSDR monitoring site locations have been jittered to maintain confidentiality.

Table 2. Types of Measurements, Measurement/Sampling Devices, and Method Detection Limits/Detection Ranges

Particulate Matter (PM) Type	PM Sampler	Method detection limit	References
PM_4 crystalline silica	Thermo Scientific™ Partisol™ 2000i	0.3 µg/m^3 (Bruker D2 Phaser XRD)*	Thermo Fisher Scientific (2011)
PM_4 gravimetric mass	Thermo Scientific™ Partisol™ 2000i	5.5 µg/m^3 (Mettler Toledo XP6)	Mettler-Toledo (2013)
$PM_{2.5}$	Environmental Beta Attenuation Monitor	6 µg/m^3 (1-hour measurement)	Met One Instruments (2016)
PM_{10}	Environmental Beta Attenuation Monitor	6 µg/m^3 (1-hour measurement)	Met One Instruments (2016)
Meteorological Measurement†	**Measurement device**	**Detection range**	**References**
Ambient temperature	ONSET HOBO U30-NRC Weather Station Kit	-40 to 75 degrees Celsius	ONSET (2017)
Relative humidity‡	ONSET HOBO U30-NRC Weather Station Kit	0-100% at -40 to 75 degrees Celsius	ONSET (2017)
Wind direction	ONSET HOBO U30-NRC Weather Station Kit	0-355 degrees, 5-degree dead band; 1.0 m/s starting threshold§	ONSET (2017)
Wind speed	ONSET HOBO U30-NRC Weather Station Kit	0-76 m/s, 1.0 m/s starting threshold	ONSET (2017)

* µg/m^3 = micrograms per cubic meter
† There is not a separate sensor for dew point temperature and gust speed; these measurements are based on calculations from the wind speed, relative humidity, and temperature sensors.
‡ Exposure to conditions below -20 degrees Celsius (-4 degrees Fahrenheit) or above 95% relative humidity may temporarily increase the maximum relative humidity sensor error by an additional 1%.
§ m/s = meters per second

Results and Discussion

ATSDR compared the measured concentrations to health-based comparison values (Table 3) to decide whether further study was needed to determine if there is a potential public health hazard due to exposure to the measured contaminants. These comparison values (CVs) are intended to protect the general public from adverse health effects for specific durations of exposure. They are used to screen out contaminants that are measured at concentrations that are generally safe (below the CV). A concentration above the CV does not necessarily mean that an adverse effect will occur, but it is an indication that the specific contaminant is a contaminant of concern and should be further investigated and compared to the health effects documented in scientific literature.

ATSDR has no CVs for $PM_{2.5}$, PM_{10}, or PM_4 crystalline silica. The measured concentrations of $PM_{2.5}$ and PM_{10} were screened using the World Health Organization's (WHO) Air Quality Guidelines (AQGs), which are more protective than EPA's National Ambient Air Quality Standards. PM_4 crystalline silica was evaluated using the Chronic Reference Exposure Level (REL) derived by the California Office of Environmental Health Hazard Assessment (CA OEHHA).

Table 3. Air Contaminants and Associated Health-based Comparison Values

Type of Particulate Matter (PM)	Comparison Value (CV)*	Source	Was the CV exceeded at any site?
PM_4 crystalline silica	3 µg/m^3 annual average	California Office of Environmental Health Hazard Assessment, Reference Exposure Level, chronic	No
PM_{10}	50 µg/m^3 24-hour average	World Health Organization (WHO) 24-hour Air Quality Guideline (AQG)†	No
PM_{10}	20 µg/m^3 annual average	WHO Annual AQG	**Yes**
$PM_{2.5}$	25 µg/m^3 24-hour average	WHO 24-hour AQG	No
$PM_{2.5}$	10 µg/m^3 annual average	WHO Annual AQG	**Yes**

* µg/m^3 = micrograms per cubic meter
† The WHO AQGs for PM are based on studies that use $PM_{2.5}$ as indicator. The $PM_{2.5}$ guideline values are converted to corresponding PM_{10} guideline values by application of a $PM_{2.5}/PM_{10}$ ratio of 0.5.
‡Yes – CV exceeded, which means that further investigation is warranted.

Measured concentrations of PM_{10}, $PM_{2.5}$, and PM_4 silica exceeded CVs at some sites during the exposure investigation. The following presents a summary of theses contaminants, the results of the pollutant screening, and comparison to health effects documented in the scientific literature.

Particulate Matter

Particulate Matter (PM) is a term used in air quality that refers to particles of dust suspended in air. PM comes from industrial, manmade, and natural sources. The size of particles is directly linked to their potential for causing health problems. PM_{10}, which are particles less than 10 microns in diameter, can pass through the throat and nose to enter the lungs. Fine particles ($PM_{2.5}$), which are less than 2.5 microns in diameter, can lead to deeper penetration of the lungs and higher toxicity. $PM_{2.5}$ is a subset of PM_{10}. Both $PM_{2.5}$ and PM_{10} have been associated with short-term health effects; however, EPA believes that $PM_{2.5}$ is a better indicator of long-term health effects than is $PM_{10.}$

PM_{10} is primarily produced by mechanical processes, such as construction activities, road dust re-suspension and wind. $PM_{2.5}$ originates primarily from combustion sources—like wood smoke, motor vehicle exhaust, and emissions from power plants—and certain industrial processes [EPA 2009]. Although both can be mobilized with wind, PM_{10} is more rapidly deposited and travels shorter distances than $PM_{2.5}$ [Hiranuma 2011]. The lowest concentrations at which adverse health effects have been demonstrated are not much above $PM_{2.5}$ background concentrations, which have been estimated as an annual average of 3–5 µg/m^3 in both the United States and Western Europe [WHO 2013].

Particulate matter has been associated with a range of respiratory and cardiovascular health problems. Health effects linked to exposure to ambient particulate matter include: premature death, the exacerbation of asthma as well as respiratory and cardiovascular disease, acute respiratory symptoms, chronic bronchitis, decreased lung function, and increased risk of heart attack [EPA 2009]. Although the evidence is not as clear for the health implications of exposure to PM_{10} as with $PM_{2.5}$ health outcome studies, short-term exposure to PM_{10} has been associated with increases in mortality and cardiovascular and respiratory effects in areas with mean 24-hour average concentrations as low as 6.1 µg/m^3, 7.4 µg/m^3, and 5.6 µg/m^3, respectively [EPA 2009]. Studies on the long-term health effects from exposure to PM_{10} have been inconclusive but are likely to present similar impacts to the respiratory and cardiovascular systems.

Short-term exposures to elevated levels of $PM_{2.5}$ have been determined to cause a range of cardiovascular and respiratory effects. Epidemiology studies described in the EPA Integrated Science Assessment for Particulate Matter [EPA 2009] show a 0.5 to 3.4% increase in cardiovascular emergency department visits and hospital admissions and a 1 to 4% increase in respiratory outcomes (chronic obstructive pulmonary disease (COPD), respiratory infections, asthma) for every 10 µg/m^3 increase in $PM_{2.5}$.

There is also evidence that long-term exposure to $PM_{2.5}$ can cause an increase in mortality (i.e., all-cause and cardiovascular), respiratory symptoms, incident asthma, and pre-term birth, and reductions in birth weight, and pre-term birth with long-term mean $PM_{2.5}$ concentrations in the range of 10–32 µg/m^3 [EPA 2009, 2012].

A recent EPA study evaluated air quality trends from 2005–2007 at more than 2,000 ambient air monitoring stations in metropolitan areas around the U.S. and found that more than half of these stations had $PM_{2.5}$ and PM_{10} annual average concentrations greater than the WHO AQGs. This same study found that $PM_{2.5}$ and PM_{10} 24-hour averages exceeded the WHO AQGs in more than 5% of the samples [EPA 2009]. ATSDR is providing these data to put background concentrations into perspective for the reader—not to imply the acceptability of the levels from a public health perspective.

A summary of PM results is shown in Table 4. The 8-week integrated average concentrations are used as a surrogate for an annual mean.

Short-term exposure to $PM_{2.5}$ and PM_{10}

People with respiratory or heart disease, the elderly and children are the groups most at risk for health effects due to $PM_{2.5}$, and people with respiratory disease are the group most at risk for effects from PM_{10}.

ATSDR monitored PM_{10} during the Wedron EI at five sites with collocated monitoring at site 3 (Table 4). The highest 24-hour average PM_{10} concentrations ranged from 34 µg/m^3 at Site 1 to 48 µg/m^3 at Site 5. None of the 24-hour average PM_{10} concentrations exceeded WHO's 24-hour AQG of 50 µg/m^3. Thus ATSDR concludes that short-term exposure to PM_{10} concentrations in Wedron, IL are not likely to cause adverse acute effects. $PM_{2.5}$ was only measured at Site 2 due to lack of additional monitoring equipment (Table 4). The highest 24-hour average $PM_{2.5}$ concentration was 21 µg/m^3 and is below the WHO 24-hour AQG (25 µg/m^3).

Table 4. Summary of Particulate Matter (PM) Monitoring Results and Screening Analysis

PM Type*	Site ID†	Number of Valid	Short-Term Effects Evaluation:	Long-Term Effects Evaluation: Study Mean Concentration ($\mu g/m^3$)	Long-Term Effects Evaluation: 95% Upper Confidence Limit of Mean (UCL) §
$PM_{2.5}$	2	60	21	9.9	**10**
PM_4	1-P	29	17	7.9	15
PM_4	1-C	29	17	8.1	15
PM_4	2	29	22	10	20
PM_4	3	29	19	8.7	16
PM_4	4	29	23	11	19
PM_4	5⁋	11	22	10	21
PM_{10}	1	58	34	15	16
PM_{10}	2	60	46	**21**	**22**
PM_{10}	3-P	60	36	19	19
PM_{10}	3-C	58	36	17	18
PM_{10}	4	60	41	**20**	**20**
PM_{10}	5⁋	26	48	**20**	**21**

* For $PM_{2.5}$, health screening value is 25 micrograms per cubic meter ($\mu g/m^3$) (short-term evaluation) and 10 $\mu g/m^3$ (long-term evaluations); no health screening levels available for PM_4; for PM_{10}, health screening value is 50 $\mu g/m^3$ (short-term evaluation) and 20 $\mu g/m^3$ (long-term evaluations). Concentrations above health screening levels in bold

† C = collocated; P = primary

‡ 24-hour averages and program averages for continuous monitors were calculated based on 1-hour measurements.

§ 95% UCL = 95 percent upper confidence limit of mean

⁋ Site 5 was set up nearly a month into the program, therefore there are fewer samples at this site

Long-term exposure to $PM_{2.5}$ and PM_{10}

The 8-week average PM_{10} concentration ranged from 16 µg/m^3 (95th UCL) at Site 1 to 22 µg/m^3 (95th UCL) at Site 2. The program average PM_{10} concentration exceeded, but was nearly equal to, the WHO annual AQG of 20 µg/m^3 at Sites 2, 4, and 5.

ATSDR evaluated average $PM_{2.5}$ levels to determine the likelihood of noncancer health effects from chronic exposure to particulate matter. The average $PM_{2.5}$ concentration was 9.9 µg/m^3 (95th UCL= 10.2 µg/m^3), which is nearly equal to the annual WHO AQG used for screening. The risk for various outcomes has been shown to increase with particulate exposure, and there is little evidence to suggest that a threshold exists below which no adverse health effects would be anticipated. In fact, the lower range of concentrations at which adverse health effects has been demonstrated is not greatly above the background concentration, which has been estimated at 3-5 µg/m^3 in the United States for $PM_{2.5}$. In 2012, EPA completed a review and assessment of numerous recent studies that were not included in their 2009 PM assessment [EPA 2012]. EPA concluded that there is evidence for an association between long-term exposure to $PM_{2.5}$ and mortality (i.e., all-cause and cardiovascular) within the range of long-term mean $PM_{2.5}$ concentrations of 10–32 µg/m^3 [EPA 2012]. Studies provide evidence for respiratory symptoms and incident asthma, as well as respiratory hospitalizations, at long-term mean $PM_{2.5}$ concentrations ranging from 9.7–27 µg/m^3 [EPA 2012].

Current scientific evidence indicates that existing guidelines cannot lead to complete protection against adverse health effects of PM, as thresholds have not been identified. Rather, the standard-setting process needs to achieve the lowest concentrations possible in the context of local constraints, capabilities and public health priorities [WHO 2006].

PM_4

In occupational settings, particles of most interest are those most likely to penetrate the lower lung and are smaller than four micrometers (µm) in aerodynamic diameter (millionths of a meter), called particulate matter 4 (PM_4). Since silica dust is largely an occupational hazard, guidelines for silica only apply to the concentration in the PM_4 fraction of particulates. There are no ambient air guidelines for PM_4 mass to compare to measured concentrations. PM_4 mass was only measured to determine concentrations of silica that can be compared to CVs. An EPA health risk assessment of crystalline silica concluded that for healthy individuals not compromised by other respiratory ailments, the former PM_{10} NAAQS (50 µg/m^3) offers adequate protection against silicotic effects from environmental dust containing 10% or less crystalline silica in the PM_{10} fraction [EPA 1996].

Silica

Crystalline silica compounds are odorless solids composed of silicon and oxygen atoms. Silica is abundant in the environment and has many uses. Over 95% of the earth's crust is made of silica-containing minerals and crystalline silica. Silica sand and gravel are used for building and construction, hydraulic fracturing, ceramics, and abrasives. Quartz, one form of crystalline silica commonly found in the environment, is the major component (90–95%) of all sand and silt fractions in soil. Silica sand has been used throughout history to make glass. Crystal quartz forms of silica are used in jewelry, electronics, and the optical component industry [ATSDR 2017].

Silica compounds can be released into the environment by natural, industrial, and farming activities. Crystalline silica is emitted as a component of particulate emissions into the environment. Local meteorological conditions, such as wind and rain can influence the location and spread of silica-containing dust. Persons may be exposed to silica compounds from the air, indoor dust, food, water, soil, and various consumer products. Human exposures to crystalline silica that have the potential to impact human health occur mainly in industrial and occupational settings, and people who work where silica is mined or used are exposed to higher levels of these substances than the general population. In addition, residents living near quarries, sand and gravel operations, or drilling involving fracking may be exposed to elevated levels of respirable crystalline silica [ATSDR 2017].

Health effects on the respiratory system (i.e., silicosis) are the most sensitive effects of inhaled respirable crystalline silica. Smaller silica particles (<5 microns) may deposit in the terminal bronchioles and alveoli, from where they are cleared by lymph drainage, macrophage phagocytosis and migration, and upward mucociliary flow. Silica particle clearance can take years to occur and particles will continue to accumulation with repeated exposures to airborne silica. Various occupational exposures to respirable crystalline silica have demonstrated exposure-response relationships for silicosis and mortality due to silicosis (a progressive, fibrotic lung disease). Silicosis is a serious adverse effect that may cause death due to respiratory failure or lung cancer. Respirable crystalline silica exposure is also associated with increased risk of COPD, pulmonary tuberculosis, and renal and autoimmune diseases [NIOSH 2002; ATSDR 2017].

Silica has also been documented to cause cancer. The National Toxicology Program (NTP) 14th Report on Carcinogens listed respirable crystalline silica, primarily quartz dusts occurring in industrial and occupational settings, as known to be a human carcinogen based on sufficient evidence of carcinogencity from studies in humans [NTP 2016]. Also, the WHO International Agency for Research on Cancer (IARC) has classified respirable crystalline silica in the form of quartz or cristobalite dust as carcinogenic to humans (Group 1) based on sufficient evidence in humans for the carcinogenicity of crystalline silica in the form of quartz or cristobalite and sufficient evidence in experimental animals for carcinogencity of quartz dust. Neither NTP nor IARC have derived inhalation unit risk for respirable crystalline silica [NTP 2016; IARC 2012]. ATSDR and EPA has no carcinogenicity assessment for crystalline silica. In the absence of other CVs, ATSDR compared the measured concentrations of silica in Wedron to cancer effect levels found in the literature.

Although neither ATSDR nor EPA have derived CVs for any route or duration of exposure to crystalline silica, the agencies agree on the following:

- Health effects on the respiratory system (i.e., silicosis) are the most sensitive effects of inhaled crystalline silica.
- Identification of a no-effect or threshold level for silicosis is highly uncertain due to several factors.
- Silicosis is a serious adverse effect that has the potential to cause death due to respiratory failure or lung cancer.

CA OEHHA derived a chronic inhalation REL of 3 µg/m^3 to prevent silicosis. The REL was based on a study on gold miners exposed to dust with 30% respirable crystalline silica – alpha quartz that observed an increase in silicosis with continuous lifetime exposure at a human equivalent concentration of 9.8 µg/m^3. The REL is defined as the concentration at or below which no adverse health effects are anticipated for a specified exposure duration.

There are no acute- or intermediate-based comparison values for crystalline silica. ATSDR compared study-average concentrations against the CA OEHHA chronic inhalation REL (3 µg/m^3) to assess the potential for chronic noncancer effects. To assess the potential of silica concentrations in Wedron to cause cancer, ATSDR compared the measured concentrations to cancer effect levels found in the literature. The results of PM_4 crystalline silica dust samples are presented in Table 5.

Table 5. Summary of Particulate Matter Four Microns or Smaller (PM_4) Mass and Crystalline Silica Concentration Results

Site*	Number of Samples	PM_4 Max, µg/m³†	PM_4	Number of Silica Non-	Silica Max, µg/m³	Number of Silica Samples > comparison value§	Silica Mean, µg/m³	Silica 95% UCL⁋, µg/m³
1-P	29	17	7.9	9	1.2	0	0.63	0.70
1-C	28	17	8.1	11	3.4	1	0.67	0.88
2	29	22	10	7	3.8	2	1.1	1.3
3	29	19	8.7	10	2.1	0	0.82	0.97
4	29	23	11	6	3.6	1	1.3	1.6
5**	11	22	10	4	2.2	0	0.88	1.2

* C = collocated; P = primary
† µg/m³ = micrograms per cubic meter
‡ Mean concentrations calculated with robust regression on order statistics (ROS) to handle non-detect results.
§ California Office of Environmental Health Hazard Assessment Reference Exposure Level, 3 µg/m³
⁋ 95% UCL = 95 percent upper confidence limit of mean
** Site 5 was set up nearly a month into the program, therefore there are fewer samples at this site

Crystalline silica content of a bulk sample, collected about 100 meters from Fairmount, was 31% of alpha-quartz and other silicates. Cristobalite and tridymite were not detected. Mined and processed sand typical grade crystalline silica content is usually above 99% alpha-quartz.

The highest 8-week average of 1.3 µg/m³ (UCL 1.6 µg/m³) occurred at Site 4. None of the location averages exceeded the CA OEHHA Chronic REL of 3 µg/m³. The maximum 24-hour concentrations ranged from 1.2 to 3.8 µg/m³.

The findings at Site 4 are consistent with the year-long monitoring that Wedron Silica conducted on their property. The Wedron monitor near the north property line had an arithmetic mean of 1.4 µg/m³ during March 2015-March 2016 [EPA 2016]. Site 4 is the closest of the EI locations to the north property line. Good comparability between the two air monitoring studies also gives some evidence that an 8-week snapshot of air quality conditions may be representative of longer-term exposures. Additional analysis can be found in Appendix C.

ATSDR did not obtain a detailed inventory of process emissions at Fairmount. This EI cannot assess which specific operations contribute the greatest amount of crystalline silica and PM to the concentrations measured at residential areas. However, it is notable that the polar plots for PM_4 silica show a dominant influence when winds are from the southeast, while $PM_{2.5}$, PM_4, and PM_{10} mass are all highest when winds are directly from the south. This distinction is consistent with the knowledge that operations south of Wedron residential areas work with rough mined silica sand (which contains both silica itself and sand/soil contaminants), while the portion to the southeast (Technisand) transports and treats refined PM_4 crystalline silica. Additional information is in Statistical, Temporal, and Spatial Analysis section below.

Non-cancer health effects

ATSDR evaluated the average concentration at each site for the duration of the EI to estimate the potential for non-cancer chronic effects. The highest site 8-week average 24-hour concentration was 1.3 µg/m³ measured at Site 4. The 95% UCL of the 8-week EI was 1.6 µg/m³. These concentrations are both lower than the REL.

The highest 24-hour concentration of PM_4 crystalline silica concentration was 3.8 µg/m³ (measured at Site 2), which is just above the REL of 3.0 µg/m³ for long-term exposures, i.e., the level below which no adverse health effects are anticipated for chronic exposure. This 24-hour peak was below the lowest observed adverse effect level of 9.8 µg/m^3 for a continuous lifetime of exposure. Thus, long-term exposure to PM_4 silica concentrations in Wedron are not expected to cause adverse health effects.

Quantitative Carcinogenic Assessment

In the absence of a cancer comparison value, ATSDR also compared the concentrations measured in Wedron with cancer effect levels documented in literature. NTP, NIOSH and IARC have independently reviewed and published summaries of lung cancer studies [ATSDR 2017, NTP 2016]. In its review of literature, ATSDR identified two studies that characterize the lower end of silica exposures that show an increased risk of lung cancer for comparison to the concentrations measured in the EI. The first [Hughes 1995] observed an increase in lung cancer (90 cases in 2,670 total workers) in industrial sand workers exposed to 160-260 µg/m^3 silica dust for a duration of employment between 2.4 and 41.1 years. The highest site UCL, measured at site 4 (1.6 µg/m^3) was roughly 100 times lower than that associated with an increase in lung cancer in this occupational study.

The second study [Steenland 2001] also reported an increase in lung cancer in a pooled study of industrial sand workers (74 cases in 4,626 total workers). This study incorporated 10 cohorts with a range of median cumulative exposure concentrations (0.13-11.37 mg-years/m^3) and durations (3.7-26.8 years). Statistically significant increases in lung cancer were observed in the 3rd quintile of cumulative exposure (2-5.4 mg-years/m^3). Using the highest measured site UCL from Wedron of 1.6 µg/m^3 and assuming continuous exposure (over a similar duration 30 years) would yield a cumulative exposure of 0.048 mg-years/m^3.The lowest exposure associated with lung cancer in the Steenland et al. 2001 study (2 mg-years/m^3) is nearly 42 times higher than what was measured at Wedron.

Although there may not be a threshold for the onset of lung cancer, exposure levels measured in Wedron were more than an order of magnitude lower than those associated with an increase in lung cancer. ATSDR concludes that exposure to silica in Wedron is not likely to result in unreasonably elevated risk of cancer.

Statistical, Temporal and Spatial Analysis

This section discusses the relationship of the PM_4 crystalline silica to PM_4 mass, as well as $PM_{2.5}$, PM_4, and PM_{10} temporal and spatial trends, providing insights to the local and regional sources of silica and PM.

Polar plots show relationships between measured concentrations of a pollutant, wind speed, and wind direction. Polar plots of PM_4 silica are shown in Figure 3. Similar plots for PM_{10} and $PM_{2.5}$ are shown in Figure C6 and C8 in Appendix C.

The highest measured PM_4 silica concentrations were from Site 4 when winds were from the southeast (Figure - 4). A general pattern of higher concentrations with winds from the south (ranging from southwest to southeast) was observed at Site 2, Site 3, Site 4, and Site 5; this is consistent with silica emissions from Fairmount and associated truck/rail loading operations. Additionally, Site 2 showed impacts from the northwest, which may indicate emissions from truck traffic. Site 1, located across the Fox River, showed a slight elevation in silica concentrations when winds were from the industrial areas to the north/northwest. These polar plots suggest that the largest source of silica is to the southeast of Site 4 and that there may be additional sources to the south and southwest of Site 4.

To further investigate the source of silica, the ratio of PM_4 silica to total PM_4 mass was calculated for each sample. Polar plots of this ratio are shown in Figure 4. These plots show that there is more silica (relative to total mass) at Site 4 and Site 5 when winds are from the South or Southeast. Ratios at all other sites, for all wind directions, are typically below 15%. These plots indicate that there may be two sources of PM_4 silica, a dominant source to the southeast of Site 4 and Site 5 (the silica sand loading operations), with a smaller source to the south of these two sites (Wedron Silica sand processing). Additional analysis is provided in Appendix C.

Figure 3. Polar Plots of PM_4 Silica

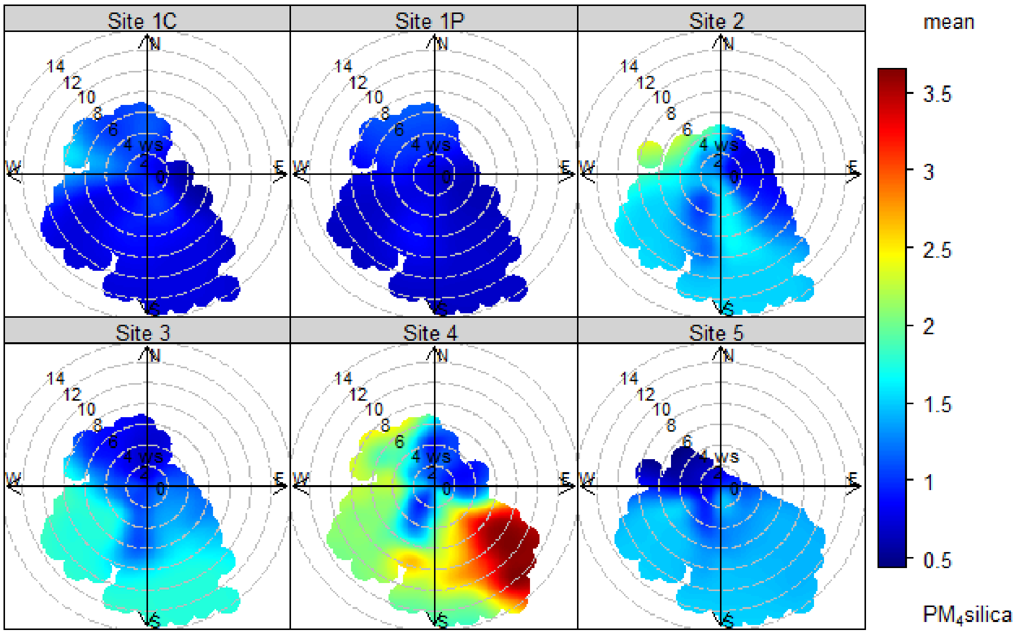
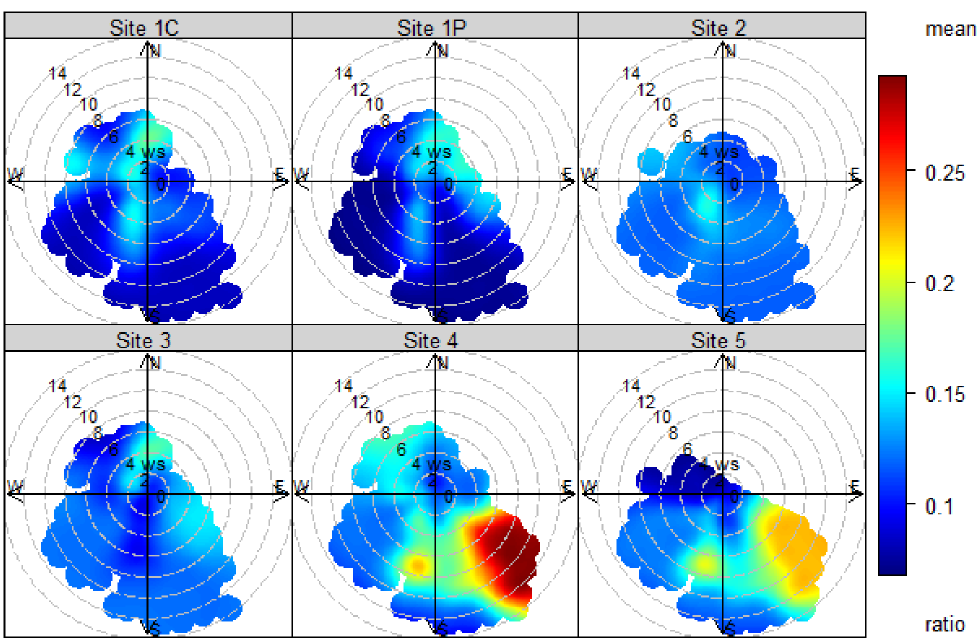


Figure 4. Polar Plots of PM_4 Silica: PM_4 Mass Ratio



Limitations

ATSDR acknowledges that all scientific investigations, such as the Wedron EI, have limitations. These include:

- Monitoring was conducted at fixed, stationary locations; however, people move around, and do not remain in one place all day long. Therefore, the data collected at the fixed locations are not directly equivalent to actual exposures that may have occurred.
- The monitoring only measured some of the potential contaminants associated with large surface sand mining, processing, and transportation of the final product. ATSDR's choice of contaminants was based on community concerns and careful review of current scientific knowledge about potential hazards in Wedron. ATSDR did not evaluate exposures to volatile and semi-volatile organic contaminants from Fairmount, such as vehicle emissions, and the resin coating operations.
- The data collected during this program represent air quality conditions from October 5, 2016 to December 3, 2016. While this 8-week time period represents just a snapshot of time, results are consistent with previous long-term monitoring and may be representative of community exposures throughout the year.
- Collocated $PM_{2.5}$ measurements were not collected, thus there were no measurements available to assess monitoring precision of the E-BAM results for this pollutant. However, collected measurements were available for the other two pollutants evaluated during this EI (PM_4 crystalline silica and PM_{10}).
- $PM_{2.5}$ was only measured at one site, Site 2, which is the station that recorded the highest PM_{10} concentration. $PM_{2.5}$ was not measured at Site 4, which observed the highest PM_4 crystalline silica levels.
- The EI program met most, but not all, of its intended data quality objectives. PM_{10} measurement precision, which is quantified by comparing two side-by-side monitors, was not within the specified bounds.

Conclusions

After a careful evaluation of the measured pollutant concentrations, ATSDR has come to the following conclusions:

Conclusion 1

Long-term and short-term exposure to PM_{10} and $PM_{2.5}$ in Wedron and the surrounding area is not likely to result in harmful health effects to the general population.

Basis for Conclusion 1

- The 8-week average concentrations for PM_{10} and $PM_{2.5}$ were approximately equal to long-term health-based guidelines from the WHO.
- None of the 24-hour average PM_{10} or $PM_{2.5}$ concentrations exceeded the WHO's 24-hour Air Quality Guidelines.
- Reported literature indicates that exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6-13% per 10 micrograms per cubic meter ($\mu g/m^3$) of $PM_{2.5}$ and susceptible groups are particularly vulnerable [WHO 2006]. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur. However, no significant health effects are expected in healthy individuals among the general public.

Conclusion 2

Long-term exposure, and to a lesser extent short-term exposure, to PM_{10} and $PM_{2.5}$ in Wedron and the surrounding area may contribute to harmful health effects in sensitive populations: the elderly, children, and individuals with preexisting heart and lung disease.

Basis for Conclusion 2

- Prolonged, long-term, exposure to PM, especially $PM_{2.5}$, above the AQGs may slightly increase the likelihood of harm to individuals with pre-existing health conditions, such as lung and heart diseases, the elderly, and children.
- Although short-term exposures were below the AQG, current science does support evidence that in some instances, small increases in risk are possible for highly sensitive populations at concentrations below the AQGs.

Conclusion 3

Concentrations of PM_4 crystalline silica in outdoor air are not likely to cause harmful health effects to people in the residential areas of Wedron.

Basis for Conclusion 3

- The highest average concentration for the 8-week EI period is below the CA OEHHA Reference Exposure Level (REL) of 3.0 $\mu g/m^3$. These short-term results are consistent with a previous 1-year monitoring study that EPA required Fairmount to conduct.

- Study sites were near the sand processing operations, as well as truck and train car loading, sand coating, and along the truck transit routes offsite of Fairmount. By monitoring at five distinct locations, with varying distances from different facility operations, ATSDR was able to document that silica was below the CV throughout the Wedron community.

Recommendations

Following its review of available information, ATSDR recommends that:

1. Fairmount should implement best practices to limit point and fugitive emissions of particulate matter throughout their site operations. Particle emissions should be well controlled at all stages of production: extraction, transportation to the facility, processing and production, handling and storage of intermediate, byproducts and waste, and shipping of final products. Trucks that drive through the community should be covered and cleaned off before leaving the facility.
2. If Fairmount workers are concerned about occupational exposures to PM_4 crystalline silica dust and potential health effects, they may request that a Health Hazard Evaluation should be performed by the National Institute for Occupational Safety and Health (NIOSH). Any actions to reduce silica dust emissions will benefit workers and the community alike, because crystalline silica dust generated from Fairmount activities migrate offsite to nearby residents.

Public Health Actions Planned

ATSDR will share results of this investigation at a public meeting in Wedron. ATSDR should educate the community on actions that the elderly, children, and individuals with heart and lung disease can take to protect themselves against particulate matter exposures. Fairmount will be invited and given the opportunity to tell the community what they are doing to control PM emissions from sand processing and transportation activities. ATSDR will also invite other stakeholders including EPA Region 5, State Agencies, and local agencies to communicate the findings and public health options available to reduce community exposures to PM_4 crystalline silica, $PM_{2.5}$ and PM_{10}. ATSDR will also follow-up with all partners to assure that the recommendations or public health actions were taken.

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Appendix A. Exposure Investigation Protocol

Exposure Investigation Protocol

Ambient Exposures to Airborne Crystalline Silica Dust in Wedron, Illinois

Cost Recovery Number: AP6J00

September 22, 2016

Prepared by:
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Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations

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Abbreviations

Abbreviation	*Definition*
ATSDR	Agency for Toxic Substances and Disease Registry
CA OEHHA	California Office of Environmental Health Hazard Assessment
CDC	Centers for Disease Control and Prevention
COC	chain of custody
CV	health-based comparison value
DAS	data acquisition system
DQO	data quality objectives
E-BAM	beta attenuation monitor (Met One)
EI	exposure investigation
ERG	Eastern Research Group, Inc.
HASP	health and safety plan
HC	health consultation
Illinois EPA	Illinois Environmental Protection Agency
LPM	liter per minute
MDL	method detection limit
MDPH	Minnesota Department of Health
$\mu g/m^3$	micrograms per cubic meter
mg/m^3	milligrams per cubic meter
NAAQS	National Ambient Air Quality Standards
NIOSH	National Institute for Occupational Safety and Health
PEL	permissible exposure limit
PM	particulate matter
QA	quality assurance
QC	quality control
REL	reference exposure level
TWA	time-weighted average
U.S. EPA	United States Environmental Protection Agency

Introduction

Purpose

The Agency for Toxic Substances and Disease Registry (ATSDR) will conduct an exposure investigation (EI) to assess community exposures to ambient airborne crystalline silica dust near the operations of Wedron Silica Company and Technisand, Inc. (collectively "Wedron Silica"), in Wedron, Illinois. Residents of Wedron are concerned about exposure to airborne crystalline silica dust from the nearby silica sand mining, processing, and transportation operations for natural and resin-coated silica sand. ATSDR is interested in crystalline silica particles that are 4 micrometers (millionths of a meter, abbreviated as µm) or less in diameter, called PM_4 for short. PM_4 represents the respirable fraction of particulate matter, with a 50% probability of penetration to the alveolar region of the lung.[1] For this EI, ATSDR will conduct a community-based ambient air monitoring program from October to early December 2016 to obtain representative concentrations of PM_4 crystalline silica for the community, as well as concentrations of PM_{10} (particulate matter whose particles are 10 µm or less in diameter) and $PM_{2.5}$ (particulate matter 2.5 µm or less in diameter) and local meteorology data.

Objective

The objective of this EI is to determine if community exposures to PM_4 crystalline silica, $PM_{2.5}$, and PM_{10} are occurring at levels of health concern in Wedron, Illinois. Ambient air concentrations of these pollutants will be measured at locations downwind from the sources (silica plant and rail/truck routes) within the residential area. ATSDR will examine the data for public health implications, considering the magnitude, the frequency, duration, and location of exposure as well as meteorological conditions.

Note that this investigation is designed to evaluate community exposures to the selected pollutants, not to determine regulatory compliance with any National Ambient Air Quality Standards (NAAQS).

Explanation of Exposure Investigations

An ATSDR EI is used to fill data gaps in evaluating community exposures. Its purpose is to better characterize exposures to hazardous substances in the environment and to evaluate possible public health consequences related to those exposures.

An EI is designed to identify the most highly exposed people and to characterize the magnitude of their exposure. It is intended to be a public health service for the participants. EI results are not generalizable to other populations, and not considered to be research.

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[1]Recommended exposure limits for crystalline silica (quartz, cristobalite, tridymite) apply to particles of respirable size fraction, which occupational hygiene methods define as particles with aerodynamic diameters of 4 micrometers or less with a 50% probability of penetration to the alveolar region of the lung. This is where the most critical toxic effects for crystalline silica—silicosis and cancer—are believed to occur (Cal EPA 2005). The occupational hygiene classification is different the U.S. Environmental Protection Agency's definition: inhalable coarse particles are those with nominal mean aerodynamic diameters greater than 2.5 and less than or equal to 10 micrometers, and inhalable fine particles as those less than or equal to 2.5 micrometers in diameter (U.S. EPA 2009).

An EI must meet four criteria:

1. Can an exposed population be identified?
2. Does a data gap exist that affects your ability to determine if a health hazard exists?
3. Can an EI address the data gap?
4. How would the EI results impact public health decisions?

These questions were used in the decision-making process for the Wedron EI; the responses are presented in Appendix A and are also discussed throughout the sections that follow.

Results

The results of this EI will be presented in a health consultation (HC) report. The HC will include an evaluation of the data, conclusions, and recommendations for appropriate actions to reduce exposures if necessary. ATSDR will also use the data collected from this EI to inform Wedron residents about the potential exposure levels to PM_4 crystalline silica, coarse and fine dust (PM_{10} and $PM_{2.5}$, respectively) and potential health implications associated with the detected levels.

ATSDR will work with partners including the U.S. Environmental Protection Agency (EPA), LaSalle County Health Department, Illinois EPA, and Illinois Department of Public Health to determine appropriate health-protective actions based on the EI findings.

Investigators/Collaborators

Agency for Toxic Substances and Disease Registry

Motria Caudill, PhD, and Custodio Muianga, PhD, MPH, will serve as co-principal investigators for this EI. They will serve as the primary liaison and contact between ATSDR and the U.S. EPA, the LaSalle County Health Department, and the community.

The co-principal investigators have developed this protocol and will work with a support contractor, Eastern Research Group, Inc. (ERG), to implement the field program. They will obtain participant consent and oversee the overall deployment, operation, and recovery of the air monitoring/sampling systems. The co-principal investigators will oversee the data reporting, quality control/quality assurance, report writing, and communications with ERG.

ERG's program manager, Ms. Naida Gavrelis, will provide administrative oversight for ERG. Mr. Schott Scholar will serve as ERG project director. Mr. Dave Dayton will serve as the ERG senior technical advisor. ATSDR co-principal investigators will work with this ERG leadership to implement and manage all EI activities from planning through reporting. ERG will identify and choose the laboratory for analysis of the samples as well as coordinating and executing the chain of custody (COC) as part of quality control assurance plan.

Mr. Sholar also will serve as the primary field scientist. He will secure equipment, perform the pre-deployment checkout of the measurement and sample collection systems, and deploy those systems. Mr. Sholar is also responsible for ensuring that ERG staff perform daily site visits, collect samples, download data, and recover equipment. He will coordinate and train other qualified staff, as needed, to implement these activities.

Other Partners

The U.S. EPA required Wedron Silica to collect 1 year of monitoring data for PM_{10} and respirable crystalline silica in ambient air in the Wedron community. The company performed PM_4 crystalline silica and PM_{10} monitoring from February 2015 to March 2016. ATSDR's preliminary analysis of the data is presented in the "Background and Community Concerns" section below.

U.S. EPA Region 5 and the LaSalle County Health Department will also support this investigation. ATSDR will involve these partners in review of the draft HC, including findings and recommendations for follow-up action.

Background and Community Concerns

Inhalation of respirable crystalline silica particles has long been known to cause silicosis and is associated with increased risk for lung cancer (NTP 2014). The International Agency for Research on Cancer and the U.S. National Toxicology Program have designated respirable crystalline silica as a human carcinogen (IARC 1997; NTP 2014). In addition, inhalation of crystalline silica has been associated with other respiratory diseases such as chronic obstructive pulmonary disease, bronchitis, and emphysema, as well as kidney and immune system diseases.

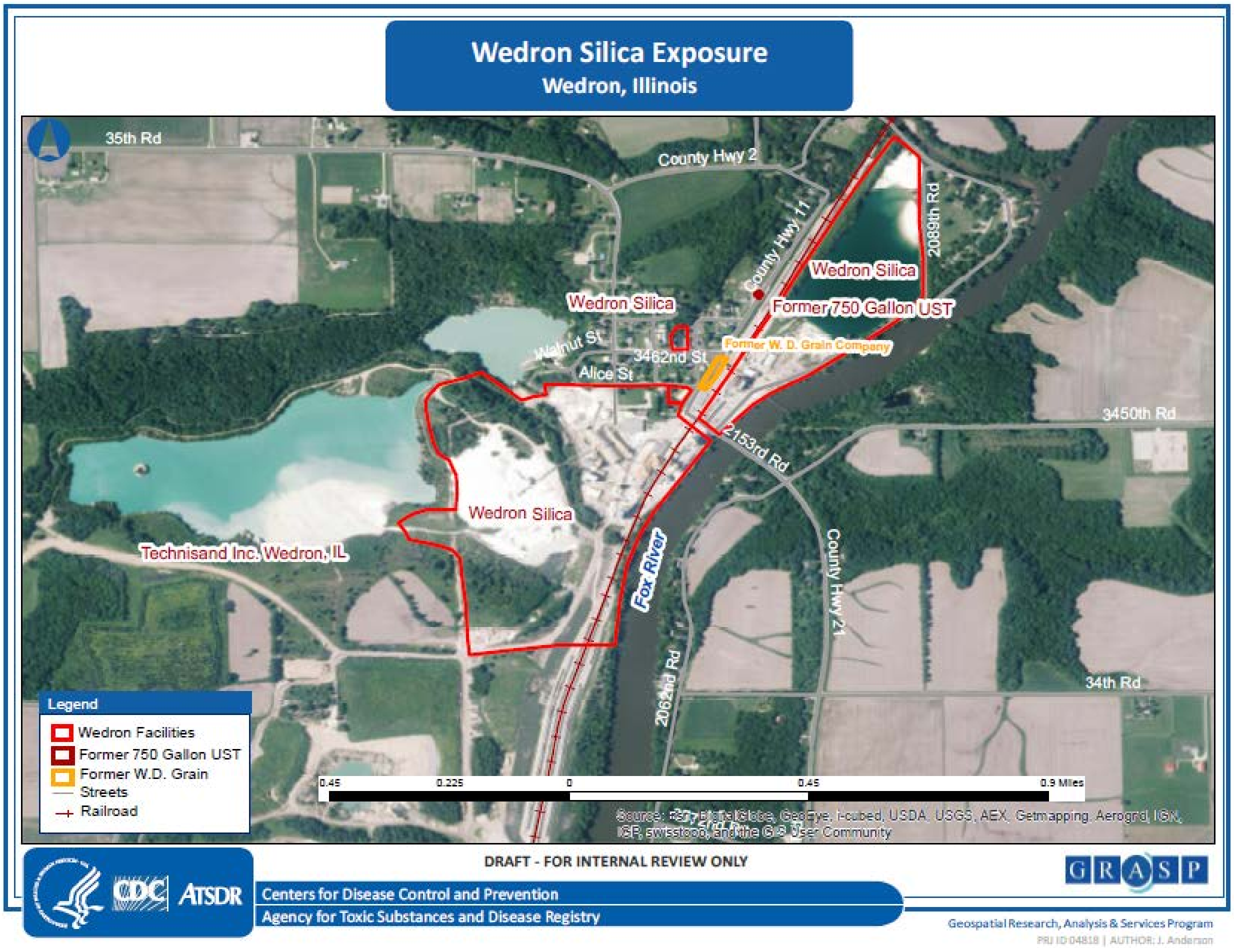
The residential community of Wedron lies close to silica sand mining and silica sand processing operations, truck and railcar loading operations, and phenol resin sand coating operations. Fugitive sand has been observed on the sides of streets and on residential properties. Residents have reported that the sand enters their houses, fills their gutters, and covers their cars. Residents are concerned about their levels of exposure to silica and potential associated health effects.

Site Description

Wedron Silica is housed in a mixed rural, residential, and industrial area of Wedron, an unincorporated community in LaSalle County, Illinois. North of the site are residential homes, agriculture, and undeveloped land. East of the site are the Fox River, agriculture, and undeveloped land. South are Wedron Silica's sand-mining facility and mining pits; to the west are two Wedron Silica quarries, agriculture, and undeveloped land. The main rail line that runs generally north-south through Wedron is owned by the Illinois Railway Company. Figure 1 shows an aerial view of the area, which contains about 50 residential properties, a few businesses, and a fire station.

Sand has been mined in Wedron for many years. Commercial and industrial properties in the area include Fairmount Minerals Ltd., the Wedron Silica Mining Co., and the Illinois Railway Railroad Company. (Fairmount was formed in 1986, when Wedron Silica Company merged with the Best Sand Corporation.) The Fairmount Minerals subsidiaries, Wedron Silica Company and Technisand Wedron, operate the railroad spurs. Wedron Silica Company owns and operates a sand mining facility, with sand mining pits and ancillary operations for mining, processing, and loading for shipment by rail or truck; the main Wedron Silica processing facility is south of County Highway 21. Technisand, Inc., north of Highway 21, owns and operates a resin coating facility and rail/truck loading facilities.

Figure 1. Aerial View of Wedron Silica and the Surrounding Area



Target Population: Age, Sex, Race/Ethnicity, and Sensitive Population

The 2010 U.S. Census reports that 419 people reside within 1 mile of the Wedron Silica site. The population is predominantly white. About 4% of the population identify as American Indian, Alaska Native, or Hispanic or Latino. Twenty-five children and 47 adults 65 years and older live within 1 mile of the town of Wedron. Figure 2 presents more information, including age, race and ethnicity, and population within certain distances of the site.

Figure 2. General Population Profile: Wedron, LaSalle County, Illinois

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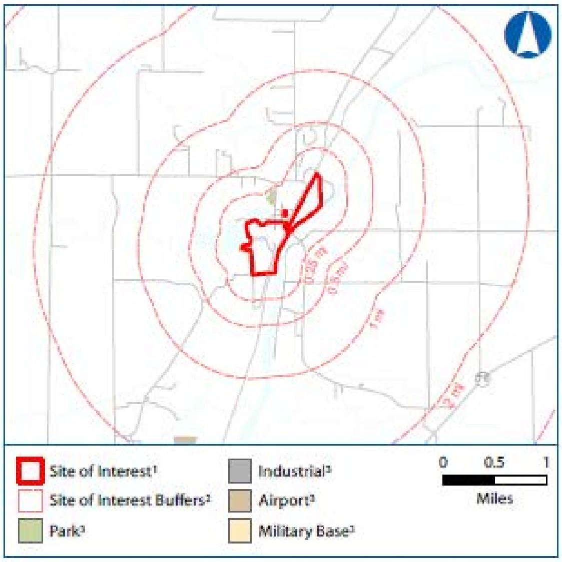
INTRODUCTORY MAP SERIES

Wedron Silica Exposure Investigation

Wedron, LaSalle County, IL

GENERAL SITE PROFILE

Site Vicinity Map



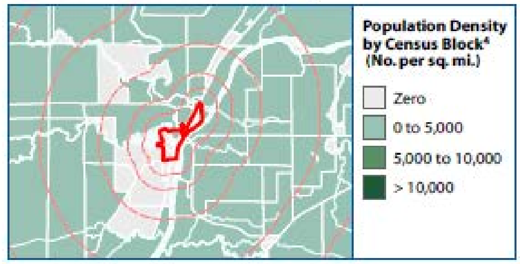
The **General Site Profile Map** depicts the hazardous waste site of interest, along with any airport, industrial, military, or park land uses. It also provides community demographic and housing statistics.

Demographic Statistics[4,5]

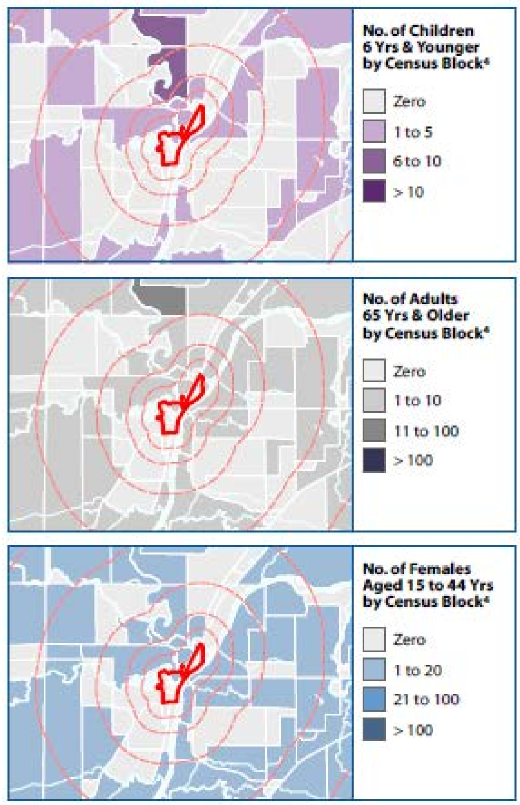
Within 1 Miles buffer of site boundary

Measure	2000	2010	Change
Total Population	460	419	-8%
White Alone	459	416	-9%
Black Alone	0	0	+0%
Am. Indian & Alaska Native Alone	0	1	N/A
Asian Alone	0	0	+0%
Native Hawaiian & Other Pacific Islander Alone	0	0	+0%
Some Other Race Alone	0	1	N/A
Two or More Races	1	1	+0%
Hispanic or Latino[6]	6	14	+133%
Children Aged 6 and Younger	43	25	-41%
Adults Aged 65 and Older	60	47	-21%
Females Aged 15 to 44	98	61	-37%
Housing Units	197	231	+17%
Housing Units Pre 1950	80	75	-6%

General Population Density



Sensitive Populations



Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom International BV (2012). [4]US Census 2010. **Notes:** [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race.
Projection: Projection used for all map panels is NAD 1983 StatePlane Illinois East FIPS 1201 Feet.

PRJ 04818 DXA0 4/7/16

GRASP

Agency for Toxic Substances and Disease Registry

Division of Toxicology and Human Health Sciences

ATSDR

FINAL - FOR PUBLIC RELEASE

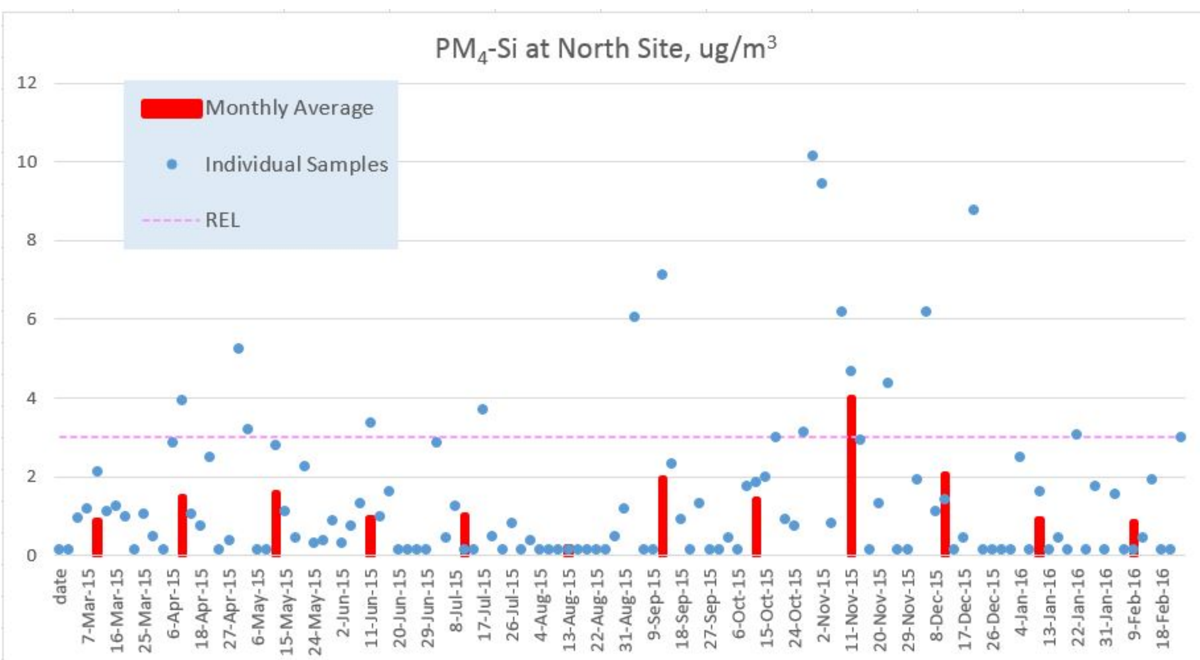
Ambient PM_4 Crystalline Silica and PM_{10} Monitoring Conducted by Wedron Silica

In response to a 2013 U.S. EPA Request for Information, Wedron Silica installed and operated ambient air samplers to measure PM_4 crystalline silica and ambient PM_{10} in two locations: one near the southern boundary of the mining area (upwind) and the other on the north side (downwind) of the Wedron Silica facility. These samplers operated for 12 months, from February 2015 to March 2016.

A total of 121 filter-based PM_4 samples were collected and analyzed for silica in both locations. For the north location, the nondetect rate was 46 samples (38%); half of the detection limit (0.30 µg/m^3) was used to produce the data summary statistics. The maximum measured concentration was 10.1 µg/m^3. The average silica concentration was 1.4 µg/m^3, with a 95% upper confidence limit of 1.8 µg/m^3. That average is approximately half the California Office of Environmental Health Hazard Assessment (OEHHA) recommended exposure level (REL) of 3 µg/m^3, the health-based comparison value (CV) for PM_4 crystalline silica. Only one monthly average exceeded the REL. During 10 of the 12 months of sampling, at least one individual sample result equaled or exceeded the REL.

Figure 3 summarizes the PM_4 crystalline silica ambient air concentrations at the "north" (downwind) monitoring site. At the same location, the 24-hour PM_{10} average concentration was 20.14 µg/m^3, with a maximum concentration of 89.32 µg/m^3. (The U.S. EPA NAAQS for PM_{10} is 150 µg/m^3.)

Figure 3. Ambient Air Concentrations of PM_4 Crystalline Silica at the Wedron Silica North Monitoring Site



Wedron Silica's air monitoring program was designed to respond to the U.S. EPA request for information on the company's emissions of airborne PM containing silica The company chose its monitoring sites to collect silica dust associated with the sand processing area and excluded other sources, such as silica dust emissions from mining operations and transportation of final product (i.e., resin-coated and uncoated silica sand). Therefore, the downwind location where samples were collected did not capture the concentrations of PM_4 crystalline silica from all potential sources that may affect the community. The monitor was on the lawn directly north of the Wedron Silica office building. The north site was downwind of the kiln dryer and various transfer and storage buildings on the Wedron Silica Company property. However, this monitor was not ideally located to capture fugitive emissions from the sand truck and train loading and resin coating operations at the east end of the Wedron Silica Company property and the adjacent Technisand plant.

The truck and train loading activities occur along the eastern edge of town on the banks of the Fox River, which is at a lower elevation than Wedron Silica's monitor site. These fugitive plant emissions and silica loss from loading and transport truck are re-entrained into the ambient air by continuous truck traffic on 2153^{rd} Road, the main public road through Wedron. The loading operations are enclosed by a chain link fence, which does not prevent sand from migrating to nearby residences.

The goal of this EI to is measure silica dust concentrations including PM_4 crystalline silica and airborne PM (PM_{10} and $PM_{2.5}$) in the residential area most impacted by all major sources of airborne silica dust (i.e., silica sand mining operations, silica sand processing operations, and resin-coated and uncoated silica sand transportation by trucks and trains).

Monitoring/Sampling Approach

Criteria for Choosing Monitoring and Sampling Locations (Siting)

ATSDR conducted a scoping visit to the area to help plan the EI. During this trip, ATSDR met with community members in Wedron. ATSDR used information gathered through these meetings and observations to develop this EI protocol, determine candidate monitoring/sampling site locations, and prepare the overall design of the monitoring approach. ATSDR will recruit and obtain informed consent agreements from the participant property owners upon approval of this EI protocol.

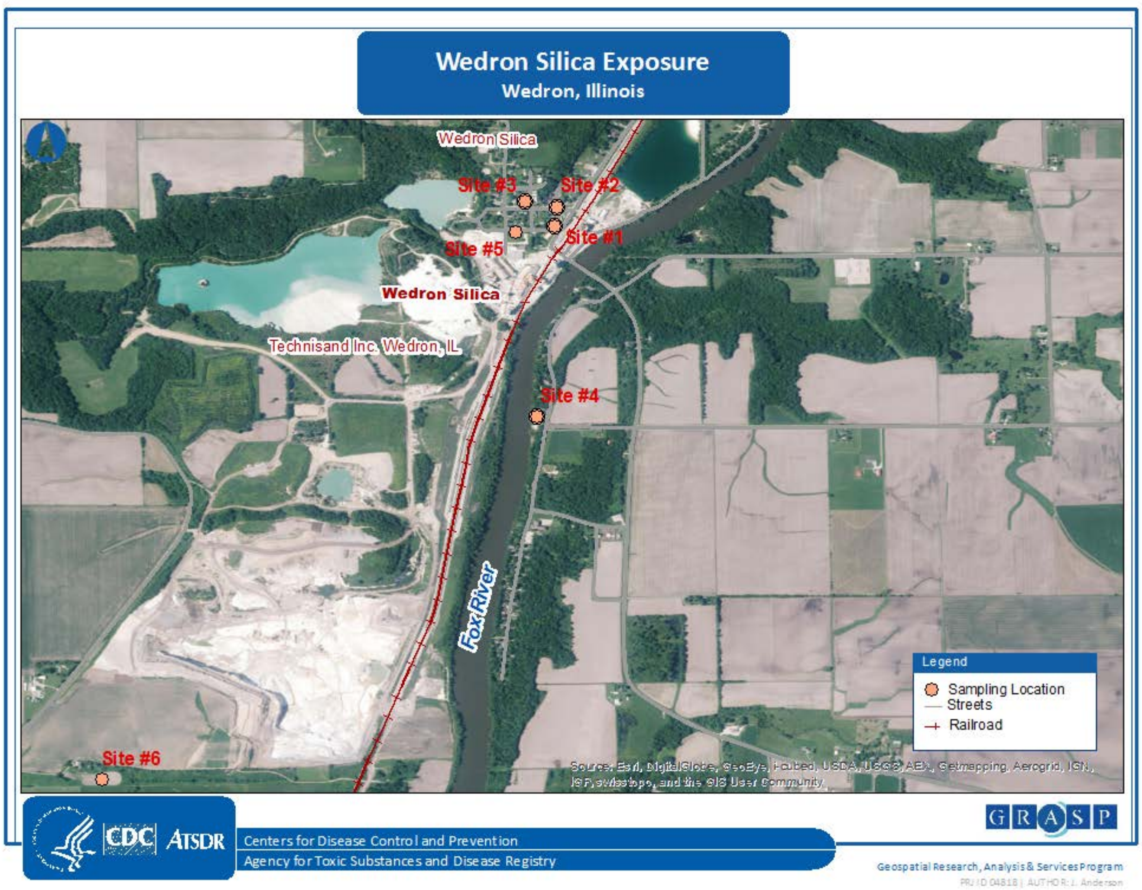
ATSDR has identified several candidate monitoring site locations, focusing on sites that were:

- Most likely to capture community exposure to airborne crystalline silica dust (PM_4 crystalline silica, PM_{10}, and $PM_{2.5}$) from fugitive dust emissions from mining operations, silica sand processing, and railcar and truck loading and transportation operations.
- Close to residential areas (from a few feet to less than 3 miles), and in places where community exposures are most likely.
- In areas where electrical service is available to support EI-related equipment.

ATSDR also considered meteorological conditions (e.g., wind direction), drawing on annual and seasonal wind roses based on meteorological data from the nearby National Weather Service station at Illinois Valley Airport. These are shown in Appendix B.

Sampling/monitoring locations generally meeting siting criteria are shown in Figure 4. Sites 1 to 4 in the figure are the proposed sampling locations for this EI; sites 5 and 6 are the monitoring locations that Wedron Silica used for their 1-year monitoring program. During the scoping visits, ATSDR received verbal approval from the property owners and verified the availability of electricity and security of prospective locations. If two or more of these prospective sites cannot be used, the site co-leads will consult with ATSDR's Division of Community Health Investigations' Associate Director of Science and the Science Support Branch Chief before beginning the monitoring.

Figure 4. Areas of Potential Exposure to Silica in Wedron, Illinois



Choosing the Investigation Time Period and Duration

The objectives of an EI are to fill data gaps relating to community exposures to environmental contaminants. EIs are not designed to be long-term environmental sampling programs (i.e., extending six months or more). If longer-term sampling is identified as being needed as a result of an EI, ATSDR may recommend further sampling to the appropriate agency or authority and indicate the sampling duration needed.

ATSDR chose late autumn for the air monitoring period. This period was chosen to coincide with the expected worst-case ambient concentrations of PM_4 crystalline silica, PM_{10}, and $PM_{2.5}$ associated with the Wedron Silica operations. Late-autumn weather is characterized by moderate temperature, and dry and windy. The prevailing wind patterns are from the west (13% to 14.5% of the time), from the west-northwest (8.5% to 14% of the time), from the south (7.5% to 12% of the time), from the southwest (4% to 7% of the time) and from the southeast (up to 6% of the time during autumn only). These conditions promote airborne dust dispersion and potential silica dust exposure to nearby community members. The 1-year Wedron Silica monitoring program recorded the highest PM_4 crystalline silica concentrations during the month of November (Figure 3).

Measurements and Data Acquisition

This EI will focus on ambient air monitoring/sampling of PM_4 crystalline silica dust, as well as PM_{10} and $PM_{2.5}$. These are the pollutants of concern to the Wedron community. The contaminants to be measured during the EI are listed in Table 1, along with their CVs. The contaminant-specific method detection limits (MDLs) or detection ranges are listed in Table 2.

The EI field staff will visit the air sampling equipment daily. In case of equipment failure, the ERG field staff will repair it as quickly as possible. Any missed sample collection will be re-scheduled to the extent possible.

Table 1. Exposure Investigation Contaminants and Associated Health-Based Screening Values

Chemical Measured	*CV*	*Source **
PM_4 crystalline silica	3 µg/m^3	CA OEHHA chronic silica REL† (Cal EPA 2005)
PM_{10}	150 µg/m^3	U.S. EPA: NAAQS, 24-hour primary‡
$PM_{2.5}$	35 µg/m^3 for 24-hour average 98th percentile averaged over 3 years 12.0 µg/m^3 annual mean, averaged over 3 years	U.S. EPA NAAQS $PM_{2.5}$ of 35 µg/m^3 for 24-hour average 98th percentile, averaged over 3 years EPA NAAQS $PM_{2.5}$ of 12.0 µg/m^3 annual mean, averaged over 3 years

CA OEHHA: California Office of Environmental Health Hazard Assessment
NAAQS: National Ambient Air Quality Standards
REL: reference exposure level
µg/m^3: micrograms per cubic meter
* In the absence of ATSDR-derived CVs, health-based screening values from other authoritative/reliable sources are used. Health-based screening values are periodically updated.
† The chronic REL represents a yearly average concentration.
‡ NAAQS are used in this document for comparison only. This investigation is not designed to determine adherence to any NAAQS.

Table 2. Exposure Investigation Contaminants, Sampling Device, and Method Detection Limit (MDL)/Detection Range (Range)

Chemical Measured	*Sampling Device*	*MDL/Range*	*Sample Duration and Frequency*
PM_4 crystalline silica	Thermo Fisher Scientific Partisol 2000i	0.3 µg/m^3–over 200 µg/m^3	24 hours every second day
$PM_{2.5}$ and PM_{10}	Met One E-BAM	0–65 mg/m^3	Hourly, continuous

mg/m^3: milligrams per cubic meter

PM_4 Crystalline Silica

ATSDR will use Thermo Fisher Scientific Partisol 2000i air samplers to collect silica samples. The Partisol 2000i uses a pump to pull air through a PM_{10} inlet and $PM_{2.5}$ sharp-cut cyclone sequentially. This air is then pumped across a pre-weighed polyvinyl chloride (PVC) filter cassette provided by the contracted analytical laboratory. The flow rate for the Partisol samplers will be set at 11.1 liters per minute (LPM) to obtain the desired size to 4.0 micrometers size particles. The samplers use a mass flow controller coupled with temperature and humidity sensors to adjust actual flow rates and maintain a rate of 11.1 LPM. The total sample volume will be calculated in accordance with the U.S. EPA's *Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere* (40 CFR Part 50, Appendix L).

Silica filter samples will be collected once every two days. The 2-day cycle will involve setting up the filter (day 1), beginning the sample collection (day 1), and recovering the filter sample (day 2). Samples will be shipped to a contracted laboratory for analysis, along with the necessary COC forms. Sample collection and analysis will be conducted in accordance with National Institute for Occupational Safety and Health (NIOSH) Method 0600 (gravimetric determination) and NIOSH Method 7500 (X-ray diffraction). The analyses will measure the following forms of respirable crystalline silica: quartz, cristobalite, and tridymite (Richards and Brozell, 2014).

Quality assurance (QA) of the Partisol samplers will be performed according to the Thermo Fisher Scientific *Partisol 2000i Air Sampler/Partisol 2000i-D Dichotomous Air Sampler Instruction Manual* and the U.S. EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems* (U.S. EPA 2013).

Crystalline Silica Bulk or Settled Dust Samples Interference Check

A variety of PM air pollutant sources contain silica. Accordingly, a contracted laboratory will conduct qualitative analysis of settled dust samples to evaluate potential interferences in determining crystalline silica content, in accordance with NIOSH 7500 (NIOSH 2003).

Fugitive Emissions of $PM_{2.5}$ and PM_{10}

$PM_{2.5}$ and PM_{10} are both associated with sand mining, bulk transfer, processing, and transportation operations.

- PM_{10} is emitted from plant processing, including operations such as conveying, screening, crushing, storing, hauling, and drying.

- $PM_{2.5}$ emissions come from both primary and secondary sources. Primary source $PM_{2.5}$ emissions include combustion-related operations either from stationary or mobile machinery at the mining site, processing facility, and train and truck traffic diesel exhaust. Secondary sources are associated with sulfur dioxide and nitrogen oxides from the dryers and combustion-related exhaust at the mining site.

Technisand, Inc. produces a resin-coated silica called Novolac. This process also may emit both PM_{10} and $PM_{2.5}$. Novolac is a phenol-formaldehyde based resin. During the coating process Novolac may decompose to phenol, formaldehyde, and ammonia. Cured coated silica sand is unlikely to release any of these volatile organic compounds during the packaging or shipping process.

Particulate Matter ($PM_{2.5}$ and PM_{10}) Monitoring Method

Measurements of continuous $PM_{2.5}$ and PM_{10} particulates will be made using Met One Instruments, Inc., real-time beta attenuation monitors (E-BAMs). These portable self-contained units are consistent with U.S. EPA requirements for automated particulate measurement. Their measurement range is 0–65 mg/m^3. They will provide measurement data on an hourly basis. Data will be stored automatically to a unit-specific internal data acquisition system (DAS). The E-BAMs used to measure $PM_{2.5}$ will incorporate a PM_{10} pre-cutter inlet followed by a sharp-cut $PM_{2.5}$ cyclone. The monitors used to measure PM_{10} will incorporate a PM_{10} pre-cutter inlet only.

Continuous measurements of $PM_{2.5}$ and PM_{10} will allow ATSDR to evaluate peaks of respirable particulate. “Real-time” monitoring will help ATSDR evaluate whether PM_{10} and $PM_{2.5}$ readings might be attributed to time-specific silica mining, processing activities, or truck traffic fugitive and exhaust emissions. For these continuous particulate monitors, the field staff will check the status of the filter tapes daily, reload the filter tapes as needed, and download the data twice a week.

Meteorological Parameters

Wind speed, wind direction, air temperature and relative humidity will be measured using a stand-alone meteorological monitoring system. This system is attached to a secured tripod or mast assembly. Measurements will be made at about 10 feet above grade or rooftop level (site-dependent).

Electronic signals from the meteorological monitoring system will be collected and stored using HOBO Micro Station DASs with 4–20 milliamp adapters and BoxCar® Pro 4.3 software. Each DAS can collect four channels of input signal simultaneously, and offers internal storage for 1 million data points per system.

Field staff will download data weekly and perform a visual check of the meteorological sensors daily. If a failure occurs, the equipment will be repaired as quickly as possible and returned to the network.

Schedule of Major Exposure Investigation Events

Table 3 lists EI major program events and timelines for an assumed 8-week program.

Table 3. Wedron Silica EI: Major Events and Timeline

Event	*Activity*	*Date*
Pre-deployment	Assess equipment before deployment. Make any necessary adjustments or repairs before deployment. Bring systems online.	Pre-deployment
Deployment	Obtain written informed consent from property owners and verify sampling/monitoring equipment placement conditions.	Before sampling
Deployment	Install/set up all equipment. Check out and calibrate equipment. Bring systems online. Repeat for all other sites.	Before sampling
Monitoring	Check and service equipment daily. Perform sample collections as scheduled (every other day for filter collection). Ship samples to lab.	Week 1
Monitoring	Download data; electronically transfer data to reporting task manager.	Week 1
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 2
Monitoring	Download data; electronically transfer data to reporting task manager.	Week 2
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 3
Monitoring	Download data; electronically transfer data to reporting task manager.	Week 3
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 4
Monitoring	Download data; electronically transfer data to reporting task manager, and perform calibration checks.	Week 4
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 5
Monitoring	Download data; electronically transfer data to reporting task manager.	Week 5
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 6
Monitoring	Download data; electronically transfer data to reporting task manager.	Week 6
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 7
Monitoring	Download data; electronically transfer data to reporting task manager.	Week 7
Monitoring	Check and service equipment daily. Perform sample collections as scheduled. Ship samples to laboratory.	Week 8
Monitoring	Download data; electronically transfer data to reporting task manager. Perform calibration checks.	Week 8
Recovery	Break down and pack equipment for storage and transport. Return sites to their pre-deployment status.	Week 9
Recovery	Transport equipment as needed to Research Triangle Park.	Week 9
Recovery	Set up instruments at the equipment laboratory; perform instrument calibrations and post-deployment quality control checks as needed.	Week 10
Recovery	Perform any required service on ATSDR-owned equipment. Return or dispose of any unconsumed materials/supplies (as appropriate).	TBD
Reporting	Perform preliminary data review.	TBD

Quality Assurance and Quality Control

Data Quality Objectives

Data quality objectives (DQOs) are measures used to ensure that the quality of the collected data is sufficient to achieve the project goals. DQOs for this EI are presented in Table 4. DQOs were developed considering the air contaminants of concern, sampling and analytical methods, and information obtained during the site visit.

Table 4. Preliminary Data Quality Objectives

	Element	***Objective***
Operational DQOs	Where to conduct monitoring	All sites must be close to the potentially affected population.
	Number of sites required	Four to six monitoring sites will provide a representative and direct relationship to the potentially affected population (e.g., private residences, businesses).
	When to conduct monitoring	Daily, from 00:00 to 23:59 hours.
	Frequency of monitoring	Continuous for E-BAM particulate so short duration excursions can be assessed, and hourly and daily average concentrations can be calculated. Every 2 days for PM_4 crystalline silica..
Technical DQOs	Overall completeness	80% data capture from start to finish of each sampling event.
	Acceptable laboratory measurement accuracy for PM_4 silica (NIOSH 7500)	Per NIOSH method 7500.
	Acceptable laboratory measurement accuracy for PM_4 silica (NIOSH 0600)	Per NIOSH method 0600.
	Acceptable field measurement accuracy for PM_4 silica	Based on QA protocol detailed in EI sampling and analysis plan (manufacturer calibrations and field checks).
	Acceptable measurement precision for PM_4	+/- 15% coefficient variation of measurements >3 $\mu g/m^3$.
	Acceptable measurement accuracy for PM_4 and PM_{10}	Based on QA protocol detailed in EI sampling and analysis plan (manufacturer calibrations and field checks).
	Acceptable measurement precision for $PM_{2.5}$ and PM_{10}	Based on the protocol; instrument manufacturer's instructions; 40 CFR Part 50, Appendix B; and 40 CFR Part 50, Appendix L.

Measurement Completeness

For this EI, completeness is defined as the number of valid measurements collected, compared to the number of possible measurements expected. Monitoring/sampling programs that consistently generate valid results tend to have higher measurement completeness than programs that consistently invalidate samples. Therefore, the completeness of an air monitoring program is a qualitative measure of the reliability of air sampling and laboratory analytical equipment and the efficiency with which the field program and laboratory analysis was managed.

Measurement Precision

For this EI, measurement precision is defined as the ability to acquire the same concentration from two independent instruments with an acceptable level of uncertainty, while concurrently sampling the same air stream. In other words, precision characterizes the repeatability of measurements made by a particular monitoring or measurement approach.

ATSDR will measure E-BAM precision by collocating two E-BAMs configured for PM_{10} sampling at one site consistent with 40 CFR Part 58, Appendix A, Section 3.2.5. One E-BAM system will be labeled as the primary system and the other will be labeled as the collocated system. The measurements recorded above the NAAQS of 150 µg/m^3 will be compared and expressed as the percentage coefficient of variation (%CV), defined as follows:

$$\%CV = 100 \cdot \sqrt{\frac{\sum_{i=1}^{n}\left[\frac{(p_i - r_i)}{0.5 \cdot (p_i + r_i)}\right]^2}{2n}}$$

where:

p_i = the principal result for the sample *i*

r_i = the replicate result for the sample *i*

n = the number of samples having primary-collocate result pairs

Similar procedure for measurement precision for PM_{10} will be used for $PM_{2.5}$ and PM_4 crystalline silica using E-BAM and Partisol samplers, respectively.

Measurement Accuracy

Measurement accuracy for this project is defined as the ability to acquire the correct concentration measurement from an instrument or analysis with an acceptable level of uncertainty, while it is sampling a known concentration. Accuracy will be assessed to determine whether systematic deviations occurred from the true concentrations being reported.

Met One's initial calibrations for the E-BAMs are valid and serve as primary demonstrations of accuracy. The accuracy for the Partisol samplers will also be assessed according to quality assurance checks developed by the manufacturer. Several quality assurance checks will be performed according to the manufacturer's recommendation prior, during, and afte the field program.

Analysis of PM_4 silica will be performed by a laboratory accredited through the American Industrial Hygiene Association's program. The laboratory will provide pre-weighted filters and cassette holders. Samples sent to the laboratory will be collected, shipped, and analyzed under a COC. Sampling laboratory requirements will be consistent with NIOSH 0600; NIOSH 7500; 40 CFR Part 50, Appendix L; and the U.S. EPA *Quality Assurance Handbook for Air Pollution Measurement Systems* (U.S. EPA 2013). ERG will identify and choose the laboratory for analysis of the samples.

These QA checks will be detailed in the EI sampling and analysis plan and field report.

Data Management

All data will be maintained in accordance with the Wedron EI data management plan.

Electronic data. Electronic data from the E-BAMs and meteorological monitoring systems will be downloaded and stored on a laptop. Data will then be backed up onto a project USB storage device. The data files will be sent electronically to ERG's database administrator for processing at the end of each sampling week. The data will be stored on a project-specific shared drive on the ERG laboratory server, backed up daily. All data received from the analytical laboratory will be kept on the same project-specific shared drive as the electronic data from the field. All spreadsheets and databases generated for the EI will be restricted to project staff. When data analysis is complete and quality reviews are completed, applicable calculation cells and spreadsheets will be locked. Data processing steps will be detailed in the EI field report.

Hard copy data. Copies of all field-generated COC forms generated for the PM_4 crystalline silica samples will be kept in a project-specified file, along with any other paper records that are generated specific to the Wedron Silica EI. All hardcopy information will be filled out in indelible ink. Corrections will be made by inserting one line through the incorrect entry, initialing the correction, and placing the correct entry alongside the incorrect entry, if this can be accomplished legibly, or by providing information on a new line.

Field staff will use field notebooks throughout the duration of the Wedron Silica EI. Individual notebooks will be uniquely numbered and associated with the project field personnel. The notebook will be used to record other information about the program operation, such as exposure conditions and equipment malfunctions. Field notebooks will be specific to this investigation only and maintained as part of the program records.

Laboratory data. PM_4 crystalline silica (mass and morphology data) will be transmitted electronically from the contracted analytical laboratory to ATSDR (via ERG) in spreadsheet format. The laboratory also will provide a PDF report with sample-specific findings and QA/QC results. Only valid data will be used for ATSDR analysis.

Confidentiality

The only personal identifiers collected during the EI will be adult names and addresses of persons allowing ATSDR to use their properties for monitoring/sampling results. ATSDR will protect confidentiality by giving each EI participant an identification number that does not include personal identifiers. These ID numbers will be used in datasets and reports. Personal identifiers will not be included in any reports produced for the investigation and will not be used for any other purpose. Adult names and addresses will be used to provide a copy of the final summary report to each EI participant. Personal identifiers and corresponding IDs will be kept in a locked cabinet or on a password-protected computer.

Biological sampling and public surveys will not be part of this EI.

Risks/Benefits

Risks are minimal for those participating in this EI:

- The first risk is that property owners/occupants could be slightly inconvenienced during setup, checks, and removal of equipment; to reduce this inconvenience, field personnel will only access properties during time frames agreed on with participants.
- The second risk is that steps will need to be taken to provide electric power and to secure sampling equipment. A single 110-volt power source will be needed for most sampling locations. Field personnel will provide all supplies and equipment needed to access electrical power and will ensure that all equipment is secured. Although electrical power usage is expected to be minimal, EI participants will be given a one-time payment of $75 to ensure participants do not incur costs to engage in the EI. Should any participant decide to withdraw from the EI before it is completed, payment will be based on the $75 payment prorated on the number of days of participation. Payment information is also included in the consent agreement.

The potential benefits for this EI are that participants will learn whether they and/or the community are being exposed to the particulate air contaminants at levels of health concern. The results of the EI are expected to give ATSDR information to evaluate public health concerns of community members in Wedron. The results will be used to inform decisions by the U.S. EPA, Illinois EPA, Illinois Department of Public Health, and LaSalle County Health Department to address potential health hazards.

Informed Consent Procedures

If participants indicate a willingness to allow air monitoring/sampling on their property, ATSDR personnel will explain what the EI will entail, and will obtain written, informed consent (see Appendix C).

If tenants live on the property and the tenants and the property owner agree to participate in the EI, both property owner and tenant will need to sign the consent form. If either the property owner or the tenant does not want air monitoring equipment on the property, ATSDR will not include the property in the EI.

ATSDR staff will emphasize that participation in the EI is strictly voluntary, and that EI participants can withdraw at any time without penalty.

Reporting and Disseminating Results

Analysis of Data

EI results will be used to answer the following questions:

1. Do maximum contaminant levels exceed their respective acute CVs?
2. Do contaminant levels, on average exceed their respective chronic CVs?
3. Are there temporal, meteorological, or spatial factors that affect contaminant levels measured?

ATSDR will analyze the data for question 1 by calculating a sample mean and two-sided 95% confidence interval of the mean, fitting either a parametric distribution or a nonparametric bootstrap to the data. If some results are below the limits of detection, appropriate statistical methods will be used to account for non-detect values as outlined in Helsel (2012). Maximum values will be compared directly to the CVs presented in Table 1 (after appropriate averaging for time). Temporal, environmental, and spatial factors will be analyzed using the R package *openair* (Carslaw and Ropkins 2012).

Reporting Results to Participants

Community members who host monitors will be mailed the HC report when it is published. ATSDR staff will give them an opportunity to ask questions about the monitoring results.

Early Notification Process, If Needed

During monitoring/sampling, field staff will review data when downloads occur for PM_{10} and $PM_{2.5.}$ If measured concentrations exceed the CV for at least two consecutive 24-hour periods, field staff will request the EI Database Manager to provide averaging data for the sampling period. If the measured concentrations exceed the CVs for the entire monitoring period, ATSDR will report the situation to the local, county, and state partners in a timely manner. As soon as is reasonable, ATSDR will decide what to inform the EI participants and the community about the results, and what recommendations to make about eliminating or reducing exposure.

Summary Report

At the conclusion of this investigation, ATSDR will prepare an HC report that will include data evaluation and an overall public health interpretation. On completing the investigation, ATSDR will send a copy of the EI-HC report to each EI participant; ATSDR staff will offer to meet with each EI participant to discuss the report.

Depending on the findings, the report will provide:

- Recommendations to regulatory agencies for reducing/eliminating exposures.
- Community health education and public health outreach.
- Recommendations for further sampling and/or study.

ATSDR will disseminate the results of the EI-HC through a public meeting, as well as releasing the report and related materials on its website for public comment.

Limitations

This EI has two main limitations.

The first is that it will only measure some of the potential contaminants associated with large surface sand mining, processing, and transportation of the final product. ATSDR's choice of contaminants was based in part on community concerns. Substantial effort has been made to choose those contaminants considered most likely to be of health concern based on current scientific knowledge.

The second is that monitoring will only capture ambient air quality measurements during an 8-week period. This may not be enough time to fully characterize exposures to community members living near Wedron Silica—in part because the ambient concentrations of PM_{10}, $PM_{2.5}$, and PM_4 crystalline silica are influenced by environmental and meteorological conditions that may change daily and seasonally, and by the production rates of nearby facilities that emit similar air pollutants.

However, ATSDR's choice of monitoring period means the EI will collect data during what is expected to be a worst-case scenario. In addition, meteorological data for multiple years from the closest National Weather Station will be used to predict the dispersion of airborne particulate in all yearly seasons. If site conditions change or if additional EI procedures are determined to be needed during the course of the EI, the scope of the EI may be revised.

Health and Safety Plan

All field staff will read, understand, and sign the Health and Safety Plan (HASP) for this EI. The HASP is included in this document as Appendix D.

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Attachments

Appendix A. Summary of Exposure Investigation Criteria for the Wedron Silica EI

Appendix B. Three-Year Wind Roses Developed Using Metrological Data Collected at Illinois Valley Airport

Appendix C: Consent Form

Appendix D: Health and Safety Plan

Appendix A1. Summary of Exposure Investigation Criteria for the Wedron Silica EI

Wedron Silica Exposure Investigation

Background

Inhalation of respirable crystalline silica particles has long been known to cause silicosis and is associated with increased risk for lung cancer. The International Agency for Research on Cancer and the U.S. National Toxicology Program have designated respirable crystalline silica as a human carcinogen. In addition, inhalation of crystalline silica has been associated with other respiratory diseases such as chronic obstructive pulmonary disease, bronchitis and emphysema, as well as kidney and immune system diseases. The impact of respiratory exposure to silica on human health has been well-studied; however, these studies have been conducted among workers exposed to silica in varying industries, whose cumulative and average daily exposure levels are much higher than what would be expected for community-based ambient air levels. Moreover, none of the studies included children or other vulnerable populations, nor have studies been conducted to evaluate potential exacerbation of asthma, which may have a more severe impact on children than adults

1. Can an exposed population be identified?

Yes. The residential community of Wedron is in close proximity to sand mining and processing operations, truck and railcar loading operations, as well as phenol resin sand coating operations (Figure 1). Fugitive sand has been observed on the sides of streets and residential properties. Residents have reported that the sand enters their houses, fills their gutters, and covers their cars. There are approximately 50 residential properties in this area, as well as a few businesses and a fire station. Preliminary air monitoring data collected by Wedron Silica show detections of PM_4 crystalline silica on the majority of days which sampling was performed.

Monthly PM_4 crystalline silica detections (µm/m³) at Wedron Silica beginning March 2015

Month (2015)	*No. days sampled*	*No. days detected*	*Lowest PM_4 value*	*Highest PM_4 value*
August	11	9	0.5	5.50
July	10	6	0.44	3.69
June	10	7	0.31	3.83
May	10	8	0.31	5.25
April	8	6*	0.38	4.50
March	11	8	0.50	2.13

*A power outage occurred on two of the scheduled sampling days during April 2015.
Data for the whole sampling/monitoring period is now available at U.S. EPA (2016).

2. Does a data gap exist that affects ability to determine if a public health hazard exists?

Yes. Although the Wedron Silica Company is currently conducting air monitoring through an agreement with the U.S. EPA, the location of their primary downwind monitor does not capture the concentrations of PM_4 and crystalline silica from all potential sources that impact this community. The monitor is located on the lawn in front of the Wedron Silica office building, which is directly south of the residential area and west (upwind) from the mining production, rail and truck loading operations. There is a tall stand of trees between the monitor site and the processing and loading areas, which partially protect the monitor from easterly winds. Because of this, the monitor may not be capturing the full concentrations of PM_4 and crystalline silica when winds are blowing directly from the east. Placing air monitors more to the north and east would better capture PM_4 and silica concentrations due to fugitive dust from mining processes, railcar loading operations, truck loading operations, and truck transportation that would directly impact Wedron residences.

3. Can an EI address the data gap?

Yes. The proposed EI would provide community-based air monitoring in an area impacted by multiple sources of potential crystalline silica exposure, including sand mining processes, rail and truck filling and loading processes, and fugitive emissions from these mobile transportations sources. On-going monitoring at other sand mines in the region is not adequate to capture potential residential exposures. Detailed air monitoring studies are critically needed to track levels of airborne silica and other pollutants near sand mining and processing operations, and along routes driven by trucks transporting the sand. This EI would address this gap in knowledge and provide critically needed data. The EI will be combined with a health consultation and appropriate health education and outreach activities.

4. How would the EI results impact public health decisions?

The data collected from this proposed EI will enable health agencies to more accurately inform Wedron residents about the potential health impacts of airborne crystalline silica at the concentrations measured around their homes

ATSDR will work with partners including the U.S. EPA, LaSalle County Health Department, Illinois Environmental Protection Agency (Illinois EPA), and Illinois Department of Public Health to determine appropriate health-protective decisions based on the EI findings.

Appendix A2. Three-Year Wind Roses Developed Using Metrological Data Collected at Illinois Valley Airport

Figure B-1. 2003-2015 Wind Rose for Illinois Valley Airport

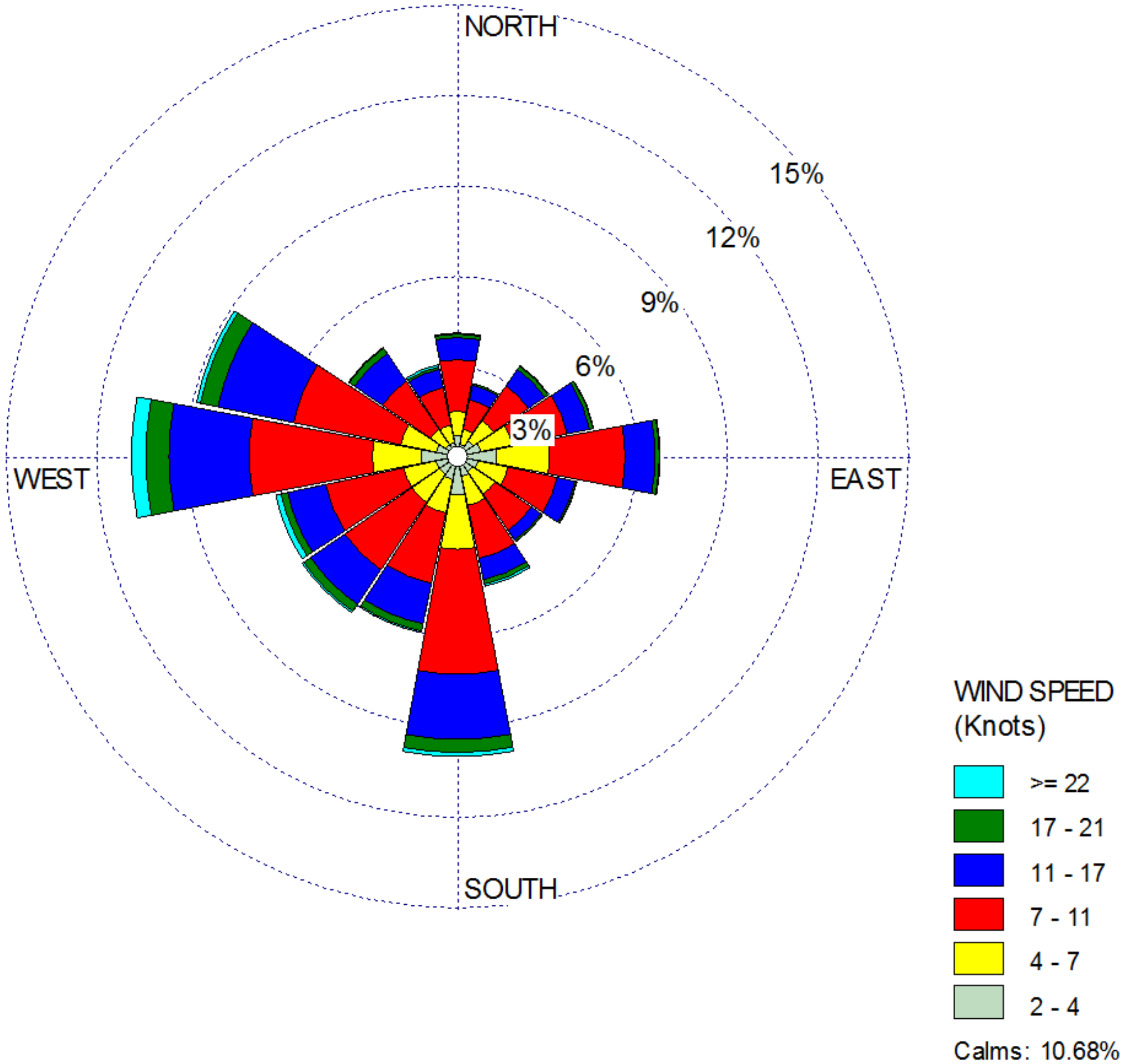


Figure B-2. 2013-2015 Spring Wind Rose for Illinois Valley Airport

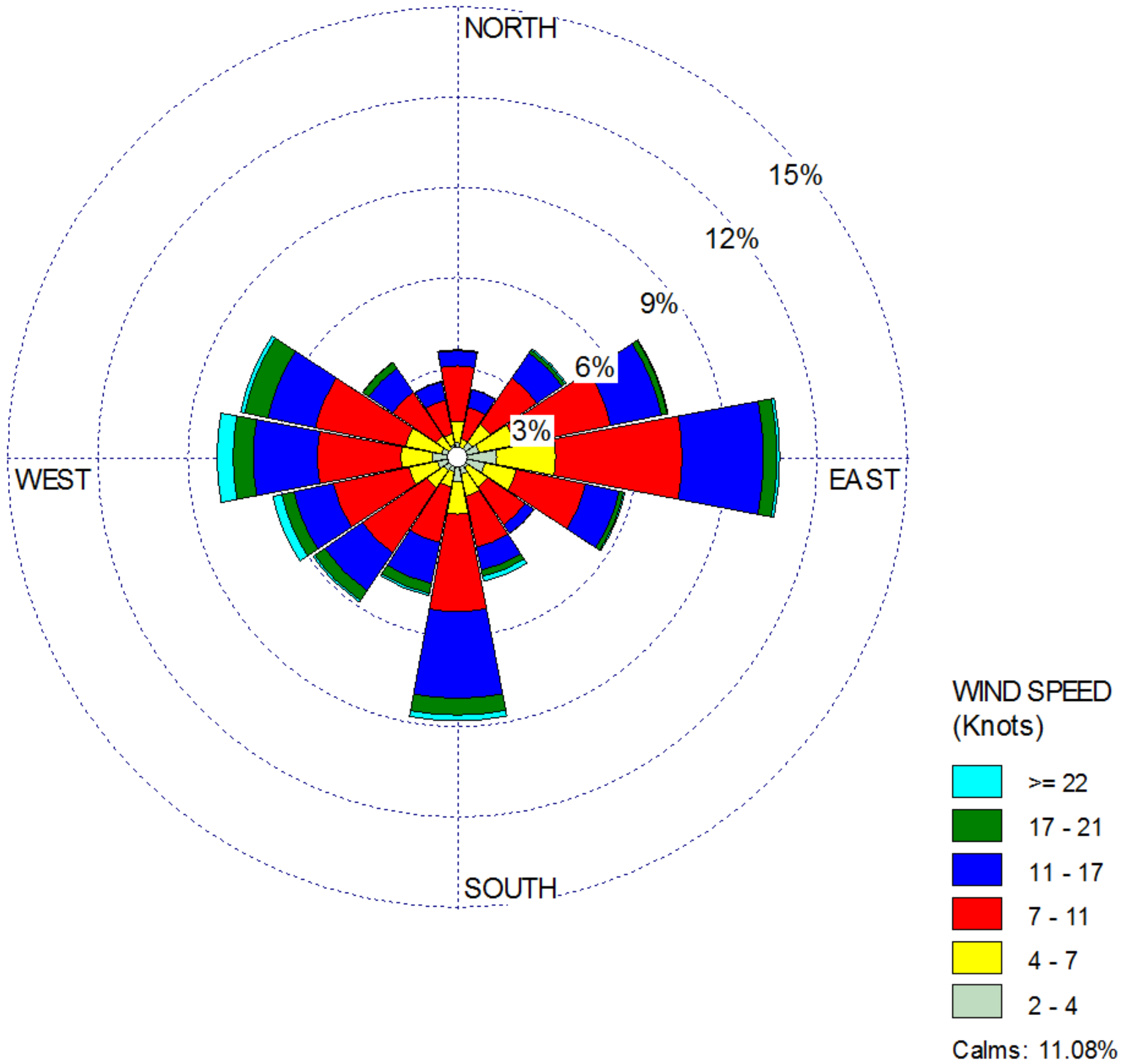


Figure B-3. 2013-2015 Summer Wind Rose for Illinois Valley Airport

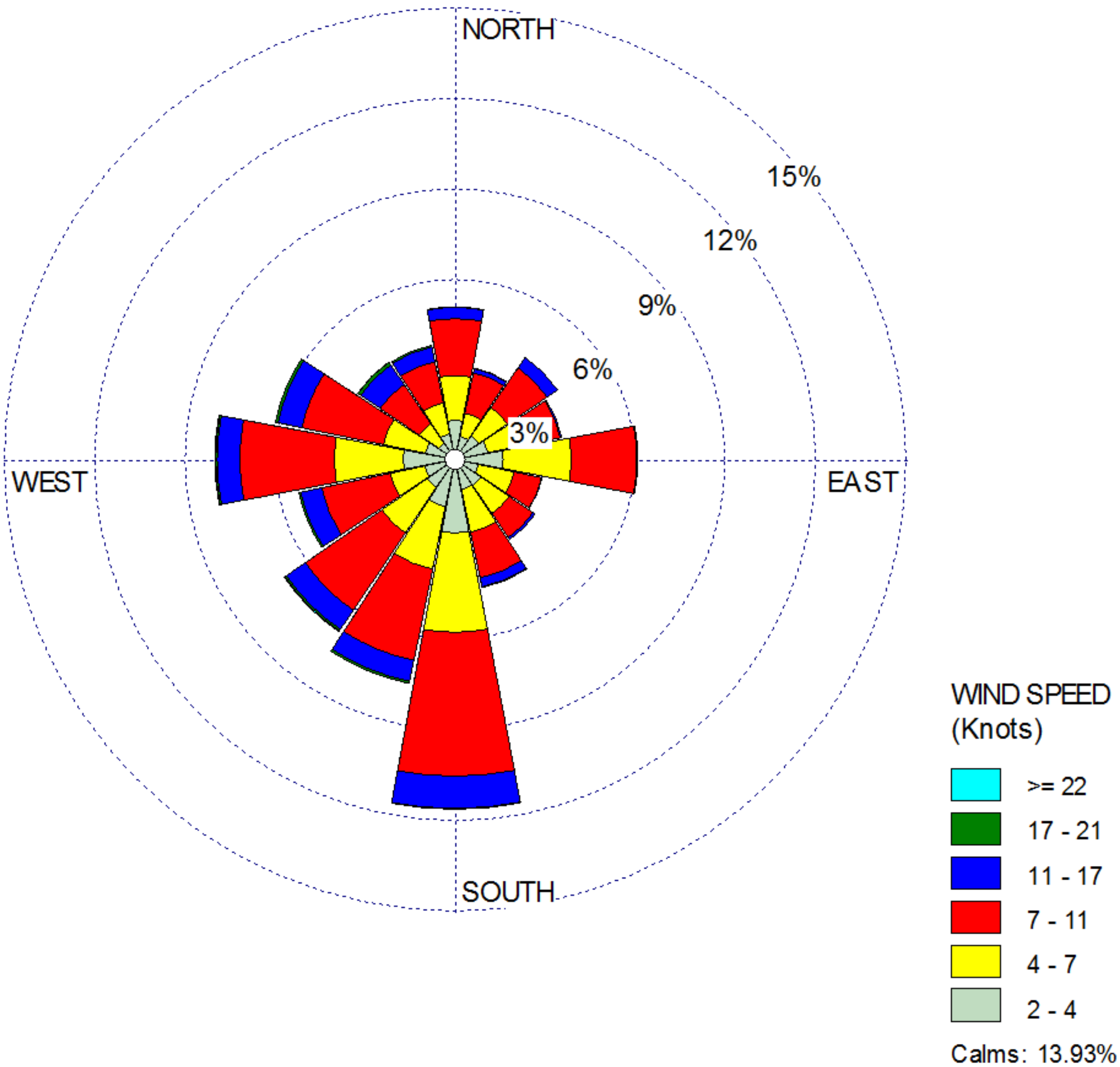


Figure B-4. 2013-2015 Autumn Wind Rose for Illinois Valley Airport

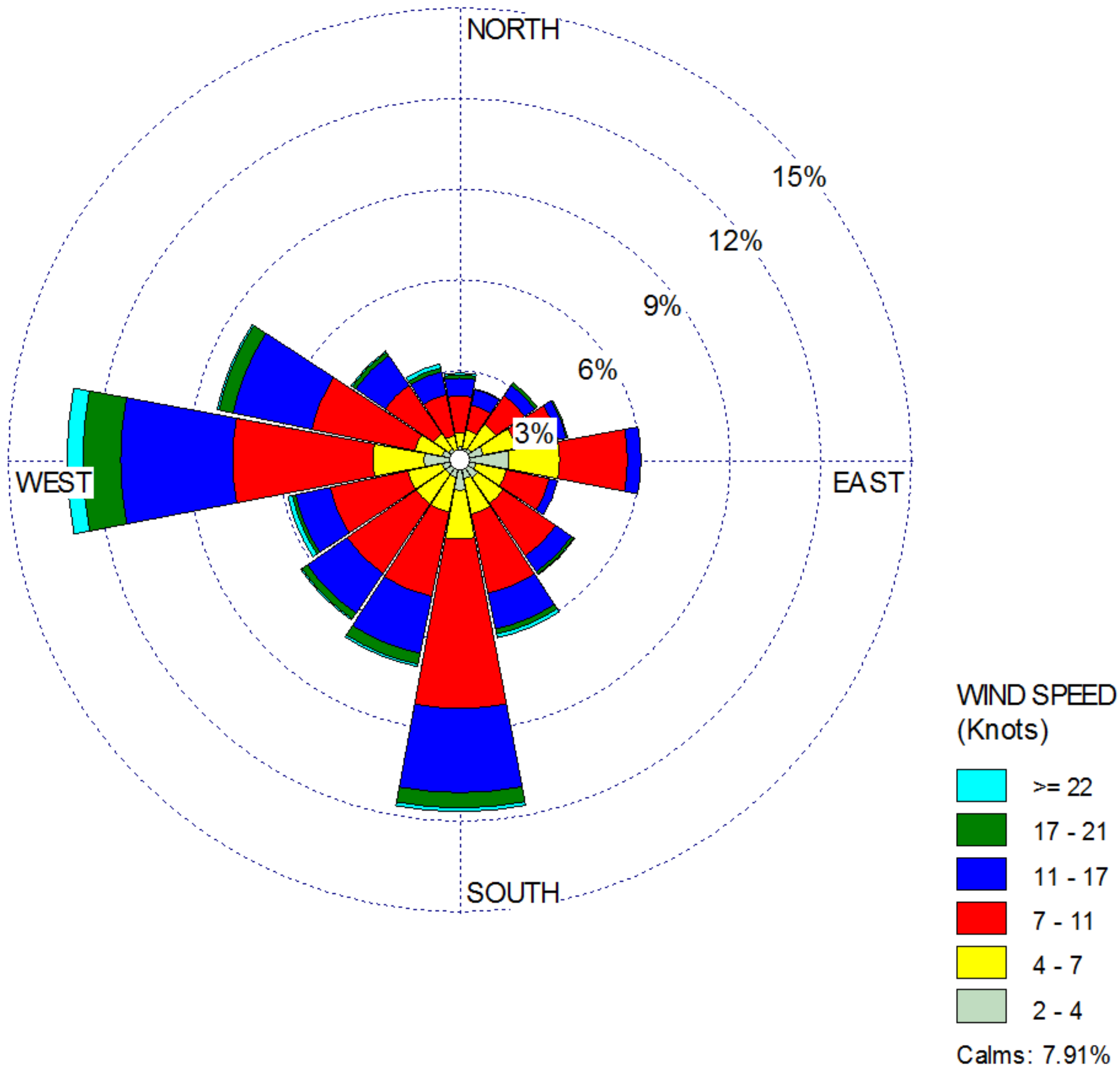
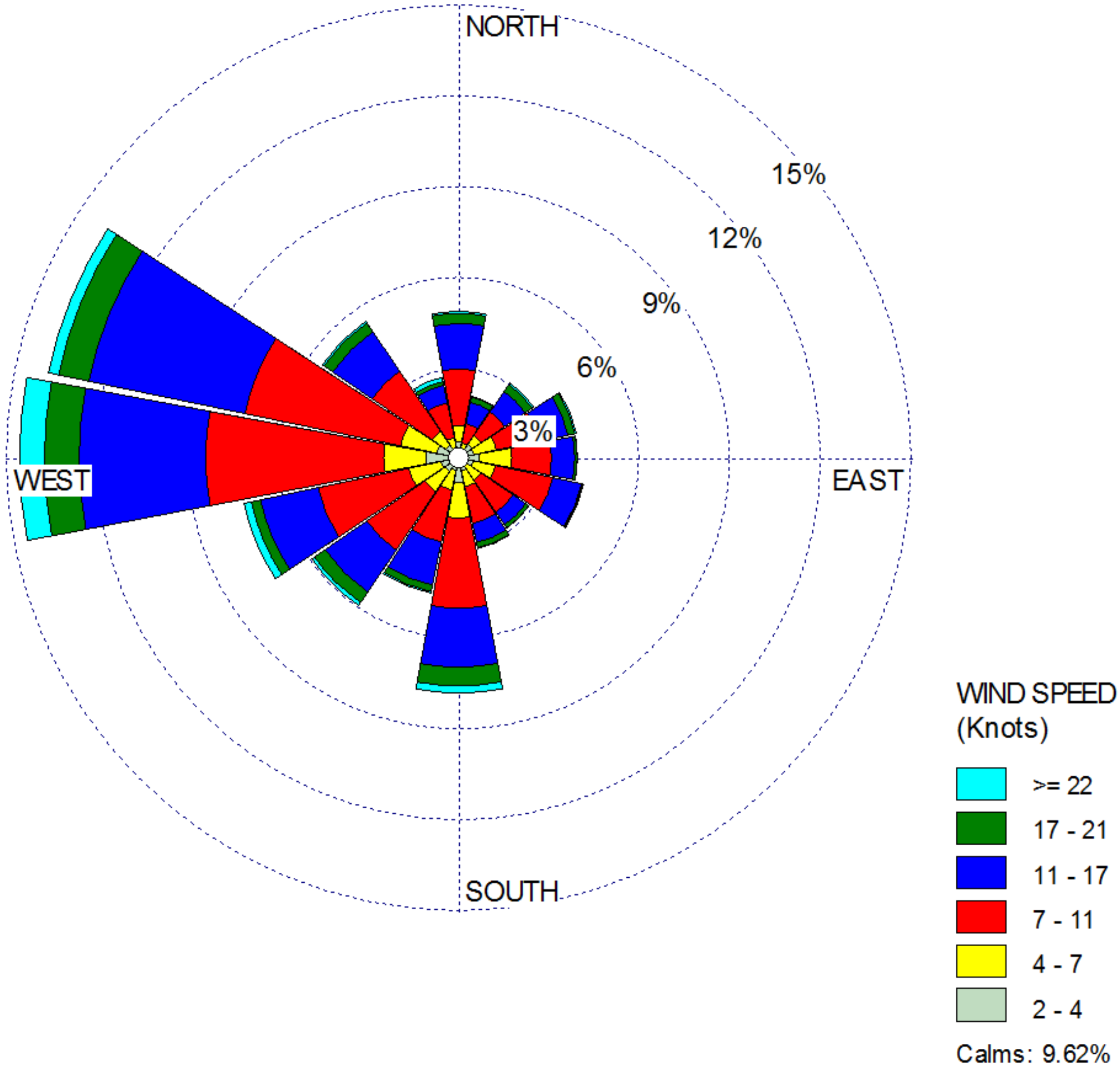


Figure B-5. 2013-2015 Winter Wind Rose for Illinois Valley Airport



Appendix A3. Consent Form

Consent Form for EI Participants

(Flesch-Kincaid reading level = 8.0)

ATSDR Exposure Investigation (EI)

Ambient Air Exposures to Silica and Dust Particles

Wedron, IL

Who are we and why we are doing this EI?

- We are from the Agency for Toxic Substances and Disease Registry (ATSDR), Centers for Diseases Control and Prevention (CDC)
- We are doing this Exposure Investigation to find out if people living near Wedron Silica Company and Technisand, Inc. (Wedron Silica), are breathing outdoor air with elevated levels of silica and small dust particles.
- We are inviting you to be part of this effort by allowing us to put air monitoring equipment on your property.

Location for the testing

- The air monitoring testing will occur in several areas in or near Wedron Silica Company.

What is involved in this EI?

- We will put air monitoring equipment on your property.
- We may need to keep the equipment on your property for about 8 weeks, from early October to early December 2016.
- We will make all arrangements to have the equipment on your property. You will not have to do anything with the equipment.
- We will check the equipment every day.
- We will lock the equipment so that children or pets cannot open the equipment.
- You will not be responsible if damage happens to the equipment on your property.

When will we get the results?

- You will receive a report about the testing on your property that summarizes the exposure investigation and provides our overall findings in about 12-18 months after testing is completed.

What are the Benefits from being in this EI?

- You will find out if any of the chemicals we test are in the outdoor air near your home or property.
- By being part of this effort, you will help your community find out if any of the chemicals we test are in your community.

What are the Risks from participating in this EI?

- We will need run an extension cord from one of your outdoor electrical outlets. You may be bothered by having an extension cord used at your property.
- You may also be bothered by us checking the equipment each day. We will arrange a time with you for us to be on your property so that we bother you as little as possible.
- You may have a small increase in your electric bill since we will need to use your electrical power outlets. We will give you a one-time payment of $75 to pay for any increase in your electric bill that may result from us using your electrical outlets. Should you decide to withdraw from being part of the EI before this effort is completed, your payment will be based on the $75 payment and the number of days you were able to be a part of this effort.

What about Privacy?	▪ We will protect your privacy as much as the law allows. ▪ We will give you an identification (ID) number. ▪ This ID number, not your name, will be used in reports we write. ▪ We will keep a record under locked key, of your name, address and ID number so that we can send you the final report.
When can we Ask Questions?	▪ If you have any questions about this testing, you can ask us now ▪ If you have questions later, you can call: ▪ Motria Caudill at (312) 886-0267 ▪ Custodio Muianga at (770) 488-3890 ▪ Or at the ATSDR toll free number 1-888-320-5291
Property Owner Voluntary Consent	▪ I give permission to allow air monitoring equipment to be put on my property ▪ If you have a tenant living on your property, both you and your tenant will need to agree to be part of this EI ▪ I was given the chance to ask questions and feel my questions were answered ▪ I know that having this test done is my/our choice ▪ I know that even though we have agreed to this testing, I may change my mind at any time without penalty.

Signatures

Printed name of property owner or designate

____

Signature of property owner or designee/tenant Date

____ ______________

Address of Property owner or designate/tenant

____

____

____

Telephone___________________

Certification of Consent Form Administrator:

I have read the consent form to the person name above. He/she has had the opportunity to ask questions about the EI and had the questions answered.

____

Signature of person administering consent

Appendix A4. Health and Safety Plan

HEALTH AND SAFETY PLAN

Purpose

The purpose of this Health and Safety Plan (HASP) is to inform field personnel of known or potential health and safety hazards they may encounter during ambient air monitoring activities planned for Wedron, Illinois. It describes the possible hazards and the procedures required to minimize the potential for exposure, accidents, and/or injuries during the scheduled work activities. ATSDR has reviewed this HASP.

Scope

To better assess potential human exposure to selected chemicals in ambient air in Wedron, ATSDR will conduct an exposure investigation (EI). During this EI, an ambient air monitoring program will be operated to obtain representative concentration data for PM_4 crystalline silica, PM_{10}, $PM_{2.5}$, as well as meteorological data, over an 8-week period.

Physical Hazards Assessment

Possible dangers associated with project activities include physical hazards related to heat stress; slips, trips, or falls; electrical hazards; excessive noise; lifting; and animals, poisonous plants, and poisonous insects. This section briefly describes these hazards, along with measures for preventing them or mitigating their consequences.

Sun exposure. Staff should apply sunscreen 30 minutes before any outdoor field work and reapply every two hours. Appropriate clothing such as hats is recommended to shade exposed skin.

Heat stress. Ambient temperatures may be high enough to induce heat stress if field staff do not take appropriate preventive measures. High winds and high temperatures combined also contribute to heat stress, and both of these conditions may persist in Wedron during the investigation periods. Field staff must be familiar with the signs and symptoms of heat stress as presented below, and be aware of measures necessary to prevent its occurrence. Field staff can prevent heat stress using good common sense and awareness. Sampling team members should wear appropriate clothing and drink ample quantities of water and electrolyte solutions (water and drinks such as Gatorade should be purchased ahead of time). Flexible working and resting schedules should be used as needed depending upon conditions. If ambient temperatures exceed 90°F, field personnel should strive to limit their time in hot sunny areas and rotate where possible into cooler areas. If such heat waves persist, field personnel should monitor their heart rates regularly. An employee's resting pulse rate should not exceed 110 beats per minute; if it does, the employee should stop work immediately, contact the field team leader, and reduce workloads accordingly.

Heat rash. Heat rashes may result from continuous exposure to excessive heat and humidity. Fieldworkers with heat rashes will be instructed to seek medical attention if symptoms persist.

Heat cramps. Heat cramps are caused by heavy sweating with inadequate electrolyte replacement. Symptoms include muscle (e.g., calves) or abdominal cramps. Field workers with heat-related cramps will be instructed to seek medical attention if any of the symptoms persist.

Heat exhaustion. Heat exhaustion occurs when one's body loses the ability to maintain proper temperature. The signs of heat exhaustion include shallow breathing; pale, cool, and moist skin; profuse sweating; dizziness; nausea; and fatigue. Fieldworkers will be trained in the recognition of these symptoms and will be provided electrolyte solutions to help prevent heat exhaustion. If symptoms of heat exhaustion persist, the employees will be instructed to immediately move to a cool location and contact emergency medical services.

Heat stroke**.** Heat stroke is the most severe form of heat stress, with an estimated mortality rate of 50%. Its signs and symptoms include red, hot, dry skin; body temperatures exceeding 105°F; lack of perspiration; strong, rapid pulse; nausea; dizziness; confusion; and unconsciousness. If signs of heat stroke occur, victims will be instructed to immediately retreat to a cool place and contact the nearest medical facility (see "Contacts for Local Emergency Services" below). The affected person may return to work only with a doctor's approval.

Slips, trips, and falls**.** Testing at the site is expected to occur primarily at ground level. Field personnel will use good safety sense in evaluating walking and working surfaces. It is expected that ATSDR will choose monitoring sites such that neither testing personnel nor the general public will be injured by tripping or falling over test equipment. If work must be done above ground level (e.g., on rooftops), field personnel must take measures to ensure the safe access to these areas, including the use of safe equipment. OSHA requires standard guardrails on all leading edges 4 feet or higher; if work must be conducted on rooftops with no guarding, temporary guardrails must first be installed. Where possible, roofs should be accessed from windows or stairways. If ladders are needed, the environment must be inspected to ensure that no overhead power lines are present and that the footing of the ladder can sit solidly on the ground. Avoid using a metal ladder near power lines or exposed energized electrical equipment. All ladders must be inspected before use for damage and removed from service if damages found. Field team leaders will review applicable OSHA rules with team members before assigning employees to work on roofs.

Electrical**.** Before installing equipment in the field, field staff will verify that all electrical equipment and cords are in good working condition. If the team needs more extension cords after arriving on site, the team leader will purchase a high-quality extension cord that works well under the testing conditions. Field workers will be instructed to immediately report to their team leaders any signs of malfunctioning electrical equipment.

Lifting hazards**.** When carrying and lifting equipment, field staff should practice good lifting techniques and avoid carrying heavy loads. When lifting, staff should get as close as possible to the object, tighten their core to support the spine, lift with legs and use proper posture, pivot by taking small steps instead of twisting at the waist, and set the object down slowly while bending at the knees. When possible, the use of dollies or other carrying/lifting assistance devices is advised.

Noise: OSHA's permissible exposure limit (PEL) for noise is 90 dBA—about the volume of noise created by diesel truck 50 feet away, driving at 50 miles per hour. OSHA's noise action level is 85 dBA as an 8-hour time-weighted average (TWA). Because the EI field work is completed in various stations and for short periods in each station (15 minutes to an hour), the team is advised to have hearing protection devices available and wear them when it is necessary. Engineering and administrative controls are not feasible.

Animals, poisonous insects, and poisonous plants. Field staff should be alert for and stay clear of wild and unsupervised animals, poisonous insects, and poisonous plants (e.g., poison ivy, poison sumac). They should be particularly aware of poisonous spiders (e.g., black widows). Poisonous snakes (e.g. rattlesnakes) could also be encountered.

As a field staff member, wear thick leather gloves, long pants, and long-sleeve shirts. When entering the room that houses the monitoring equipment, turn on all lights; if lights are not available, use a flashlight to look around the sampling area before opening the sampling container. Be aware of your surroundings—do not just blindly wander in the monitoring locations. Observation is critical to avoidance. Learn to check around with a sweeping glance for anything that seems out of place: your subconscious may notice a camouflaged animal. All monitoring equipment will be kept in a large sealed container, with screened vents to reduce the chance of animals and insects entering the container. Even so, tap the monitoring container before opening it. Snakes and other animals have many ways to sense your presence. Make plenty of noise and movements while entering the monitoring room to warn them.

If a field staff member is bitten by a snake, rodent, or spider, they should be taken to a medical facility immediately for treatment. Give the medical staff as much detailed information about the animal as possible. Describe the size, shape, and color of the animal.

Chemical Hazards Assessment

Although the field staff for this EI will use no chemicals, they will be working near the silica sand and resin-coated silica sand processing facility—where respirable crystalline silica dust may be released to air. Other chemicals (e.g., phenol, ammonia) are associated with resin production. Because the EI field work will be outdoors and beyond the fenceline of Wedron Silica, it is unlikely that harmful levels in air would occur. NIOSH-approved N-95 filtering half–face piece respirator will be worn if high silica dust levels (i.e., above the PEL of 50 $\mu g/m^3$) are observed/measured. Quantitative fit-testing for this respirator is required, and all staff must first be medically cleared by the ESHCO clinic and fit-tested before departing for field work.

Contacts for Local Emergency Services

Before the first field activity, the field team leader will provide each of member of the field staff with the pertinent emergency contact information for the study area:

Police department
Ottawa City Police Department
301 W Lafayette St., Ottawa, IL 61350

Phone: 815-433-2131

Fire department
Serena Community Fire Department
2286 US-52, Serena, IL 60549
Phone: 815-496-2629

Nearest hospital
Ottawa Regional Hospital and Healthcare Center
1614 E Norris Dr., Ottawa, IL 61350
Phone: 815-433-1010
or
OFS Saint Elizabeth Medical Center
1100 E Norris Dr., Ottawa, IL 61350
Phone: 815-433-3100

Staff Concurrences

Before they work on this ambient air monitoring program, ATSDR will require all of field staff to read and understand this HASP.

I have read, understood, and agree to comply with this project Health and Safety Plan.

______________________	______________________	______________
Signature	Printed Name	Date
______________________	______________________	______________
Signature	Printed Name	Date
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Appendix B. Field Monitoring/Sampling and Quality Assurance/Quality Control Measures

Appendix B. Field Monitoring/Sampling and Quality Assurance/Quality Control Measures[1]

Monitoring/Sampling Methodologies

Exposure Investigation (EI) field staff, comprised of ATSDR and ERG, transported and set up all monitoring/sampling equipment and measurement systems at the established sites. Once installations were completed, all measurement systems were tested to ensure that damage had not occurred during transport. Monitoring/sampling at each EI site commenced after that location's measurement systems were determined to be operating correctly. Throughout the monitoring/sampling event, at least one field staff member was resident in the area to visit the sites daily to assess the functional status of the pollutant and meteorological measurement equipment and correct any problems identified. During the EI, the field staff maintained a field notebook, which included critical monitoring/sampling information, system audit and calibration data, and observations related to the EI. The field staff recorded any observations that could potentially influence particulate level measurements (e.g., nearby fires, rain, high winds, construction, lawn mowing). As shown in Table 2 of the Health Consultation, measurement analysis for the EI varies by the collection method for each type of pollutant and meteorological parameter.

PM_4 Crystalline Silica Sampling Method

ATSDR used Thermo Scientific™ Partisol™ 2000i Air Samplers to collect integrated 24-hour measurements of PM_4 crystalline silica. Research Triangle Institute (RTI) in Research Triangle Park (RTP), North Carolina, analyzed the samples in accordance with the NIOSH Manual of Analytical Methods 0600 (gravimetric determination) and 7500 (x-ray diffraction [XRD]) for crystalline silica. As shown in Table B1, RTI's reported method detection limit for the PM_4 gravimetric mass determination was 5.5 µg, and ATSDR set the samplers to have a measurement range on each instrument of 0.3->200 $\mu g/m^3$ for PM_4 crystalline silica.

The Partisol™ 2000i uses a sample pump to pull air through a PM_{10} inlet and Sharp Cut $PM_{2.5}$ cyclone sequentially. This air was then pumped across a pre-weighed PVC filter cassette provided by RTI. The flow rate for the Partisol samplers was set at 11.1 liters per minute (LPM) to obtain the desired 4.0 micrometers or less size particles. The samplers used a mass flow controller coupled with temperature and humidity sensors to adjust actual flow rates and maintain a rate of 11.1 LPM.

ATSDR collected silica filter cassette samples on a one every 2-day integrated basis. The 2-day cycle involved setting up the filter (Day 1), beginning the sample collection (Day 1), and recovering the filter sample (Day 2). The field staff shipped the samples weekly to RTI, along with the necessary chain of custody forms. RTI's provided ATSDR with a report of its analysis of respirable dust and airborne crystalline silica.

[1] Appendix B is an excerpt from the EI Report prepared by ATSDR's contractor, ERG, and provided to ATSDR in month/year. To avoid repetition with the main document, only selected information is included.

In addition, the EI field team collected a bulk sample of local soil and delivered the sample to RTI for analysis. Because a variety of PM air pollutant sources contain silica, the purpose of this sample analysis was to evaluate potential interferences in determining crystalline silica content in the ambient air samples. Based on the findings of its bulk soil sample evaluation, RTI included an acid washing step to remove calcium magnesium carbonate material prior to analyzing the Partisol sample filters. RTI's description of this bulk soil sample analysis was also provided.

$PM_{2.5}$ and PM_{10} Monitoring Method

ATSDR used Met One Instrument's real-time Environmental Beta Attenuation Monitors (E-BAMs) to collect continuous volumetric mass measurements of $PM_{2.5}$ and PM_{10}. E-BAMs are portable self-contained units that operate consistent with the EPA Class III designated method for particulate measurement. Beta attenuation is the measurement of the decrease in the number of beta particles due to absorption by the filter media employed. The E-BAM uses carbon-14, a naturally occurring radioactive isotope, as the source for beta particles. Carbon-14 beta particles are electrons emitted from the nucleus of an atom when a neutron decays to a proton and an electron. This electron is a subatomic particle with a mass of 0.00054858 atomic mass units and an average energy of 49 kilo electron volt (KeV). Due to the low mass and energy, beta particles can only travel short distances through the air (e.g., 1-2 feet); this allows the beta particles to be completely attenuated on the filter media used by the system, which in turn, allows the mass measurements to be made.

The E-BAM devices measured collected particulate in a three-step process:

- Step 1: A first, or preliminary, particle count was made across the unexposed filter media.
- Step 2: Particle-laden air was passed through the filter media and the associated particulate was deposited for measurement.
- Step 3: A second, or final, count was made across the filter media with the deposited particulate.

The second count was less than the first count due to the absorption of beta particles by the deposited particulate. Based on calibration data, particulate mass was quantified based on the beta particle reduction observed. The measured mass was then divided by the volume of air sampled across the 10-minute or 1-hour duration to calculate the concentration of mass per volume of air sampled.

The monitors used to measure $PM_{2.5}$ incorporated a PM_{10} pre-cutter inlet followed by a Sharp Cut $PM_{2.5}$ cyclone. The monitor used to measure PM_{10}, however, incorporated a PM_{10} pre-cutter inlet only. $PM_{2.5}$ and PM_{10} measurements were collected using the E-BAMs with a flow rate of 16.7 LPM. These components ensure that the devices measure the desired particle size ranges. The E-BAMs were set to record 10-minute and 1-hour measurements throughout the EI. Data were stored automatically to a unit-specific internal DAS. The lower detection limit for the E-BAM's 1-hour measurements, which are used to develop summary statistics in this report, was $<6\ \mu g/m^3$, as shown in Table B1.

Meteorological Measurement Method

Throughout the EI, ATSDR measured meteorological parameters using a stand-alone meteorological monitoring system attached to a secured tripod assembly. ATSDR collected meteorological measurements from Site 3.

The meteorological system incorporated the following sensor technologies:

- A cup anemometer to measure wind speed: The cup anemometer used three wind-catching cups that relate the rate of rotation (i.e., revolutions per second) to the speed of the wind at the time of measurement. Calibration data for the sensor measuring the revolutions per second were used to calculate the corresponding wind speed in meters per second.
- A directional mast and vane to measure wind direction: The mast and vane used a balanced fin, mounted on a vertical shaft. As wind force was applied, the shaft rotated seeking the minimum force position. The shaft turned within a vane transducer/ potentiometer and supplied an analog output signal. The transducer was fixed in a position orientating it towards the direction of North. Transducer calibration data allowed the analog signal to be converted into 0-360 degree compass directions.
- A resistance temperature detector (RTD) to measure ambient temperature: The RTD used a thermistor resistance bridge to provide the relationship between temperature (as °F) and output signal change. Calibration data for the thermistor were used to calculate corresponding temperature measurements.
- A resistance/capacitance wire-wound salt-coated bobbin assembly to measure relative humidity: The bobbin assembly used a thin hygroscopic film affected by the presence of moisture to provide the relationship between percent relative humidity and output signal change. Calibration data for the bobbin sensor were used to calculate the corresponding relative humidity measurements.

Measurements were made at a height of approximately 10 feet (3 meters) using Onset HOBO Wind Speed and Direction Smart Sensors (Model: S-WCA-M003) with Onset Temperature/ Relative Humidity Sensors (S-TMA). Electronic signals from the meteorological monitoring systems' sensors were collected and stored using HOBO Micro Station DASs. HOBOware data logging software was used. Ranges for the measured meteorological parameters are presented in Table B1.

EI Duration/Schedule

Table B1 documents the data collection schedule for the Wedron monitoring/sampling EI by measurement type and site.

Table B1. Data Collection Schedule

Measurement Type	Site ID	Collection Dates
PM_4 crystalline silica (24-hour integrated samples) *	Site 1-Primary (Site 1P)	10/6/2016, 10/8/2016, 10/10/2016, 10/12/2016, 10/14/2016, 10/16/2016, 10/19/2016, 10/21/2016, 10/23/2016, 10/25/2016, 10/27/2016, 10/29/2016, 10/31/2016, 11/2/2016, 11/4/2016, 11/6/2016, 11/8/2016, 11/10/2016, 11/12/2016, 11/14/2016, 11/16/2016, 11/18/2016, 11/20/2016, 11/22/2016, 11/24/2016, 11/26/2016, 11/28/2016, 11/30/2016, 12/2/2016
PM_4 crystalline silica (24-hour integrated samples) *	Site 1-Collocated (Site 1C)	10/6/2016, 10/8/2016, 10/10/2016, 10/12/2016, 10/14/2016, 10/16/2016, 10/19/2016, 10/21/2016, 10/23/2016, 10/25/2016, 10/27/2016, 10/29/2016, 10/31/2016, 11/2/2016, 11/4/2016, 11/6/2016, 11/8/2016, 11/10/2016, 11/12/2016, 11/14/2016, 11/16/2016, 11/18/2016, 11/20/2016, 11/22/2016, 11/24/2016 11/26/2016, 11/28/2016, 11/30/2016, 12/2/2016
PM_4 crystalline silica (24-hour integrated samples) *	Site 2	10/6/2016, 10/8/2016, 10/10/2016, 10/12/2016, 10/14/2016, 10/16/2016, 10/19/2016, 10/21/2016, 10/23/2016, 10/25/2016, 10/27/2016, 10/29/2016, 10/31/2016, 11/2/2016, 11/4/2016, 11/6/2016, 11/8/2016, 11/10/2016, 11/12/2016, 11/14/2016, 11/16/2016,11/18/2016, 11/20/2016, 11/22/2016, 11/24/2016, 11/26/2016, 11/28/2016, 11/30/2016, 12/2/2016
PM_4 crystalline silica (24-hour integrated samples) *	Site 3	10/6/2016, 10/8/2016, 10/10/2016, 10/12/2016, 10/14/2016, 10/16/2016, 10/19/2016, 10/21/2016, 10/23/2016, 10/25/2016, 10/27/2016, 10/29/2016, 10/31/2016, 11/2/2016, 11/4/2016, 11/6/2016, 11/8/2016, 11/10/2016, 11/12/2016, 11/14/2016, 11/16/2016, 11/18/2016, 11/20/2016, 11/22/2016, 11/24/2016, 11/26/2016, 11/28/2016, 11/30/2016, 12/2/2016
PM_4 crystalline silica (24-hour integrated samples) *	Site 4	10/6/2016, 10/8/2016, 10/10/2016, 10/12/2016, 10/14/2016, 10/16/2016, 10/19/2016, 10/21/2016, 10/23/2016, 10/25/2016, 10/27/2016, 10/29/2016, 10/31/2016, 11/2/2016, 11/4/2016, 11/6/2016, 11/8/2016, 11/10/2016, 11/12/2016, 11/14/2016, 11/16/2016, 11/18/2016, 11/20/2016, 11/22/2016, 11/24/2016, 11/26/2016, 11/28/2016, 11/30/2016, 12/2/2016
PM_4 crystalline silica (24-hour integrated samples) *	Site 5†	11/12/2016, 11/14/2016, 11/16/2016, 11/18/2016, 11/20/2016, 11/22/2016, 11/24/2016, 11/26/2016, 11/28/2016, 11/30/2016, 12/2/2016
$PM_{2.5}$ (continuous)	Site 2	10/5/2016-12/3/2016
PM_{10} (continuous)	Site 1	10/5/2016-12/3/2016
PM_{10} (continuous)	Site 2	10/5/2016-12/3/2016
PM_{10} (continuous)	Site 3-Primary (Site 3P)	10/5/2016-12/3/2016
PM_{10} (continuous)	Site 3-Collocated (Site 3C)	10/5/2016-12/3/2016
PM_{10} (continuous)	Site 4	10/5/2016-12/3/2016
PM_{10} (continuous)	Site 5†	11/8/2016-12/3/2016
Meteorological parameters	Site 3	10/5/2016-12/3/2016

*At program onset on October 5, 2016, ATSDR had six E-BAMs available for field deployment. During the EI program, an additional E-BAM was repaired and sent to the field. At that time, ATSDR decided to establish a new site, Site 5, and the field team set up the additional E-BAM for PM_{10} monitoring and deployed a spare PM_4 crystalline silica Partisol sampler to the site as well.

† Field blanks for PM_4 crystalline samples were collected on 10/21/2016, 11/4/2016, and 12/2/2016 at Sites 1,2,3, and 4, and on 12/2/2016 at Site 5.

This EI used DQOs to develop the criteria that the data collection design should satisfy, including where to conduct monitoring/sampling, when to conduct monitoring/sampling, measurement frequency, and acceptable measurement precision and accuracy. The operational DQOs (Table B2) and technical DQOs (Table B3**.**) are consistent with the goals and objectives of this EI, considering the monitoring/sampling logistics, target pollutants, and specifications of the monitoring and sampling collection systems used.

Data Handling and Processing

ATSDR followed very specific processing steps to handle the data collected during this EI. Details on how the data collected from each measurement system during the EI were handled and processed are detailed in the main document. All final data are stored in a Microsoft Access database. A "ReadMe" file, which accompanies the database, indicates what each of the database fields represents (Appendix 1 of the EI report document).

Quality Assurance/Quality Control Measures

This section presents various QA/QC measures implemented throughout the Wedron EI. As part of this QA/QC effort, ATSDR establishes data quality objectives (DQOs) to outline specific criteria needed to obtain data quality standards. These DQOs help determine if data are of sufficient quality to achieve a project's specific technical goals and objectives.

Operational DQOs

The Wedron EI met all its specified operational DQOs. Detailed operational DQO performance information is presented below.

- Siting: All monitoring/sampling locations were at or near private residences or local businesses in Wedron. As outlined in the DQO, ATSDR initially planned to have four to six sampling/monitoring sites. This was met, with having a total of five locations included in the EI that directly represent the potentially impacted population.

- Duration: The monitoring/sampling event began on October 5, 2016 and ended on December 3, 2016. The EI had a total duration of 8 weeks.

- Measurement intervals: Measurements of PM_4 crystalline silica were 24-hour integrated samples collected on a 1 every 2-day basis. Measurements of $PM_{2.5}$, PM_{10}, and meteorological parameters occurred continuously throughout the day.

Technical DQOs

The Wedron EI met most, but not all, of its technical DQOs:

- Measurement completeness: For this EI, completeness was defined as the number of valid measurements collected, compared to the number of possible measurements expected. Monitoring/sampling programs that consistently generate valid results tend to have higher measurement completeness than programs that consistently invalidate samples. Therefore, the completeness of an air monitoring program is a qualitative measure of the reliability of air sampling and laboratory analytical equipment and the efficiency with which the field program and laboratory analysis was managed.

Table B2. Operational Data Quality Objectives

Element	Objective
Where to conduct monitoring/sampling (siting)	All monitoring/sampling locations must be near the potentially impacted population. Four to six sites will provide a representative and direct relationship to the potentially impacted population (private residences, businesses).
When to conduct monitoring/sampling (duration)	Daily from 00:00 to 23:59 hours across 8 continuous weeks.
Frequency of monitoring/sampling (measurement intervals)	•Continuous for $PM_{2.5}$ and PM_{10} to allow assessment of short duration excursions and calculations of hourly and daily average concentrations. •24-hour integrated samples collected on 1 of every 2 days for PM_4 crystalline silica samples to allow assessment of daily average concentrations. •Continuous for meteorological parameters.

Table B3. Technical Data Quality Objectives

Element	Objective
Measurement completeness	80% data capture or greater from start to finish for each sampling/monitoring event.
Acceptable laboratory measurement accuracy for PM_4 silica (NIOSH 7500)	Per NIOSH Method 7500
Acceptable laboratory measurement accuracy for PM_4 silica (NIOSH 0600)	Per NIOSH Method 0600
Acceptable field measurement accuracy for PM_4 silica using Thermo Scientific™ Partisol™ Samplers	•Flow ±4% of 11.1 liters per minute (LPM) •Temperature sensors ±2°C •Ambient pressure ±10 millimeter of mercury (mmHg) •External/internal leak check = pass •Sample flow variability <2% coefficient of variation •Total collection time within 10% of 1,440 minutes (24 hours) (Based on manufacturer recommendations and Appendix A of 40 CFR Part 58 for $PM_{2.5}$)
Acceptable field measurement precision for PM_4 silica using Thermo Scientific™ Partisol™ Samplers	±15% coefficient of variation for measurements >3 µg/m^3
Acceptable field measurement accuracy for $PM_{2.5}$ and PM_{10} using E-BAMs	•Flow ±2% of set point •Temperature sensors ±2°C •Ambient pressure ±10 mmHg •Leak check ≤1.5 LPM drop •Self-test = pass •Span (membrane) test = pass (Based on manufacturer recommendations and Appendix A of 40 CFR Part 58 for $PM_{2.5}$)
Acceptable field measurement precision for PM_{10} using E-BAMs	±20% coefficient of variation for measurements >3 µg/m^3

- Measurement precision: For this EI, measurement precision was defined as the ability to acquire the same concentration from two independent instruments with an acceptable level of uncertainty, while concurrently sampling the same air parcel. In other words, precision characterizes the repeatability of measurements made by a particular monitoring or sampling approach.

- Measurement accuracy: For this EI, measurement accuracy was defined as the ability to acquire the correct concentration measurement from an instrument or an analysis within an acceptable level of uncertainty. Accuracy was assessed to determine whether systematic deviations occurred from the true concentrations being reported.

Technical DQO performance and quality control information is presented in sections that follow.

Quick View of Wedron EI DQOs: Were they met?

- All **operational DQOs**—for siting, duration, and measurement intervals—were met during the EI.
- Most, but not all, of the **technical DQOs**—measurement completeness, precision, and accuracy—were met.
    - The *measurement completeness* DQO was met for all pollutants during the Wedron EI.
    - For *measurement precision:*
        - The DQO for PM_4 crystalline silica measurement precision was not met when all collocated sample pairs are included. However, the DQO is met when one collocated pair with noted preparation errors is removed.
        - The DQO for PM_4 gravimetric mass measurement precision was met.
        - The DQO for PM_{10} measurement precision was not met.
        - Data not meeting these DQOs are usable for ATSDR's evaluation, but their limitations need to be considered.
    - The *measurement accuracy* DQOs for all pollutants were all met during the Wedron EI.

DQO: Measurement Completeness

This section describes the ranges of measurement completeness by each pollutant/method and for meteorological parameters.

A. PM_4 Crystalline Silica Measurement Completeness

Measurements of PM_4 total gravimetric mass and PM_4 crystalline silica were collected using Partisol Air Samplers at Sites 1-Primary, 1-Collocated, 2, 3, 4, and 5. In total for these sites, there were 169 samples analyzed, including primary samples, collocated samples, and field blanks. Specifically, the 169 Partisol samples analyzed included the following:

- 127 primary field samples

- 29 collocated field samples
- 13 field blanks

All 169 of these were valid samples, yielding 100% measurement completeness.

B. $PM_{2.5}$ and PM_{10} Measurement Completeness

Measurement completeness was assessed based on the 10-minute measurements (Table B4) and on 1-hour measurements (Table B5.).

For 10-minute measurements, completeness ranged from 97.94% at Site 4 to 99.87% at Sites 2 ($PM_{2.5}$ and PM_{10}) and 3-Primary, with an overall completeness for all 10-minute PM measurements of 99.13% (Table B4). The invalid PM measurements resulted from power outages or data transfer errors during data downloads. As shown in Table B4, the program DQO of 80% data capture was met for all monitoring locations throughout the EI.

For 1-hour measurements, completeness ranged from 97.67% at Site 4 to 99.72% at Site 2 ($PM_{2.5}$ and PM_{10}) and Site 3-Primary, with an overall completeness for all 1-hour PM measurements of 98.91% (Table B5). The invalid PM measurements resulted primarily from power outages or data transfer errors during data downloads. As shown in Table B5, the program DQO of 80% data capture was met for all monitoring locations throughout the EI.

Table B4. Continuous Particulate Matter (PM) Measurement Completeness: 10-Minute Measurements

Type of PM	Site ID	Total Possible Measurements	Total Valid Measurements	Total Invalid Measurements	Completeness (%)
$PM_{2.5}$	Site 2	8,457	8,446	11	99.87
PM_{10},	Site 1	8,501	8,358	143	98.32
PM_{10},	Site 2	8,496	8,485	11	99.87
PM_{10},	Site 3-Primary	8,494	8,483	11	99.87
PM_{10},	Site 3-Collocated	8,495	8,379	116	98.63
PM_{10},	Site 4	8,491	8,316	175	97.94
PM_{10},	Site 5	3,545	3,537	8	99.77
All types	All sites	54,479	54,004	475	99.13

Table B5. Continuous Particulate Matter Measurement Completeness: 1-Hour Measurements

Type of PM	Site ID	Total Possible Measurements	Total Valid Measurements	Total Invalid Measurements	Completeness (%)
$PM_{2.5}$	Site 2	1,410	1,406	4	99.72
PM_{10},	Site 1	1,416	1,388	28	98.02
PM_{10},	Site 2	1,416	1,412	4	99.72
PM_{10},	Site 3-Primary	1,416	1,412	4	99.72
PM_{10},	Site 3-Collocated	1,416	1,393	23	98.38
PM_{10},	Site 4	1,415	1,382	33	97.67
PM_{10},	Site 5	591	588	3	99.49
All types	All sites	9,080	8,981	99	98.91

C. Meteorological Parameter Measurement Completeness

Measurement completeness was 99.93% for the meteorological parameters measured at Site 3 during the EI. See Table B6 for completeness measurements for each meteorological parameter monitored. The "missed" measurements (n=63) were attributable to data download periods.

Table B6. Meteorological Parameters Measurement Completeness

Number of measurements out of possible 85,003	Temperature	Relative Humidity	Dew Point	Wind Speed	Gust Speed	Wind Direction
Number of Measurements	84,940	84,940	84,940	84,940	84,940	84,940
Completeness	99.93%	99.93%	99.93%	99.93%	99.93%	99.93%

DQO: Measurement Precision

This section describes the calculated measurement precision, for PM_4 crystalline silica sampling, PM_4 gravimetric mass, and PM_{10} monitoring (precision measurements are not available for $PM_{2.5}$). *Precision* defines the level of agreement between independent measurements performed according to identical protocols and procedures. Method precision, which includes s*ampling and analytical precision*, quantifies random errors associated with collecting ambient air samples and analyzing the samples in the laboratory. For this EI, method precision is evaluated by comparing concentrations measured in collocated samples. *Collocated* samples are samples collected simultaneously using two independent collection systems at the same location at the same time. Analysis of collocated samples provides information on the potential for variability (or precision) expected between different collection systems (inter-system assessment).

For the Wedron EI, measurement precision was evaluated across pairs of collocated measurements where both measurements in the pair were numerical concentrations (i.e., not non-detects). Specifically, measurement precision was examined for PM_4 crystalline silica, PM_4 gravimetric mass, and PM_{10} collocated measurements by calculating the coefficient of variation (COV), using the equations outlined below and as described in Appendix A to Part 58—Quality Assurance Requirements for Monitors used in Evaluations of National Air Quality Standards [EPA 2015].

$$d_i = \frac{X_i - Y_i}{(X_i + Y_i)/2} \cdot 100$$

where:

d_i = the relative percent difference (%) for sample *i*

X_i = the result from the primary sampler for sample *i*

Y_i = the result from the collocated sampler for sample *i*

$$COV = \sqrt{\frac{n \cdot \sum_{i=1}^{n} d_i^2 - \left(\sum_{i=1}^{n} d_i\right)^2}{2n(n-1)}} \cdot \sqrt{\frac{n-1}{X_{0.1,n-1}^2}}$$

where:

d_i = the relative percent difference (%) for sample i

n = the number of valid data pairs being aggregated

= the 10th percentile of a chi-squared distribution with n-1 degrees of freedom

D. PM_4 Crystalline Silica Measurement Precision

- Insights into measurement precision were gleaned from the collocated PM_4 crystalline silica Partisol samplers that operated at Site 1 throughout the Wedron EI.
- Because two devices concurrently measured PM_4 crystalline silica concentrations at this site, the expectation would be that the devices' measurements would be reasonably comparable. To assess the precision from the collocated measurements, the data set was restricted to only those instances in which both devices recorded simultaneous numerical (i.e., not non-detect) measurements.
- PM_4 crystalline silica precision was first evaluated by identifying a total of 29 collocated events—when samples were collected and measurements were reported at both the primary and collocated sites. Of these 29 events:
    - Eight events were when the primary sampler and the collocated sampler both reported non-detect PM_4 crystalline silica measurements.
    - Seventeen events were when the primary sampler and the collocated sampler both reported numerical concentrations for PM_4 crystalline silica.
    - Four events were when one measurement in the pair was a non-detect and the other result was a numerical measurement for PM_4 crystalline silica.
- During the EI planning phase, a precision DQO of ±15% for measurements >3 µg/m^3 was set, as referenced in 40 Code of Federal Regulations (CFR) Appendix A to Part 58. However, the EI program yielded no pairs of collocated samples where both measurements were greater than 3 µg/m^3. To still enable an evaluation of precision for the PM_4 silica measurements, the COV was calculated for the 17 pairs of measurements where both crystalline silica results were numerical measurements. The COV for these 17 pairs was 32.39%. Upon further review, a single pair of samples was identified as driving this COV above the DQO. The samples collected at Site 1 on October 12, 2016, had a relative percent difference greater than 125%. Regarding this sample pair, RTI indicated there "likely was an error in the redeposition step from the polyvinyl chloride filter onto the silver membrane filter." If this sample pair is removed from the calculation, the COV is 14.92%—meeting the EI DQO of ±15% COV.

E. PM_4 Gravimetric Mass Measurement Precision

- Insights into measurement precision were also gleaned from the collocated PM_4 gravimetric mass data obtained from the Partisol samplers that operated at Site 1 throughout the Wedron EI.
- As noted previously, the data set was restricted to only those instances in which both devices recorded simultaneous numerical (i.e., not non-detect) measurements.
- PM_4 gravimetric mass precision was evaluated by examining the total of 29 collocated events—when samples were collected and gravimetric mass measurements were reported at both the primary and collocated sites.
- The COV was calculated for the 29 pairs of gravimetric mass measurements collected at Site 1. The COV for these pairs was 5.19%, meeting the EI DQO of ±15% COV.

F. PM_{10} Measurement Precision

- Insights into measurement precision were gleaned from the collocated E-BAMs that monitored PM_{10} at Site 3 throughout the program.
- Because two independent devices concurrently measured PM_{10} concentrations at the same site, the expectation would be that the devices' measurements would be reasonably comparable. To assess the precision from the collocated measurements, the data set was restricted to only those instances in which both devices recorded simultaneous measurements.
- Precision for PM_{10} was evaluated by calculating the COV across the pairs of collocated hourly measurements collected at Site 3, where measurements were reported from both instruments. A DQO of ±20% COV was used for PM_{10} measurements >3 $\mu g/m^3$.
- To evaluate precision, the COV was calculated using all hourly measurements from the 989 collocated events with measurements greater than 3 $\mu g/m^3$ per 40 CFR Appendix A to Part 58. As noted in Section 4c of 40 CFR Appendix A to Part 58, "At low concentrations, agreement between the measurements of collocated samplers, expressed as relative percent difference or percent difference, may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision and bias calculations only when both measurements are equal to or above..." certain limits, with 3 $\mu g/m^3$ being the limit applicable to the PM_{10} collocated measurement in this EI [EPA 2015]. For the 989 collocated events with measurements greater than 3 $\mu g/m^3$, the COV is 39.78%.
- Neither evaluation of PM_{10} precision meets the EI DQO of ±20%.
- Data not meeting these DQOs are usable for ATSDR's evaluation, but their limitations need to be considered.

DQO: Measurement Accuracy

This section describes the measurement accuracy for the entire EI program, first for PM_4 crystalline silica and then for PM.

G. PM_4 Crystalline Silica Measurement Accuracy

Measurement accuracy for PM_4 crystalline silica was determined by evaluating laboratory measurement accuracy and field measurement accuracy.

For *laboratory accuracy*, analysis of PM_4 silica was performed by RTI, a laboratory accredited with the American Industrial Hygiene Association. The laboratory provided pre-weighted filters with respective cassette holders. Samples sent to the laboratory were collected, shipped, and analyzed under a chain of custody. Per the EI DQOs, RTI met the laboratory accuracy requirements by adhering to the analytical methods outlined in NIOSH Method 0600 and NIOSH Method 7500.

Field measurement accuracy associated with the Thermo Scientific™ Partisol™ samplers was assessed using a series of manufacturer- and CFR-specified audits. At Sites 1-Primary, 1-Collocated, 2, 3, and 4, performance audits were performed during staging (October 5, 2016), after deployment (November 3, 2016), and again during recovery (December 3, 2016). The Partisol sampler came online later at Site 5, with performance audits performed at that site during staging (November 8, 2016) and recovery (December 3, 2016). These types of performance audits are outlined below and summarized in Table B7. Of note, in the table, the “reading” entries for flow rate, temperature, and pressure represent the values obtained from the Partisol samplers used at the EI site location. Each “reading” entry is compared against a corresponding “audit” entry, which is generated by the BGI deltaCal Air Flow Calibrator from Mesa Labs, a National Institute of Standards and Technology (NIST) Traceable Standard for volumetric air flow, barometric pressure, and ambient temperature.

- Flow rates of the Partisol samplers were measured, and acceptable if within ±5% of the audit value. All flow rates were deemed acceptable, with a percent difference ranging from to 0.09% to 3.61%.
- Partisol temperature sensor readings were measured and checked to ensure they were within ±2°C of the audit values collected using the BGI deltaCal calibrator. Values met the requirements, with ambient temperature ranging from a difference of 0.00°C to 1.60°C, and filter temperature ranging from a difference of 0.00°C to 1.90°C.
- Ambient pressure sensor readings were collected and assessed to ensure pressure was within ±10 mmHg of the audit value. All values met the requirements, ranging from a 0.00 mmHg to 1.00 mmHg difference between the readings and audit values.
- Automated external and internal leak checks were conducted. The samplers were determined to “pass” or “fail” when the checks automatically finished. For the external leak check, a pressure drop of ≤25 mmHg over 60 seconds was required to yield a “pass” designation. For the internal leak check, a pressure drop of ≤140 mmHg over 60 seconds was required to yield a “pass” designation. As shown in **Table B7**, all external and internal leak checks passed the requirements.

In addition to the performance audits, the field team also conducted accuracy checks related to individual sample controls, including:

- Sample flow rate variability was evaluated throughout the period of sampling to determine that COV values were less than 2% (i.e., the flow rate deviated by less than 2%

of 11.1 LPM throughout the sampling period). Specifically, during sample collection, the Partisol sampler constantly collected flow data and calculated a COV value based on deviation from the flow set-point (11.1 LPM). At the end of the 24-hour Partisol sample collection, the COV value should be less than 2%. Based on the COV data collected throughout the EI program, the COVs (excluding field blanks) ranged from 0.10% to 0.21%, meeting the requirement for accuracy.

- Sampling time was examined to ensure total sampling time for each 24-hour integrated sample was within 10% of 1,440 minutes (24 hours). Out of 156 field samples, eight samples deviated from the expected total sampling time of 1,440 minutes, likely because of a power issue. These deviated times included 765 minutes (one sample; 53.13% of 1,440), 837 minutes (one sample; 58.13% of 1,440), 1,220 minutes (one sample; 84.72% of 1,440), and 1,336 minutes (five samples; 92.78% of 1,440). Thus, three samples were not within 10% of 1,440 minutes. All samples are included in the dataset, with applicable comments accompanying these data in the Access database.
- No samples exhibited an external and internal filter temperature difference of greater than 5°C on average over any 30-minute period during any sampling event.

Table B7. Accuracy Tests on the Thermo Scientific™ Partisol™ Samplers

Site*	Audit Date	Flow Rate Reading†	Flow Rate Audit Value	Ambient Temp Reading‡	Ambient Temp Audit Value	Filter Temp Reading	Filter Temp Audit Value	Ambient Pressure Reading§	Ambient Pressure Audit Value	External Leak Check¶	Internal Leak Check**
1-P	10/5/16	11.12	11.11	26.1	26.8	26.2	26.6	746.0	745.5	Pass	Pass
1-P	11/3/16	11.09	11.15	18.9	18.0	19.1	18.0	752.0	752.5	Pass	Pass
1-P	12/3/16	11.11	11.29	2.4	3.5	4.2	4.5	755.0	754.5	Pass	Pass
1-C	10/5/16	11.09	11.11	27.4	28.3	29.2	28.5	745.0	745.0	Pass	Pass
1-C	11/3/16	11.11	11.14	17.4	17.0	19.4	17.6	752.0	752.5	Pass	Pass
1-C	12/3/16	11.11	11.22	3.1	1.5	3.9	3.6	755.5	755.0	Pass	Pass
2	10/5/16	11.08	10.68	27.1	28.1	28.5	29.5	744.0	744.5	Pass	Pass
2	11/3/16	11.11	11.22	11.4	12.6	12.9	12.9	752.0	752.0	Pass	Pass
2	12/3/16	11.11	11.27	2.8	2.5	2.8	2.8	756.0	755.5	Pass	Pass
3	10/5/16	11.12	11.14	27.6	28.5	30.3	30.7	745.0	744.0	Pass	Pass
3	11/3/16	11.12	11.16	14.1	15.1	16.8	15.3	752.0	752.0	Pass	Pass
3	12/3/16	11.11	11.26	0.1	1.1	2.1	1.1	746.0	745.5	Pass	Pass
4	10/5/16	11.13	11.16	28.1	28.5	30.9	30.5	744.0	744.5	Pass	Pass
4	11/3/16	11.11	11.21	15.3	15.9	19.5	17.6	752.0	752.0	Pass	Pass
4	12/3/16	11.13	11.31	2.5	3.3	4.5	4.8	753.0	754.0	Pass	Pass
5	11/8/16	11.09	11.00	12.4	12.6	12.0	12.6	753.0	752.5	Pass	Pass
5	12/3/16	11.11	11.25	2.8	2.8	4.0	4.8	756.0	756.0	Pass	Pass

* P = primary monitor, C = collocated monitor

† Flow rate reading should be ±5% of audit value, in liters per minute

‡ Temperature readings should be ±2 degrees of audit values, in Celsius degrees.

§ Ambient pressure readings should be ±10 millimeters mercury of audit value, in millimeters mercury

¶ External leak check requires a pressure drop of ≤25 millimeters mercury over 60 seconds, findings shown as pass/fail

** Internal leak check requires a pressure drop of ≤140 millimeters mercury over 60 seconds, findings shown as pass/fail

H. PM Measurement Accuracy

All particulate monitoring devices were operated according to the manufacturer's specifications. The primary quantifiable quality control measure typically used is to assess sample flow rates prior to deployment and compare these to manufacturer specifications.

For the Wedron EI, as shown in Table B8, the EI field team performed various accuracy tests on the E-BAM devices at the $PM_{2.5}$ site (Site 2) and all the PM_{10} sites (Sites 1, 2, 3-Primary, 3-Collocated, 4, and 5). This effort involved performing six different types of tests: a self-test, a span test, a leak check, a flow test, a pressure sensor audit, and a temperature sensor audit. Specifically,

- The span test and self-test were internal audits programmed into the E-BAMs, which the machines run on themselves. The E-BAMs ran the programmed audits and provided a "pass" or "fail" when the audits finished. All E-BAMs passed on all days tested.
- The leak check involved plugging the inlet of the sampler and ensuring the pump pulled the sampler to a vacuum with no leaks for several minutes. E-BAMs passed if test results were ≤1.5 LPM; all E-BAMs passed except for the E-BAMs at Sites 1, 2, 3-Primary, and 4, on December 3, 2016. These were due to weather conditions in the field, and the associated E-BAMs passed audits when returned to ERG's RTP laboratory.
- The flow test involved averaging several flow readings taken with a NIST traceable primary flow standard. E-BAMs passed if test results were ±2% less than 17.034 LPM, and greater than 16.366 LPM. As shown in the table, all E-BAMs passed the flow tests except in three instances (the E-BAM at Site 2 [$PM_{2.5}$] had 15.68 LPM on December 3, 2016, and the E-BAMs at Site 4 and Site 5 had 16.13 LPM on December 3, 2016). These were due to weather conditions in the field, and the associated E-BAMs passed audits when returned to ERG's RTP laboratory.
- Ambient pressure sensor audits involved reading the E-BAMs ambient pressure and comparing the levels to a NIST standard ambient pressure. The E-BAMs passed if pressure levels were ≤ ±10 mmHg of the NIST standard. As shown in the table, the E-BAMs passed the pressure sensor audits on all tested days.
- Ambient temperature sensor audits involved reading the E-BAMs ambient temperature and comparing the levels to a NIST standard ambient temperature. The E-BAMs passed if temperature levels were ≤ ±2°C of the NIST standard. As shown in the table, the E-BAMs passed these audits on all tested days.

All these test results indicate the E-BAMs were functioning properly during the EI.

Table B8. Accuracy Tests on the E-BAMs

Particle Type	Site *	Date†	Self-Test	Leak Check‡	Flow Test§	Span Test	Ambient Pressure Result¶	NIST Standard¶	Ambient Temp Result**	NIST Standard**
$PM_{2.5}$	2	10/5/16	Pass	1.4	16.72	Pass	746.7	744.0	21.7	22.5
$PM_{2.5}$	2	11/3/16	Pass	1.3	16.77	Pass	754.7	752.0	11.2	12.5
$PM_{2.5}$	2	12/3/16	Pass	2.4	15.68	Pass	758.4	755.5	1.0	1.7
$PM_{2.5}$	2	12/14/16	Pass	1.1	16.63	Pass	755.1	752.5	20.8	19.7
PM_{10}	1	10/5/16	Pass	1.0	16.78	Pass	746.7	744.5	19.9	20.6
PM_{10}	1	11/3/16	Pass	0.7	16.96	Pass	754.3	752.0	17.3	17.3
PM_{10}	1	12/3/16	Pass	1.9	16.46	Pass	758.9	756.0	1.3	2.1
PM_{10}	1	12/14/16	Pass	0.5	16.96	Pass	755.6	753.5	21.5	22.0
PM_{10}	2	10/5/16	Pass	0.3	16.75	Pass	746.3	744.0	21.5	22.7
PM_{10}	2	11/3/16	Pass	0.9	16.72	Pass	754.1	752.0	11.2	12.5
PM_{10}	2	12/3/16	Pass	1.8	16.55	Pass	758.3	755.0	1.0	1.9
PM_{10}	2	12/14/16	Pass	0.7	16.70	Pass	754.3	752.0	20.8	22.2
PM_{10}	3-P	10/5/16	Pass	0.2	16.72	Pass	746.0	744.0	21.8	21.8
PM_{10}	3-P	11/3/16	Pass	0.9	16.74	Pass	753.8	751.5	15.5	15.8
PM_{10}	3-P	12/3/16	Pass	4.2	16.52	††	745.8	745.5	0.1	1.0
PM_{10}	3-P	12/14/16	Pass	0.2	16.74	Pass	754.1	752.0	20.9	22.0
PM_{10}	3-C	10/5/16	Pass	0.3	16.89	Pass	746.4	744.0	21.9	22.0
PM_{10}	3-C	11/3/16	Pass	0.4	16.93	Pass	754.0	752.0	15.7	15.5
PM_{10}	3-C	12/3/16	Pass	0.9	16.84	††	748.3	745.5	0.5	1.0
PM_{10}	3-C	12/14/16	Pass	0.6	16.87	Pass	755.1	752.5	21.0	22.0
PM_{10}	4	10/5/16	Pass	0.7	16.68	Pass	746.7	744.5	20.8	21.7
PM_{10}	4	11/3/16	Pass	1.4	16.87	Pass	754.2	752.0	16.8	18.2
PM_{10}	4	12/3/16	Pass	3.1	16.13	Pass	756.5	754.0	1.3	3.2
PM_{10}	4	12/14/16	Pass	1.1	16.67	Pass	755.6	753.5	20.6	21.8
PM_{10}	5	11/8/16	Pass	0.2	16.68	Pass	752.4	752.5	10.8	12.1
PM_{10}	5	12/3/16	Pass	0.3	16.13	Pass	754.5	754.5	1.5	3.5
PM_{10}	5	12/14/16	Pass	0.2	16.87*	Pass	752.4	752.5	20.5	22.1

* P = primary monitor, C = collocated monitor

† All tests performed on 12/14/16 occurred in ERG's RTP laboratory.

‡ Measured in liters per minute; leak check: ≤1.5 liters per minute = pass

§ Measured in liters per minute; flow test: >16.366 and <17.034 liters per minute = pass

¶ Ambient pressure sensor audit: ≤ ±10 millimeters mercury of standard; recalibrated to 752.5 millimeters mercury

** Ambient temperature sensor audit: ≤ ±2° degrees Celsius

†† Span test not performed due to poor weather conditions (snow)

Additional Quality Control Activities

This section describes additional quality control activities conducted for the EI program.

Replicate XRD Sample Analysis of Quartz Mass for PM_4 Crystalline Silica Samples

As an additional QA measure, RTI performed replicate sample analysis during its evaluation of quartz mass for the PM_4 crystalline silica samples. Specifically, RTI prepared a select filter from a field sample for analysis following NIOSH Method 7500 and analyzed that same sample twice for quartz mass using XRD. RTI performed replicate analysis on a total of 17 samples: three pairs replicated non-detect results and 14 sample pairs replicated quartz mass measurements. For the three non-detect results (sample filter numbers 601305.321, 601305.332, and 601305.343), repeated analysis also yielded non-detect results.

For the 14 samples with quantified quartz mass on filters, RTI evaluated the replicate measurements by calculating the RPD—the difference between two numbers relative to the mean of those two numbers—of the original sample result and the replicate sample result. RTI calculated the RPD using the following formula: % RPD = [(Sample – Replicate) ÷ ½ (Sample + Replicate)] x 100.

Table B9 presents the RPD results for the replicate analysis of the 14 PM_4 crystalline silica sample filters with quartz mass measurements. RTI's Standard Operating Procedure specifies that replicate measurement must be within ±20% RPD of each other. As shown in the table, the RPD ranged from 0.00% to 16.30%, with the RPD for all sample pairs falling within RTI's acceptable range of ±20% RPD. The average RPD for all 14 replicate pairs with quartz mass above detection limits is 5.26%.

Table 1. Relative Percent Difference (RPD) for Replicate Sample Analyses of Quartz Mass

Sample ID	Filter Number	Original Result, micrograms	Replicate Result, micrograms	% RPD
PM4S2100616	601305.198	0.0219	0.0186	16.30
PM4S4100616	601305.200	0.0250	0.0239	4.50
PM4S4101016	601305.210	0.0243	0.0234	3.77
PM4S4101216	601305.214	0.0387	0.0390	0.77
PM4S3101616	601305.225	0.0105	0.0096	8.96
PM4S2102916	601305.260	0.0555	0.0524	5.75
PM4S4103116	601305.262	0.0484	0.0500	3.25
PM4S4110216	601305.268	0.0383	0.0393	2.58
PM4S2110216	601305.272	0.0263	0.0273	3.73
PM4S2111416	601305.313	0.0328	0.0332	1.21
PM4S5111416	601305.314	0.0345	0.0361	4.53
PM4S4112616	601305.347	0.0393	0.0342	13.88
PM4S2112616	601305.350	0.0231	0.0221	4.42
PM4S4112816	601305.354	0.0578	0.0578	0.00

Appendix C. Statistical, Temporal and Spatial Analysis

Appendix C. Statistical, Temporal and Spatial Analysis

ATSDR collected air pollution data from October to December 2016. A summary of the data is presented in Figures C1 and C2. Figure C1 summarizes particulate matter concentrations for 3 different aerodynamic diameters for all available sites—less than 10, less than 4 and less than 2.5 micrometers.

Figure C1. Boxplot of particulate matter concentration data for multiple sites

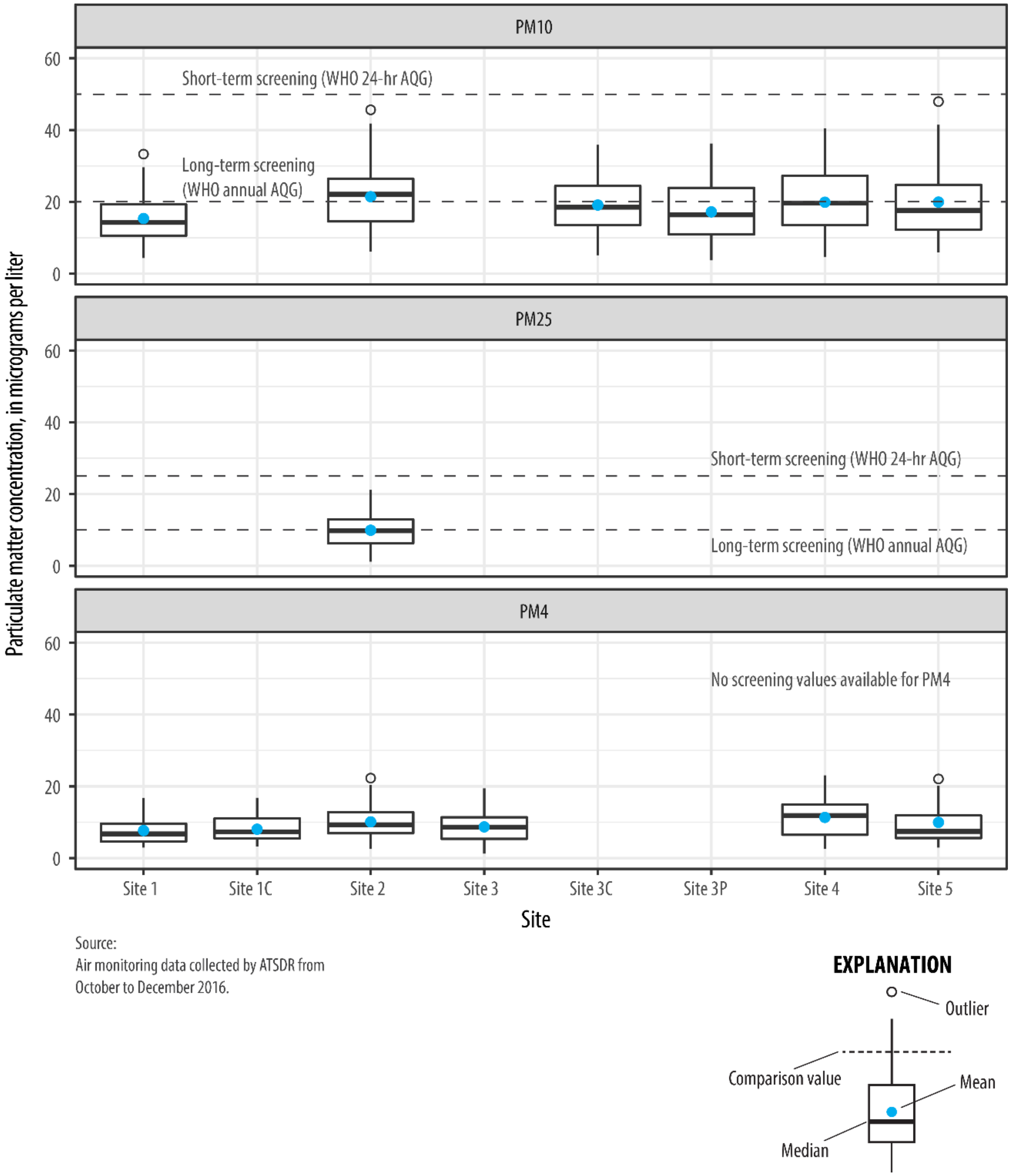
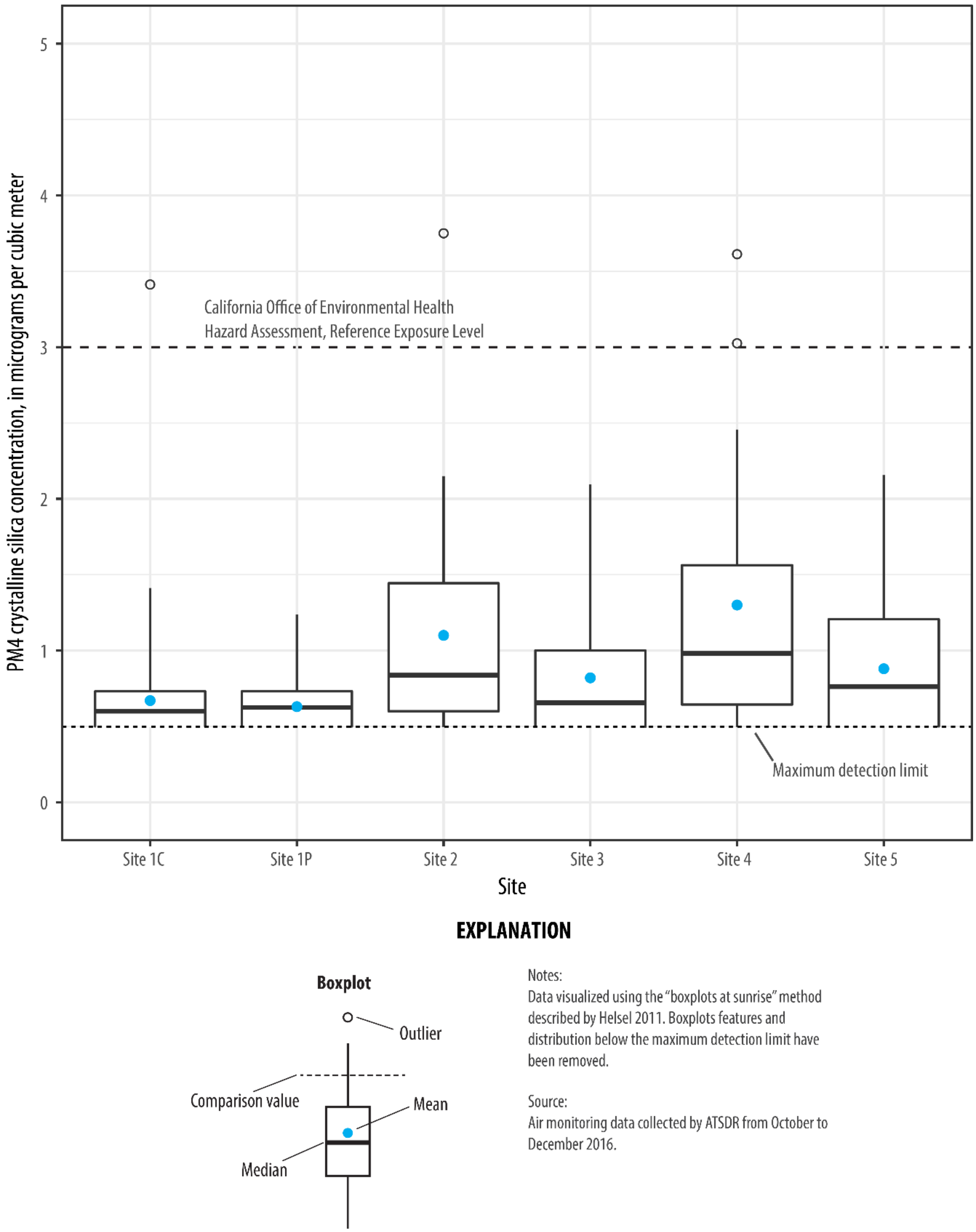


Figure C2 summarizes PM_4 crystalline silica concentrations for all available sites. This figure takes into account the censored values by blanking out the section of the box plot that is below the maximum detection limit.

Figure C2. Censored boxplot of crystalline silica concentration data for multiple sites



For silica concentrations, percentile bootstrapping was used to calculate upper confidence limits after imputation of non-detected values using robust regression on order statistics [Helsel 2012]. For 24 – hour averaged PM_{10} and $PM_{2.5}$ measurements, maximum entropy bootstrapping was performed [Vinrod and López-de-Lacalle 2009].

Analysis of temporal, environmental and spatial factors were made using the R package *openair* [Carslaw and Ropkins 2012]. Trends were plotted using the scatterplot function with a generalized additive model (GAM) smooth (Figures C3, C4, and C5) [Wood 2006].

ATSDR used bivariate polar plots to analyze how concentrations of a given chemical vary by wind speed and wind direction. Using the *openair* package function polarPlot, the data were plotted in polar coordinates indicating the wind direction. The distance from center indicates the wind speed. The use of bivariate polar plots is discussed in Carslaw *et al.* [2006] and in Westmoreland *et al*. [2007].

To assess the relationship between time and wind direction, the data were plotted using *openair's* polarAnnulus function. The polarAnnulus function produces a plot where wind direction are plotted on a polar axis, and time is plotted on the radial axis, with distance from center representing increasing time. Both polarPlot and polarAnnulus functions use a GAM smoother to the surface of the average concentration [Wood 2006].

Figure C3. Time Series of 24-Hour Average PM_{10} Measurements

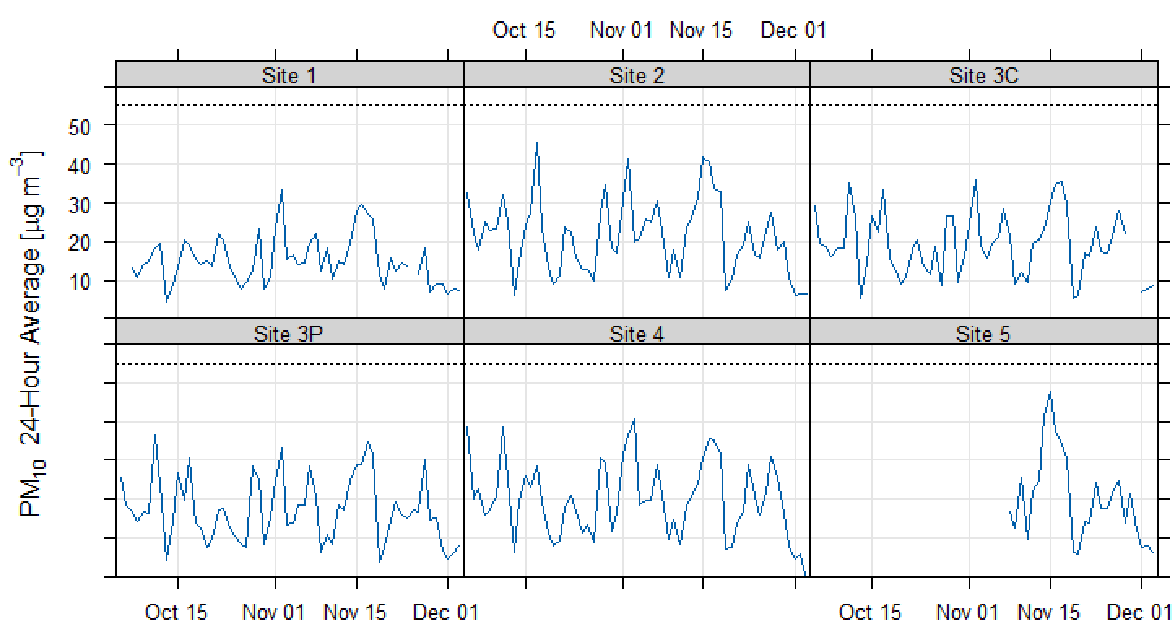


Figure C4. Time Series of 24-Hour Average $PM_{2.5}$ Measurements

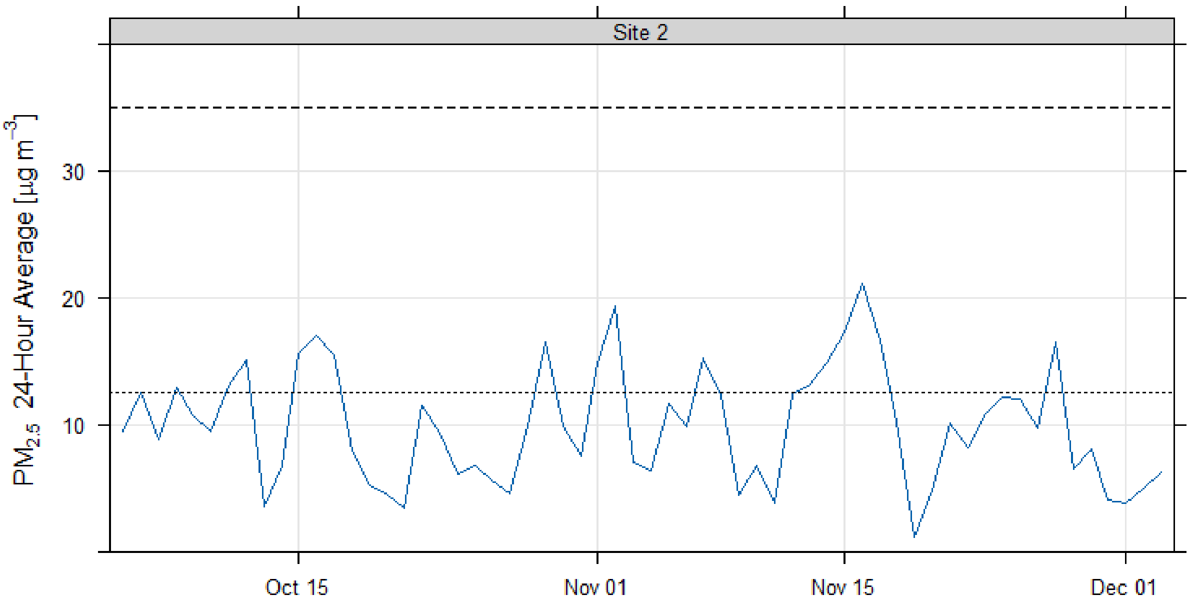
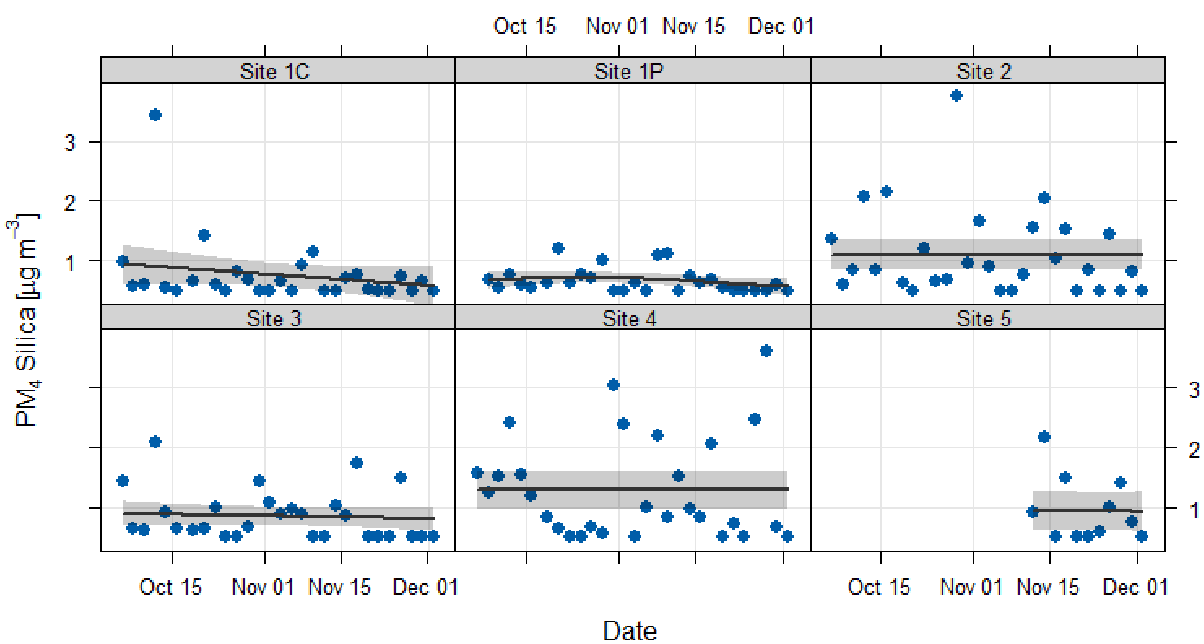


Figure C5. Time Series of PM_4 Silica



Polar plots of PM_{10} and PM_4 are shown in Figures C6 and C7, respectively. At all sites, the highest PM_{10} concentrations are when there are strong winds from the south, even at Site 1 to the south of the facility. PM_{10} concentrations at the northern sites are higher than at Site 1, so there may be some contribution to PM_{10} from the facility, but there is also indication of an additional source from the south (or regional transport from the south). A polar plot of $PM_{2.5}$ from Site 2 is shown in Figure C8. Similar to the PM_{10} polar plots, data from this site indicate that concentrations of $PM_{2.5}$ are highest when winds are from the south or southeast. This could be due to a local source, regional transport, or a combination of the two. Polar annulus plots show relationships between measured concentrations of a pollutant, wind direction, and time of day. Polar annulus plots of PM_{10} are shown in Figure C9. These plots give a consistent picture of wind direction/time of day trends at the northern sites. For each of the four northern sites concentrations in the early morning hours (just after midnight) are elevated when winds are from the southeast. Concentrations then decrease during the middle of the day, regardless of wind direction. In the evening hours at all four sites there is again an increase in concentration when winds are from the southeast.

The sites that exceeded WHO AQGs for particulate matter – Sites 2, 4, and 5 – are the closest to facility operations, whereas concentrations for all pollutants were lower at the background location (Site 1) and Site 3, which is further downwind of Sites 2, 4, and 5. As noted above, ambient PM_{10} may be a combination of regional transport and a local source. It appears that Sites 1 and 3 are largely representative of regional PM and Sites 2, 4, and 5 reflect regional PM plus the contribution from local industry that raises concentrations to the level of WHO PM guidelines.

Silica concentrations a Site 4 were the highest with an indication that there are sources of silica to the south and southeast of the site. All PM size fractions show higher concentrations (at all sites) when winds are from the South.

Figure C6. Polar Plots of PM_{10} Mass

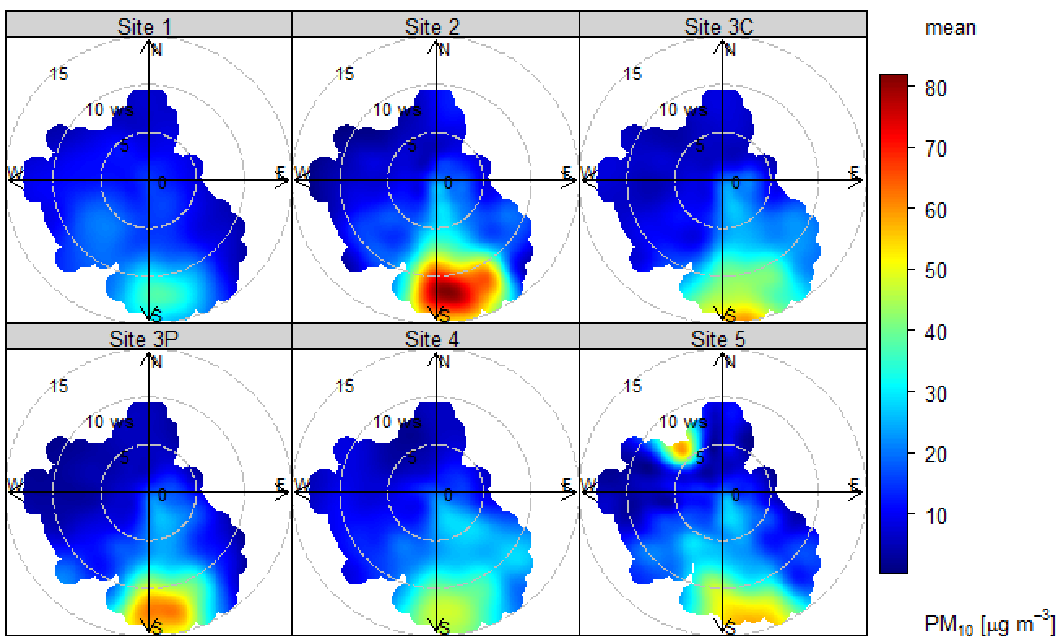


Figure C7. Polar Plots of PM_4 Mass

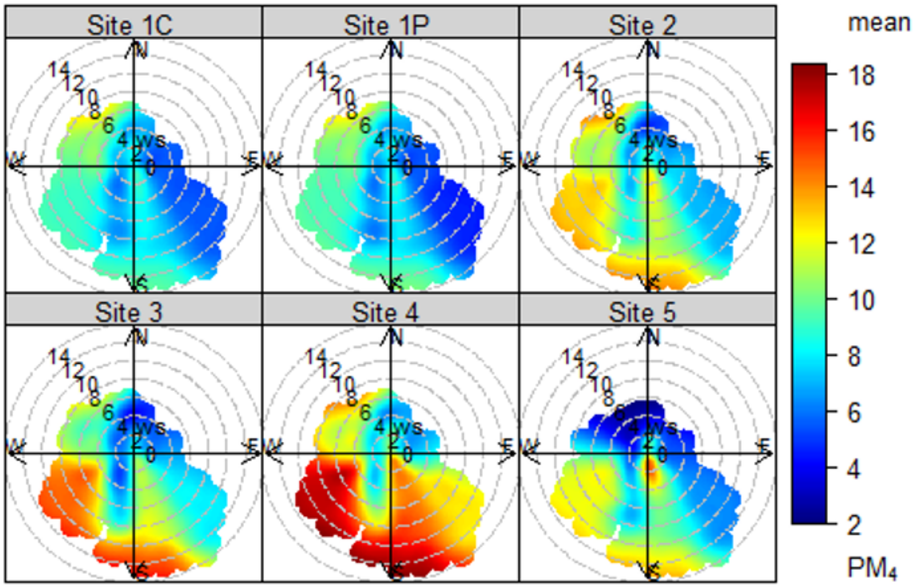


Figure C8. Polar Plot of $PM_{2.5}$ Mass

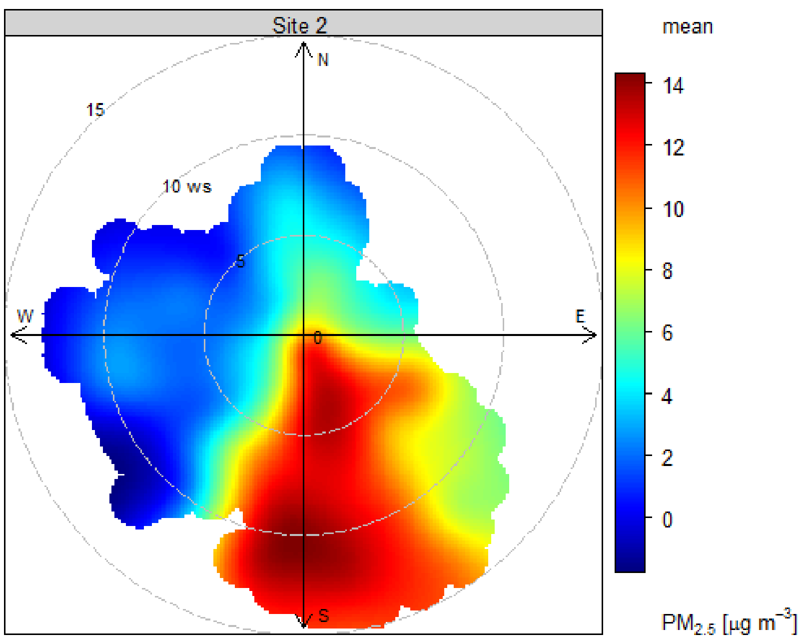


Figure C9. Polar Annulus Plots of PM_{10}