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Air Quality and Industrial Sand (Frac Sand) Mining

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Sixth and final in a series

#137 (May 2015): Environmental Impacts of Industrial Silica Sand (Frac Sand) Mining

#138 (June 2015): Economic Impacts of Industrial Silica Sand (Frac Sand) Mining

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Introduction

Industrial sand has been mined throughout the Upper Midwest for more than a century without generating negative environmental or human health impacts. The sand has been used for a variety of industrial processes, such as making cores for foundries, glassmaking, livestock bedding, and oil and gas development.

> Air quality is a high priority with all industrial sand mining companies and policymakers in areas near industrial sand operations.

As the number of industrial sand facilities increased in response to growing demand for the sand used for hydraulic fracturing, often referred to as "frac sand," an initial lack of publicly available air monitoring data led to concerns that these facilities could negatively affect air quality and public health. These concerns prompted state regulators and industrial sand operators to conduct several air-monitoring studies throughout the region.

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Air quality is a high priority with all industrial sand mining companies and policymakers in areas near industrial sand operations. They aim to protect the public from hazardous levels of small particles of silica dust. These particles, when present in unsafe concentrations, can cause health problems such as asthma and silicosis. Silicosis is a serious but preventable lung ailment that can affect workers in industries with high exposure to silica dust.

> Although air quality is an important concern that must be addressed, the issue is often raised by mining opponents to impede the permitting of sand facilities.

Although air quality is an important concern that must be addressed, the issue is often raised by mining opponents as a way to impede the permitting of industrial sand facilities. Mining opponents often merely assert these facilities will hurt air quality, and seemingly no amount of scientific evidence will persuade them to believe otherwise.

When not supported by scientific evidence, these allegations are problematic. When people perceive threats to their quality of life, such as potential risks to their air and water quality—and even climate change— these perceptions of risk can result in anxiety, depression, post-traumatic stress, and even suicidal thoughts.[1,2] Because of these potential health risks, it is important that the general public have access to accurate scientific information about the risks of industrial sand mining.

As discussed in greater detail in *Environmental Impacts of Industrial (Frac) Sand Mining,*[3] scientific studies have found frac sand mining is safe. A multitude of engineering controls, environmental regulations, and industry best practices minimize the potential environmental and human health risks posed by mining. Unfortunately, no amount of engineering controls can mitigate the risks posed to human health by the irresponsible reporting of activists and pseudoscientists, some of whom are exposed in this and prior papers.

Reports produced by various special-interest groups such as Boston Action Research (a project of the Civil Society Institute), Midwest Environmental Advocates (MEA), and the Land Stewardship Project (LSP) have asserted industrial sand mining will have dire environmental consequences. These reports provide no scientific data to support their claims, but rely entirely upon anecdotal observations.[4]

These groups have then sought to influence policymakers and the public by spreading their alarming and intentionally misleading “results” through a series of letters to the editor, interviews, and press releases. It is our opinion that this type of intentionally irresponsible reporting presents the greatest health risk to residents near sand mining operations by promoting fears unsubstantiated by scientific evidence.

The effects of industrial silica sand mining on air quality were briefly addressed in *Environmental Impacts.* However, the initial lack of air quality data near industrial sand facilities prompted state environmental protection agencies, universities, and nationally renowned air monitoring scientists to conduct several air monitoring studies in recent years. The release of these studies has led us to revisit the issue in more detail.

Part 1 of this *Policy Study* offers an introduction to particulate matter and its health implications. Part 2 presents the findings of the studies mentioned above. These studies use equipment and sampling methodologies approved by the U.S. Environmental Protection Agency (USEPA), the National Institute for Occupational Safety and Health (NIOSH), and other federal agencies, which is consistent with the industry standard of care. These studies have contributed significantly to our scientific understanding of the effect of industrial sand facilities on air quality.

Part 3 explains the limitations of less scientifically legitimate reports that attempt to quantify concentrations of particulate matter in areas near industrial sand operations. While these reports have generated significant interest among mining opponents, the use of inadequate sampling equipment and non-EPA-approved sampling procedures render the data collected irrelevant and of no use in assessing the health impact of these facilities.

While Part 2 presents studies that have concluded industrial sand mining does not generate significant quantities of respirable crystalline silica dust, Part 4 examines why that may be the case, presenting the findings of a study examining the fine-grained material between the sand grains, some of which may act as a cement holding the sand grains together, providing additional insight into the source and composition of potential dust at industrial sand mines. Part 5 offers concluding remarks.

> Every scientific study has concluded industrial sand facilities do not generate hazardous concentrations of respirable crystalline silica dust.

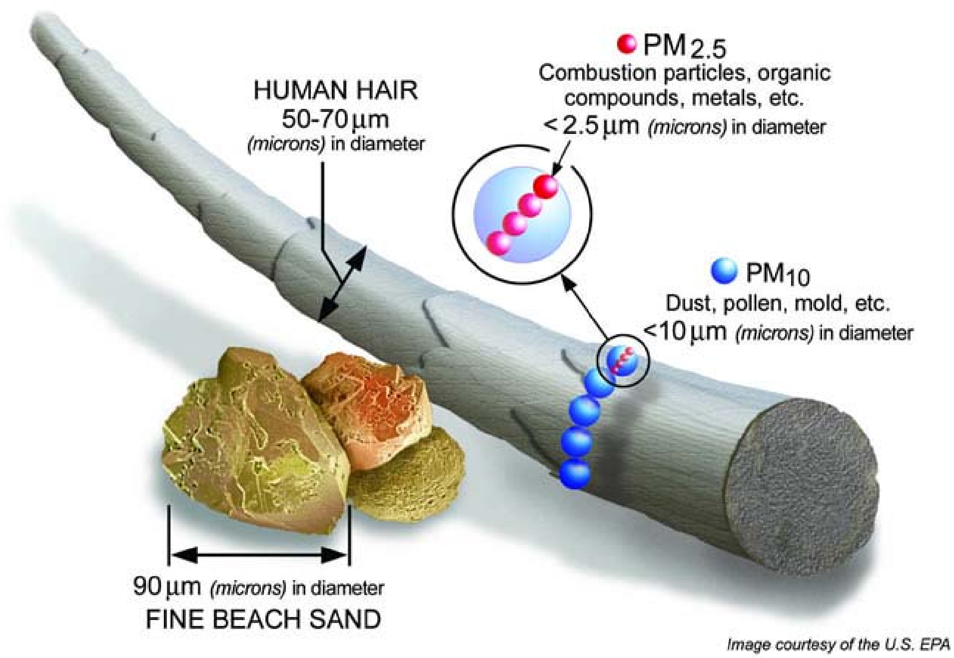
This *Policy Study* concludes industrial silica sand mining does not pose a threat to air quality or the public health. Every scientific study in which federally approved air sampling methodologies and equipment were employed has concluded industrial sand facilities do not generate hazardous concentrations of respirable crystalline silica dust.

Part 1
Respirable Crystalline Silica and Other Respirable Particles

The primary concern regarding air quality and industrial sand facilities is the fear that these operations may generate hazardous levels of small particles of crystalline silica and other small particles referred to as particulate matter (PM). These particles can be in solid or liquid form and are small enough to bypass the body's natural defenses and cause irritation of the eyes, nose, throat, and lungs.[5]

Particulate matter is commonly classified in three categories: PM10, particles that are 10 micrometers (microns) in diameter and smaller; PM4, particles measuring 4 microns in diameter and smaller; and PM2.5, particles measuring 2.5 microns in diameter and smaller. (See Figure 1.)

Figure 1
Particulate Matter Size



Particles measuring 10 micrometers in diameter and smaller are regulated by the Environmental Protection Agency, Mine Safety Health Administration, and other government agencies because these particles are small enough to bypass the body's natural defenses and penetrate deep into the lungs.

PM10 and PM2.5 are regulated to protect human health by USEPA under the National Ambient Air Quality Standards (NAAQS). The daily and annual standards set by USEPA for PM10 and PM2.5 are considered conservative and designed to protect even the most vulnerable populations, such as children and the elderly.

The smallest grains of sand sold for hydraulic fracturing are typically classified as "100 mesh." These particles measure 149 microns in diameter, meaning the grains used for frac sand are nearly 15 times larger than PM10 and nearly 60 times larger than PM2.5.[6]

PM4 is the particle size typically measured by the Mine Safety and Health Administration (MSHA) to determine concentrations of respirable crystalline silica (RCS) in occupational settings. PM4 is also the size measured to determine RCS concentrations in ambient air quality studies conducted in Wisconsin and Minnesota.

All companies operating in the United States are subject to rules, standards, and regulations promulgated by numerous federal agencies.[7] Industrial sand mining companies are subject to oversight by USEPA, MSHA, the U.S. Department of Labor, and the Occupational Safety and Health Administration (OSHA). Some industrial sand mining opponents note only the standards established by USEPA, saying they compare unfavorably to standards established by the World Health Organization. Those sand mining opponents simply ignore the other regulatory agencies whose rules and standards also apply to sand mining companies.

While small particles of all chemicals and compounds, including water, can be hazardous in large enough concentrations, exposure to RCS is of particular concern because over time these particles can cause silicosis, a preventable but potentially fatal lung disease.

Silicosis is an inflammation of the lung and other respiratory tissues that eventually causes fibrosis, a hardening of the lungs, reducing the ability to breathe efficiently. Symptoms include shortness of breath while exercising, fever, fatigue, and loss of appetite. Silicosis also renders the victim more susceptible to infection and diseases such as tuberculosis and lung cancer.[8]

The number of deaths from silicosis declined from 1,065 in 1968 to 101 in 2010.

People at greatest risk of silicosis are workers who move or blast rock and sand (miners, quarry workers, stonecutters) or who use silica-containing rock or sand abrasives (sand blasters; glass makers; foundry, gemstone, and ceramic workers; potters). Recently, silicosis has been identified in workers who fabricate or install countertops manufactured from engineered silicates (silica conglomerate). Coal miners are at risk of mixed silicosis and coal workers' pneumoconiosis.[9,10] Silicosis is also known to exist from natural environmental causes in desert regions.[11]

Silicosis and deaths caused by occupational exposure to RCS can be prevented by complying with safety procedures and taking preventative measures developed by NIOSH and USEPA and enforced by MSHA and OSHA.[12,13] In the U.S. industrial silica sand industry, silicosis can and has been prevented by adherence to the industry standard of care developed over the past century as documented by the National Industrial Sand Association (NISA) and NIOSH.[14,15]

In mining and other industrial environments, comprehensive silicosis prevention programs include substituting less-hazardous noncrystalline silica alternatives when possible; implementing engineering controls such as blasting cabinets, local exhaust ventilation, controlled and restricted use of compressed air for cleaning surfaces; using water sprays to control dust; and using surface wetting to prevent dust from becoming airborne when cutting, drilling, grinding, etc.; administrative and work practice controls; personal respiratory protective equipment; medical monitoring of exposed workers; and worker training.[16]

These protections are responsible for a dramatic decrease in the silicosis mortality rate over the past several decades. The number of deaths from silicosis declined from 1,065 in 1968 to 101 in 2010.[17] According to the American Lung Association, between 1996 and 2005, the age-adjusted death rate due to silicosis was 0.8 per million population.[18]

Concentrations of dust at a typical industrial sand mining operation are far lower than what is considered an occupational health hazard. Most sand handling is done when the sand is wet or moist; workers who may be exposed to dust are generally not working in buildings near the source of dust, where concentrations may be relatively high if building ventilation is inadequate. Residences near mines are typically exposed to more dust from gravel roads and agricultural fields than from sand mine processes.[19]

Although silicosis is an occupational hazard for workers in industries that involve exposure to RCS, claims that sand mining will result in a public outbreak of the disease are not supported by air monitoring data.

The California Office of Environmental Health Hazard Assessment (OEHHA) and Minnesota Department of Health have established a health-based standard for respirable crystalline silica of 3 micrograms per cubic meter ($\mu g/m^3$).[20] This standard represents an air concentration level below which silicosis is unlikely to occur in the most sensitive populations such as children or the elderly, even if exposure occurs over an entire lifetime.[21]

Part 2 summarizes the results of studies conducted by the Minnesota Pollution Control Agency (MPCA) and studies conducted by Dr. John Richards of Air Control Techniques (ACT), who measured levels of RCS near industrial sand facilities in Wisconsin.

Part 2
Scientific Data on the Effect of Industrial Sand Mining on Air Quality

Reliable scientific air-quality data are essential for determining whether industrial sand operations pose a risk to nearby communities. The lack of publicly available air quality data at and near industrial sand operations has likely contributed to past concerns about the effect these facilities may have on air quality.

Concerns of this nature were likely compounded by pressure from local activists and YouTube videos showing sand blowing off storage piles at frac sand facilities, prompting the industry and Minnesota Pollution Control Agency to launch ambient air sampling studies.

> Reliable scientific air-quality data are essential for determining whether industrial sand operations pose a risk to nearby communities.

These studies followed USEPA and NIOSH procedures to conduct air quality monitoring near industrial sand mining, processing, and transportation facilities, in addition to monitoring for RCS along frac sand hauling routes. Following sound scientific and industry standards, measurements include upwind and downwind samples, wind speed and direction, and weather conditions to put the air samples collected into appropriate context.

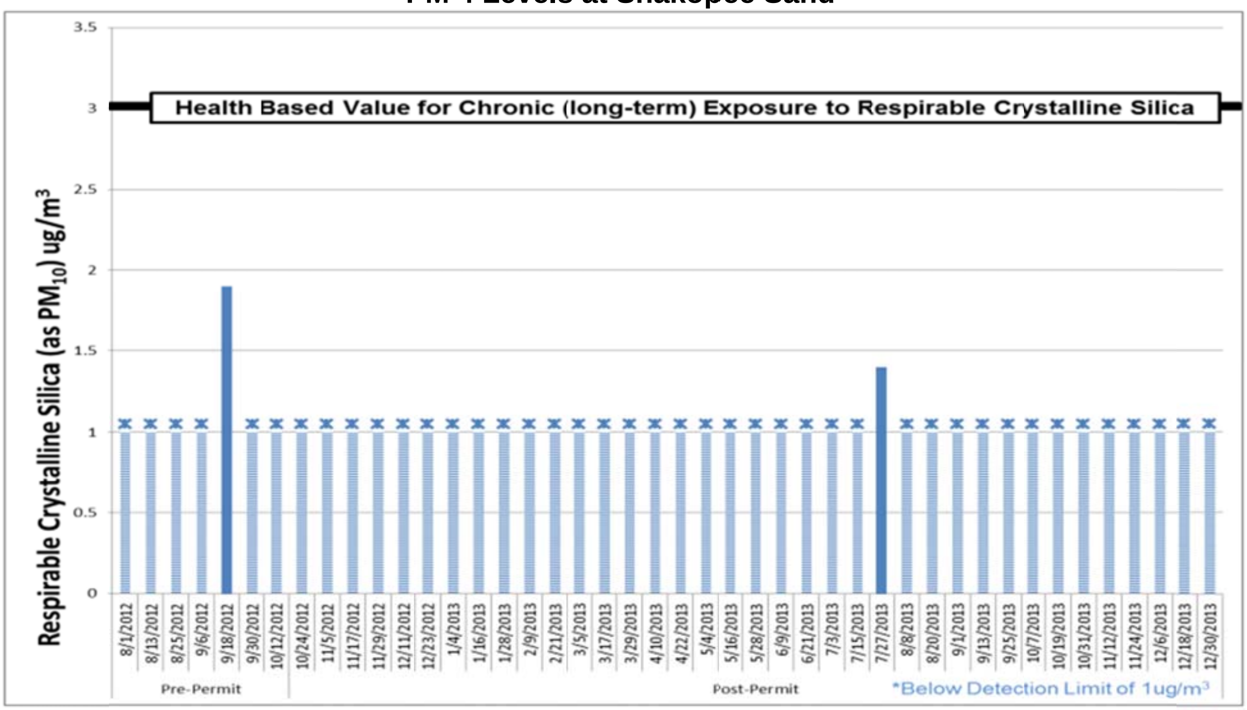
Scientists compared data collected near industrial sand operations to data collected by regional air monitoring networks, providing additional context to the discussion. Such comparisons allow researchers to determine whether particle measurements are due to local industrial sand facilities or the result of regional or worldwide air quality. These studies, conducted by state agencies and scientists, provide stakeholders with the best-available data for determining the risks posed by industrial sand mining. The results of these studies are discussed below.

Monitoring at Shakopee Sand LLC, Jordan, Minnesota

Shakopee Sand LLC placed two ambient air samplers and meteorological monitors near the fence line at its operation to measure RCS and PM10 beginning in the third quarter of 2012. RCS data were collected for more than one year, and PM10 monitoring continued for three years, ending in June 2015.[22]

The monitoring showed RCS concentrations lower than the Minnesota and California reference standard of 3 $\mu g/m^3$ in every sample. In order to be detected in a sample, there must be at least 0.31 µg/m3 of PM4 RCS. This value is known as the Limit of Quantification (LOQ). RCS concentrations measured at Jordan Sands were below the LOQ in 42 of 44 samples, 96 percent of the days sampled, meaning concentrations of RCS were so low they could not be detected in the overwhelming majority of samples. (See Figure 2.)

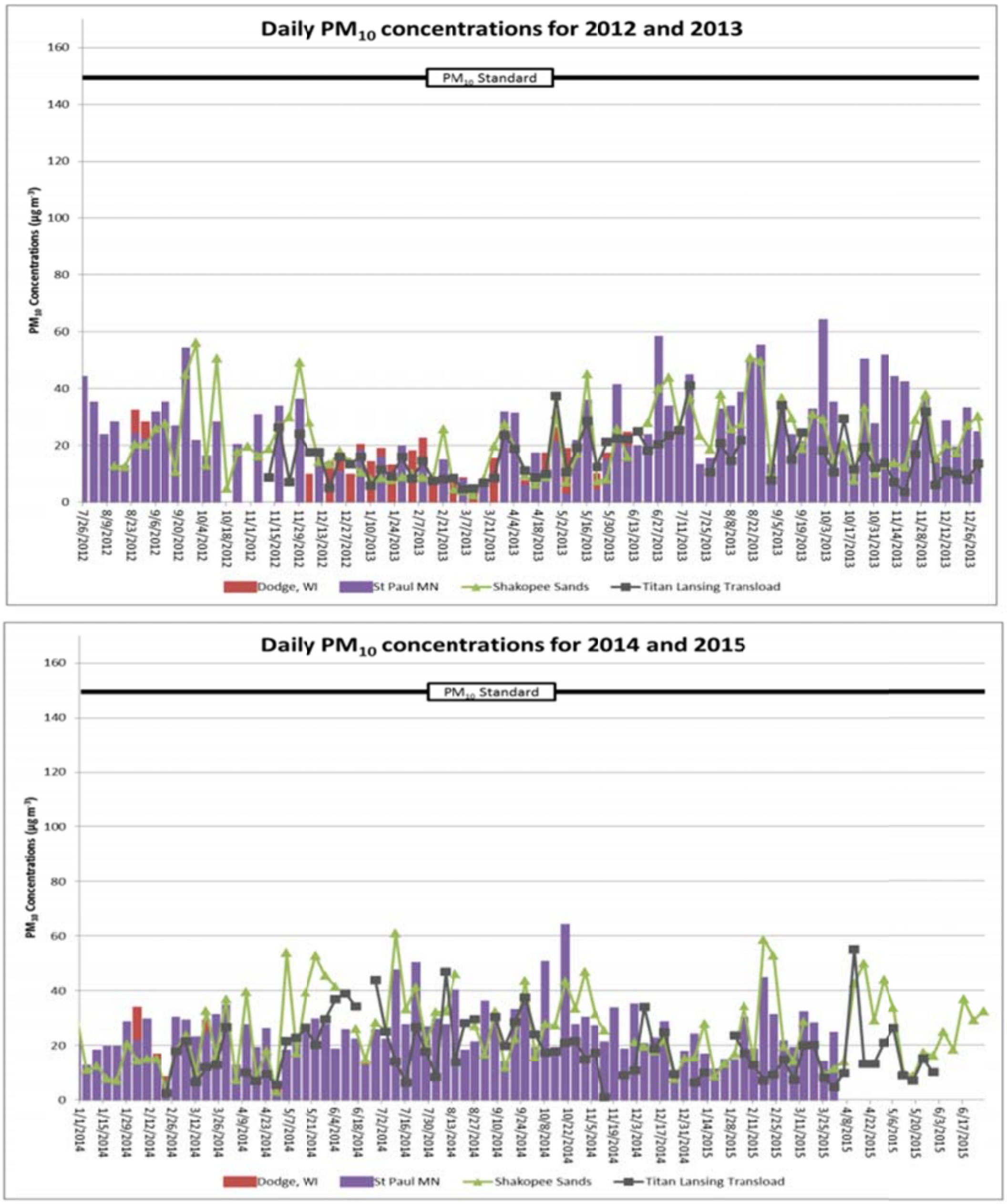
Figure 2
PM 4 Levels at Shakopee Sand



Respirable crystalline silica (PM4) was monitored at the northeast side of the Shakopee Sand fence line at a 1 in 12 day frequency. Levels of RCS were so low they could not be detected on 95.55 percent of the days sampled.[23]

PM10 measurements were substantially lower than the 150µg/m^3 standard established by USEPA and were generally lower than 50µg/m^3. The PM10 data closely correlated to background PM10 concentrations measured in other areas, indicating the Shakopee Sand facility was not a significant contributor to particle pollution at or near the mine. (See Figure 3.)[24]

Figure 3
PM 10 Levels at Shakopee Sand
2012 – 2015



Monitoring at Shakopee Sand shows maximum PM10 concentrations were less than one half of the 150µg/m^3 standard established by EPA and strongly influenced by regional trends.

Monitoring at Jordan Sands, LLC, Mankato, Minnesota

Jordan Sands is conducting ambient air monitoring at its operation for total suspended particles (TSP), PM10, PM2.5, silica in particulate matter less than or equal to four microns (PM4 silica), and meteorological parameters.[25]

Two air monitors provide upwind/downwind data. One ambient air monitoring station (South) was located on the south-southeastern area of the proposed dry plant facility and the outdoor sand storage pile near the facility's property line. The second monitoring station (North) was located on the far northern side of the mine along the property boundary.[26]

The Jordan Sands monitoring detected RCS in 18 of 89 samples, all at concentrations substantially lower than the Minnesota and California reference standard of 3 $\mu g/m^3$. RCS levels were too low to be detected in 70 of 89 samples tested, or 80 percent of the samples. (See Figure 4.) None of the 89 PM2.5 measurements approached the daily standard of 35 $\mu g/m^{3.}$ (See Figure 5.)

Wisconsin Ambient Air Monitoring

Prior to the start of air sampling programs in 2012, very little ambient RCS data were available near industrial sand operations. In response to this lack of data, several air monitoring studies were conducted by ACT at industrial sand operations in Wisconsin. These sampling programs served to address questions and concerns and supplemented the limited RCS data measured at industrial sand operations.

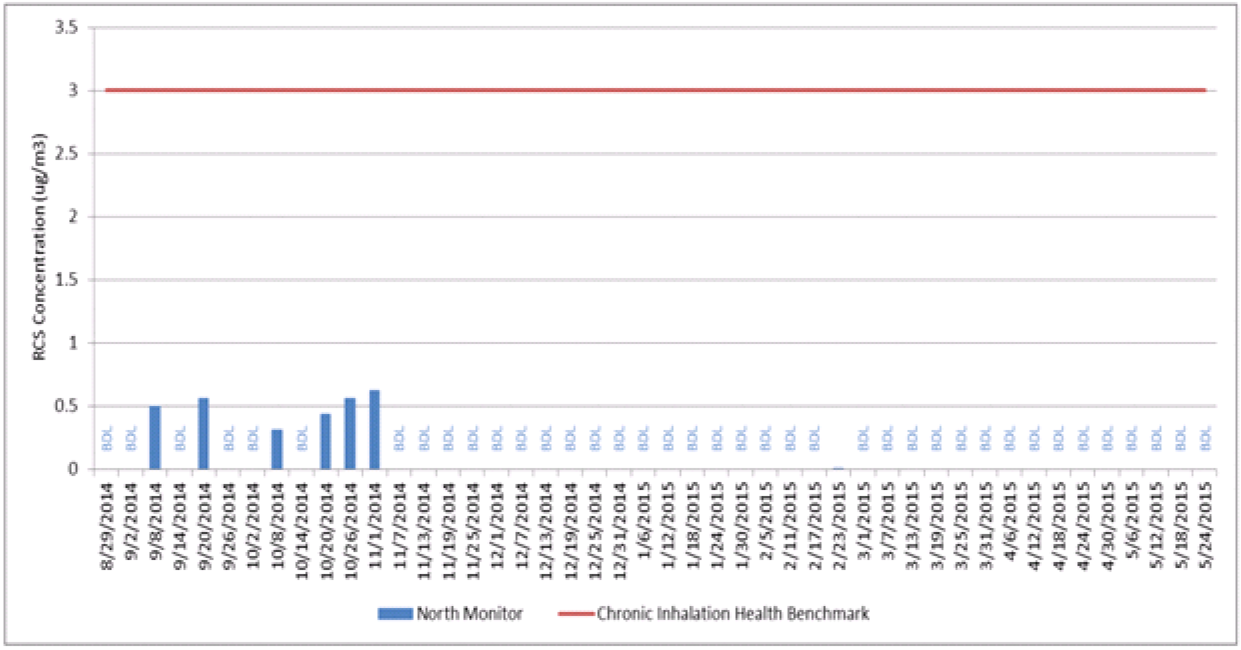
Air monitoring studies were conducted by ACT at industrial sand operations in Wisconsin, addressing questions and concerns and supplementing the limited RCS data measured at industrial sand operations.

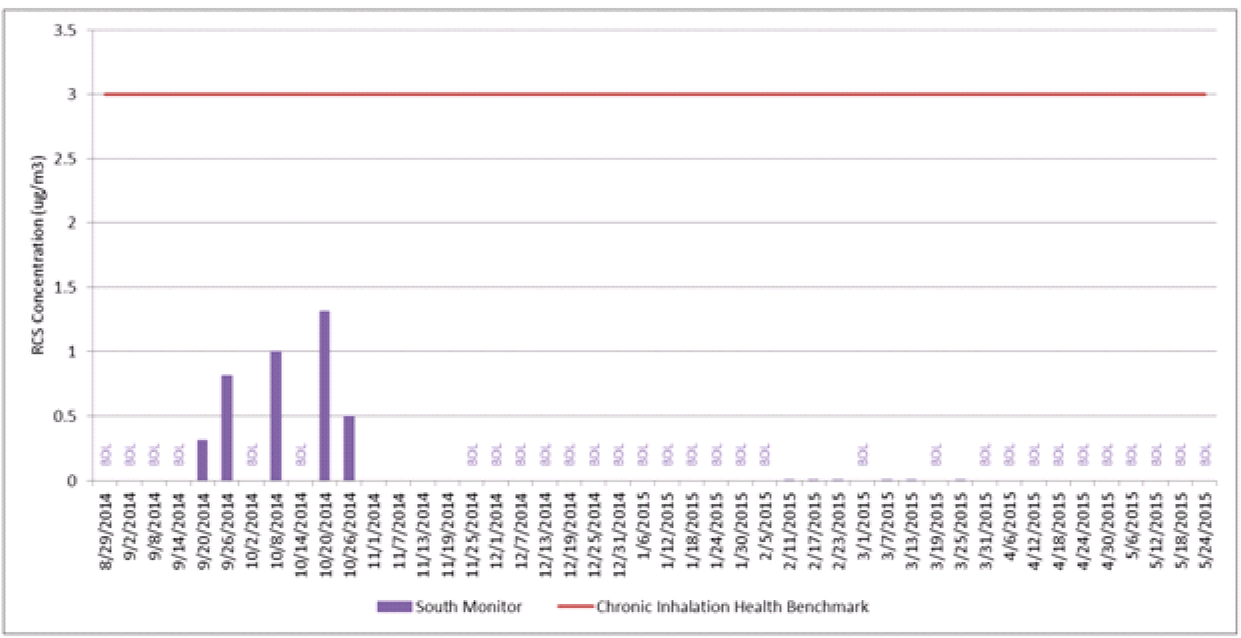
The ACT studies examined three aspects of air quality near the operations to evaluate the potential impact of these facilities on the environment: 1) the amount of RCS in the ambient air, 2) the amount of RCS that may be contributed from the mining operations, and 3) how the data collected near mining operations compare with regional ambient air testing from monitors installed throughout Wisconsin.

ACT is a national leader in air sampling technology. In 2006, the company developed a technique for measuring PM4 crystalline silica that is consistent with USEPA and NIOSH guidelines for PM2.5 sampling. This technique has been used by state regulatory agencies such as the California South Coast Air Quality Management District and MPCA, in addition to being the basis for the air monitoring studies conducted in Wisconsin.[27]

The study and results reported by ACT as summarized in this paper were the first large-scale, long-term application of this measurement method.[28] (*Wisconsin analysis continues on page 12.)*

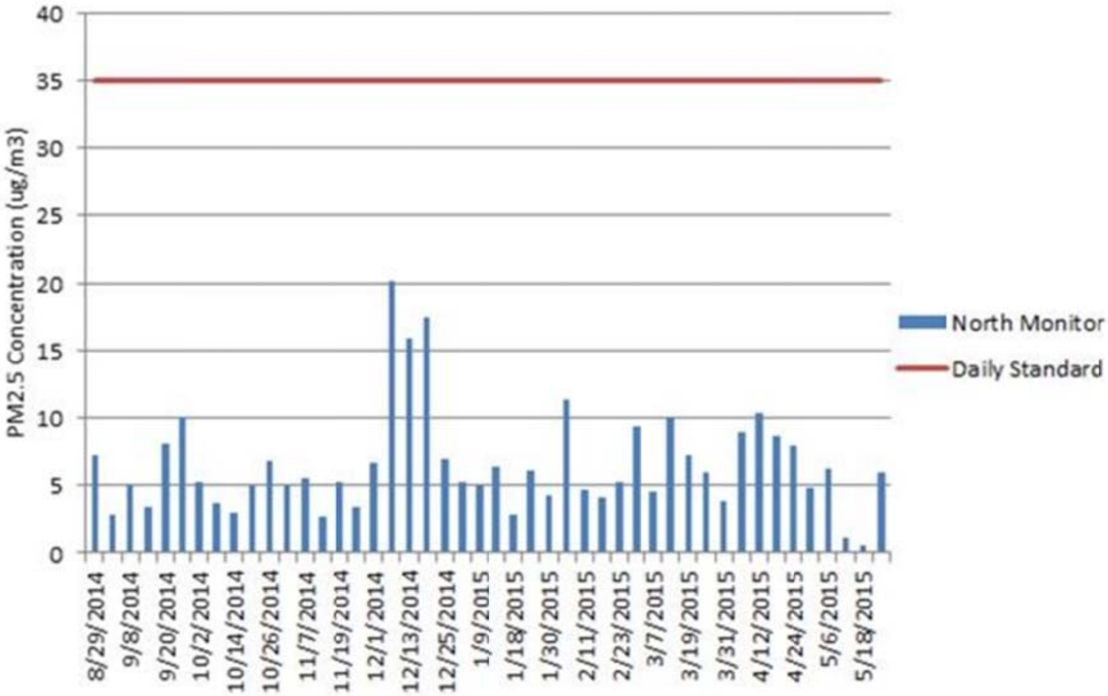
Figure 4
Respirable Crystalline Silica Monitoring at Jordan Sands, LLC

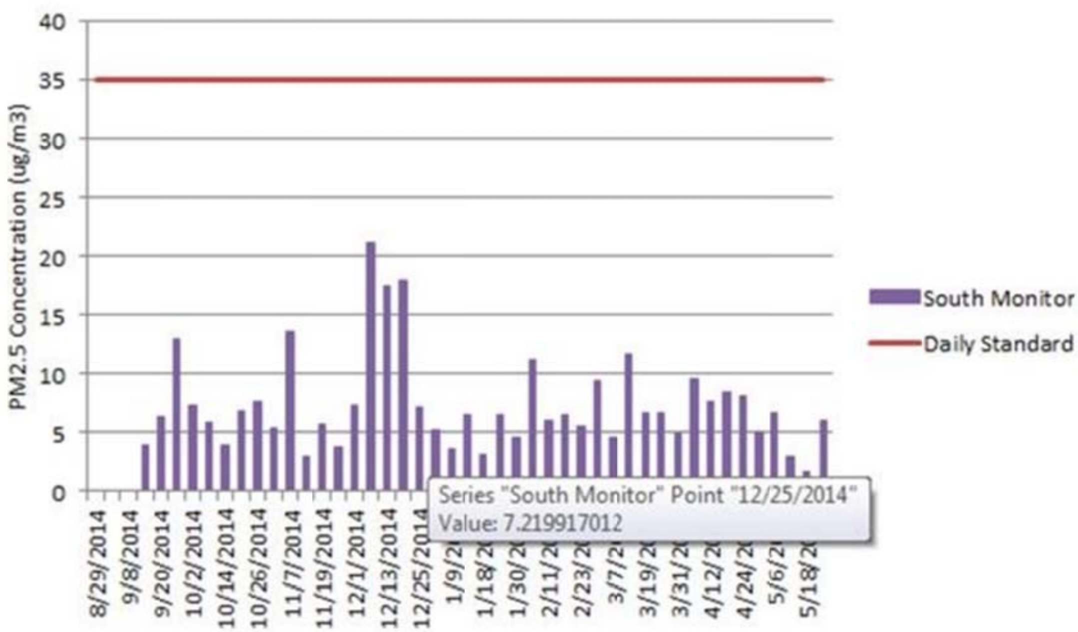




Concentrations of RCS at upwind and downwind facilities show every sample day was far below the health-based standard of 3µg/m^{3}.

Figure 5
PM 2.5 Monitoring at Jordan Sands





PM2.5 measurements at Jordan Sands showed no exceedances of the daily PM2.5 standard.

EOG, Chippewa Falls, Wisconsin

Air quality monitors were installed at four industrial sand facilities (one processing plant and three industrial sand mines) operated on a once-every-third-day schedule. Sampling days matched the sampling calendar schedule established by USEPA and used in federal and state agency air monitoring networks. Matching the federal schedule was done to provide consistency between the data collected by ambient PM4 samplers at the industrial sand facilities and the background data collected simultaneously by state agency PM2.5 samplers.

RCS levels were too low to be detected in 88 percent of the 2,128 samples tested in the 16 data sets.

Twelve samplers collected 2,128 24-hour samples, establishing a long-term data set from which conclusions can be drawn. WDNR audited the 12 samplers during the long-term sampling program.[29]

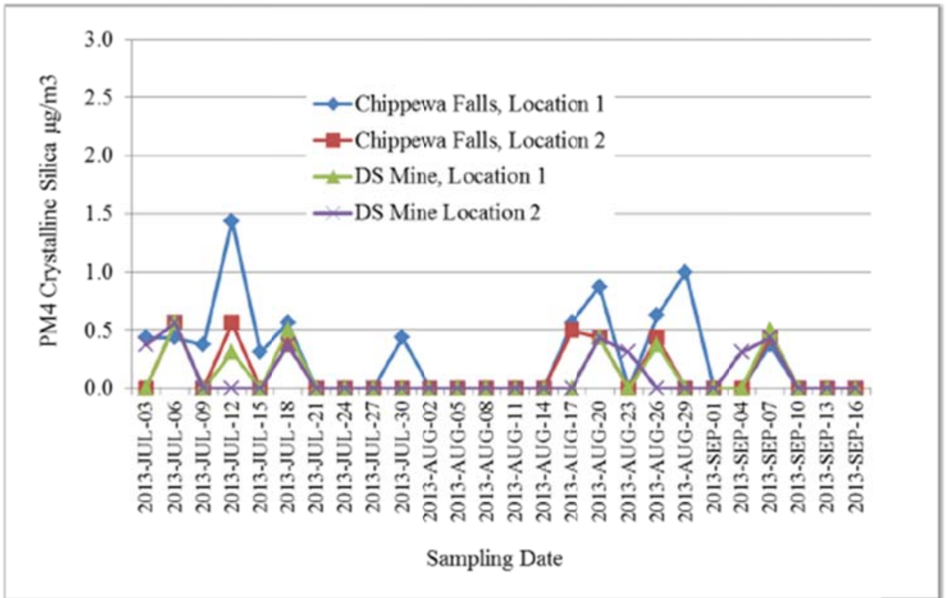
The presence of 12 PM4 particulate matter samplers at these industrial sand operations in two adjacent counties is an especially dense population of ambient air monitors. For comparison purposes, there are only 23 state-operated PM2.5 samplers in the entire state of Wisconsin.

Upwind-to-downwind concentration differences across the operations were evaluated and local background concentrations were calculated. These methods allowed the ambient data compiled to be directly comparable to the NIOSH health effects database compiled over the past 30 years concerning occupational exposure to RCS. The NIOSH Engineering Control database serves as a central repository of current NIOSH information on engineering control technology. The content of the database summarizes previously published NIOSH research findings.[30]

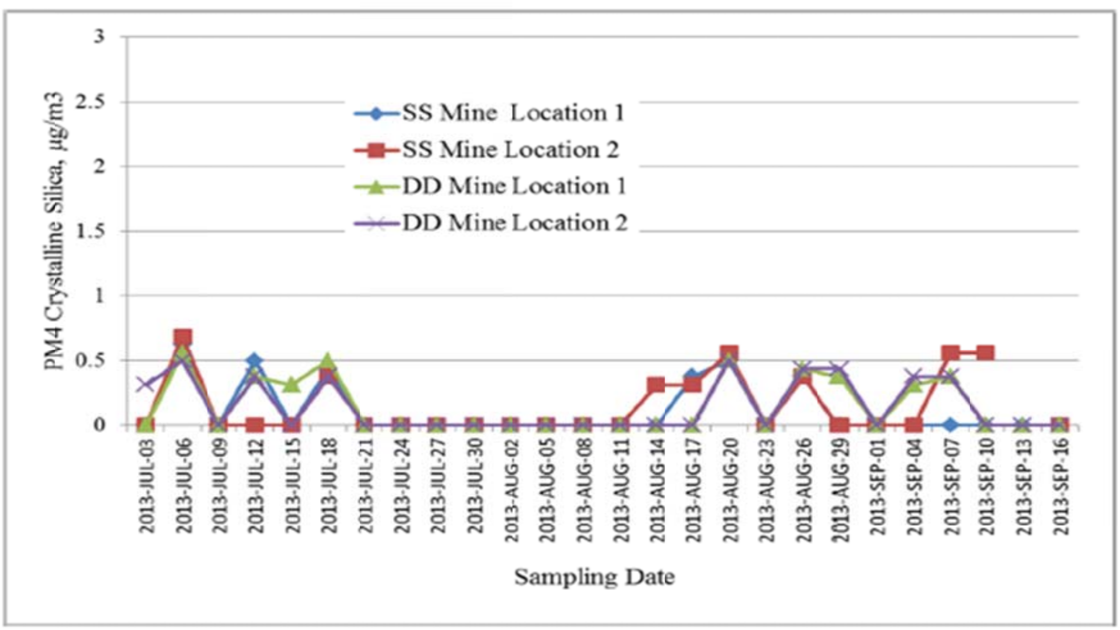
None of the sampling detected RCS at concentrations greater than the California or Minnesota health-based standards of 3 µg/m^3. RCS levels were too low to be detected in 88 percent of the 2,128 samples tested in the 16 data sets. This value is approximately one-tenth of the OEHHA and MNDOH health-based standards.[31] (See Figure 6.)

Even the highest values of RCS detected (the upper 99% percentile values) were well below California and Minnesota standards. These values of RCS ranged from 0.31 µg/m^3 at Chippewa Falls Location 2 (2014 data set) to 1.44 µg/m^3 at S&S Mine Location 2 (October 2012–December 2013 data set). Because these values examine the highest concentrations detected, they indicate there were small amounts of variability of the 24 hour average data.[32]

Figure 6
RCS Monitoring at Chippewa Falls, Wisconsin



(a)



(b)

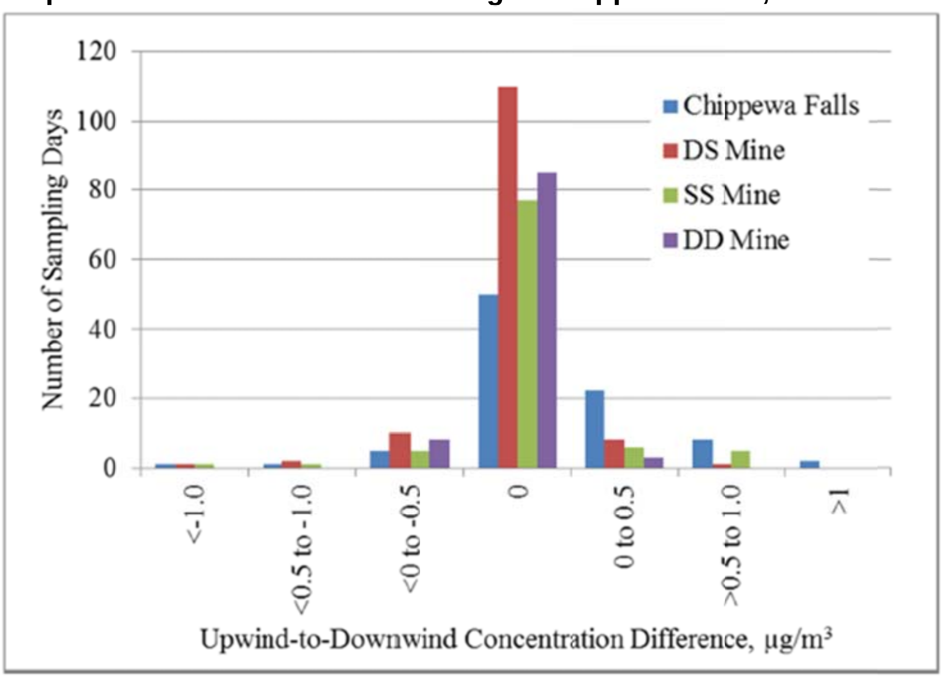
Levels of RCS were below the detection limit on 88 percent of the 2128 days sampled, and when RCS was able to be detected, it was far below levels established by California and Minnesota considered dangerous for chronic exposure. These findings strongly suggest it is not possible for industrial sand facilities to become a source of environmental silicosis. The graphs show variations of PM4 RCS concentrations over times. (a) shows variations in PM4 RCS concentrations at the Chippewa Falls plant and DS mine from July 3, 2013, to September 16, 2013, and (b) shows variations from July 3, 2013 to September 16, 2013.

The consistent variations in the sampling observed throughout the multi-year program suggest concentrations of RCS measured near industrial sand operations are consistent with the range of local background for Western Wisconsin. According to ACT, this finding was further reinforced by the fact that both the S&S and DD mines were not in operation during the two-and-one-half-month period shown in in Figure 6(b), but still had low RCS concentrations that were very similar to those shown in Figure 6(a).

While total RCS concentration is an important measure, it is also important to be able to determine how much RCS is generated by each facility. This is done by conducting upwind and downwind sampling. Upwind samples take an initial measurement, or a baseline, and measurements at downwind facilities show concentrations downwind: The difference between the two allows us to assess the impact of the facility on air quality. Think of it this way: Downwind Measurement - Upwind Measurement = contribution of the industrial sand facility to RCS.

Differences in upwind-to-downwind measurements in the 24-hour average concentrations at the four locations studied ranged from approximately −1.4 $\mu g/m^3$ to +1.5 $\mu g/m^3$. The upwind-to-downwind differences in the RCS concentrations were very small at the four facilities sampled. (See Figure 7.) Also, there was no detectable change in the upwind-to-downwind concentrations on 78 percent of the days during which the winds moved in a consistent and identifiable upwind-to-downwind direction.

Figure 7
Upwind and Downwind Monitoring at Chippewa Falls, Wisconsin



Upwind-to-downwind PM4 crystalline silica concentration differences, October 2012 to December 2013.There was no difference between upwind and downwind values on 78 percent of the days sampled, indicating these facilities did not contribute to RCS levels on a majority of the days sampled.

These very small upwind-to-downwind concentration increases and decreases indicate the industrial sand operations contribute little, if anything, to ambient RCS concentrations and suggest the observed detections can be attributed to local background. Background RCS comes from a variety of sources, including farm fields, paved and unpaved roads, de-icing sand, and construction sites.

Very small upwind-to-downwind concentration increases and decreases indicate the industrial sand operations contribute little, if anything, to ambient RCS concentrations.

To evaluate the variation in particulates from one day to another, the PM4 concentrations measured at the Chippewa Falls processing plant were compared to data from a WDNR-operated PM2.5 monitoring site in Eau Claire, Wisconsin about 14 miles south of the Chippewa Falls facility. This comparison is reasonable, because PM4 monitors collect particles sized 4 microns and smaller, which includes particles that would be gathered by a PM2.5 monitor.

The monitors show the day-to-day variations in local PM2.5 measured by WDNR at Eau Claire are very similar to the day-to-day variations in PM4 at both locations at Chippewa Falls. These closely related variations suggest most of the PM4 particulate matter measured at Chippewa Falls was background PM2.5 particulate matter from sources throughout the region, not a contribution of small particles by the industrial sand operations. (See Figures 8 and 9.)

Where differences in PM concentrations were observed, ACT found they were primarily due to nearby major highway and urban sources that affected PM2.5 air quality near the WDNR Eau Claire PM2.5 sampler but not the Chippewa Falls PM4 samplers.

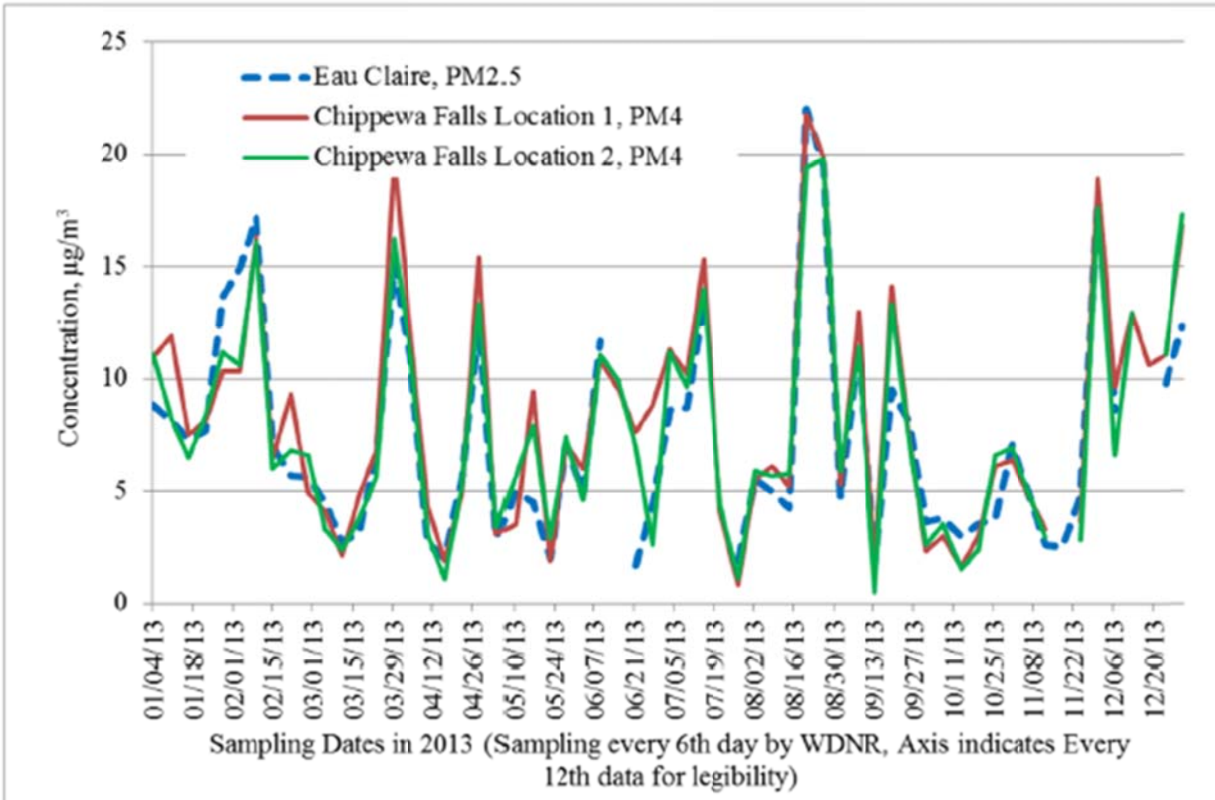
The tight relationship between the values for PM2.5 and PM4 particulate matter and similar trends suggest the daily variations in respirable crystalline silica regional air quality were primarily due to variations in local background concentrations.[33]

The long-term average respirable crystalline silica concentrations in this study are similar to those measured by the Minnesota Pollution Control Agency (MPCA) in Winona and Stanton, Minnesota, discussed below. MPCA used sampling and analytical procedures similar to those employed by ACT in Wisconsin.

The findings at these facilities led ACT to conclude the exposure to RCS near industrial sand operations is the same throughout the region because there were no significant differences in the upwind-to-downwind long-term concentrations for the three sand-producing mines and the processing plant.

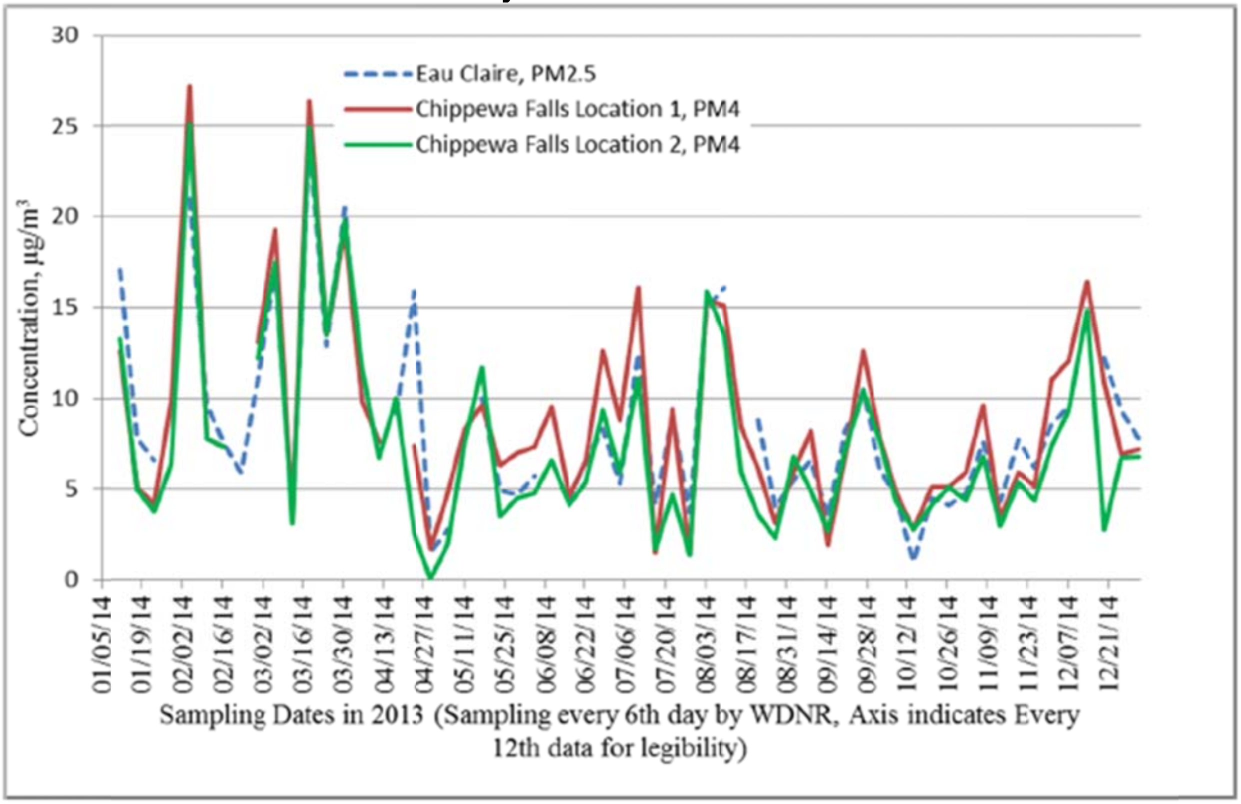
In conclusion, this study found RCS concentrations for the entire data set of 2,128 twenty-four hour respirable crystalline silica measurements and the long-term averages at each of the four facilities were less than 10% of the standards established by the state of California and Minnesota. Additionally, concentrations of PM4 particles measured near the industrial sand facilities were consistent with PM2.5 regional air monitoring concentrations, suggesting industrial sand facilities have little impact on air quality.

Figure 8
Comparison of Data from Eau Claire and Chippewa Falls, Wisconsin
October 2012 – December 2013



Comparison of the WDNR PM2.5 data from Eau Claire with the PM4 particulate matter data from Chippewa Falls Locations 1 and 2, October 2012–December 2013.

Figure 9
Comparison of Data from Eau Claire and Chippewa Falls, Wisconsin
January 2014 – December 2014



Comparison of the WDNR PM2.5 data from Eau Claire with the PM4 particulate matter data from Chippewa Falls Locations 1 and 2, January 2014–December 2014 show a nearly identical correlation in small particle concentrations, indicating these facilities have very little impact on air quality locally, or regionally.

Fairmount Santrol, Mathy Construction, and U.S. Silica, Wisconsin Mines

In addition to air monitoring at four EOG facilities near Chippewa Falls, Wisconsin, ACT conducted air monitoring studies at Fairmount Santrol Inc., Mathy Construction Inc., and U.S. Silica facilities.[34] In these studies, 657 24-hr samples were collected from seven sampling locations. Six of the seven samples were taken near industrial sand operations, and one, Cataract Green, was a "control" area where no industrial sand operations were present. Cataract Green was also not located near farm fields or unpaved roads, which are sources of RCS, allowing a more representative control for establishing regional background concentrations of RCS.

This study, like the study at EOG facilities near Chippewa Falls, found the long-term average ambient PM4 crystalline silica concentrations were low at each of the sampling locations.

A majority of crystalline silica samples taken at six locations were lower than levels that could be detected (the LOQ of 0.3µg/m^3), and average RCS values for all seven locations sampled were lower than the health-based standard of 3µg/m^3 established by California and Minnesota. (See Table 1.) Even the highest concentrations (99th percentile column) were 44 percent lower than levels considered hazardous assuming constant exposure to RCS for a 70-year lifespan.

Table 1
Summary of 24-Hour PM4 Crystalline Silica Measurements

Sampling location	No. of 24-hr samples	No. of samples above LOQ	Arithmetic average concentration (microgram/m³), values < LOQ treated as 0.0	Arithmetic average concentration (microgram/m³), values < LOQ treated as LOQ/√2	99th percentile concentrations (microgram/m³)
Maiden Rock Northwest	126	18	0.09	0.28	0.67
Maiden Rock Southwest	128	74	0.45	0.54	1.69
Maiden Rock Northeast	128	27	0.11	0.28	0.97
Sparta	90	10	0.05	0.24	0.51
Cataract Green	60	8	0.07	0.26	0.70
Downing West	62	12	0.11	0.29	1.10
Downing East	63	13	0.10	0.27	0.72
Weighted average			**0.15**	**0.32**	

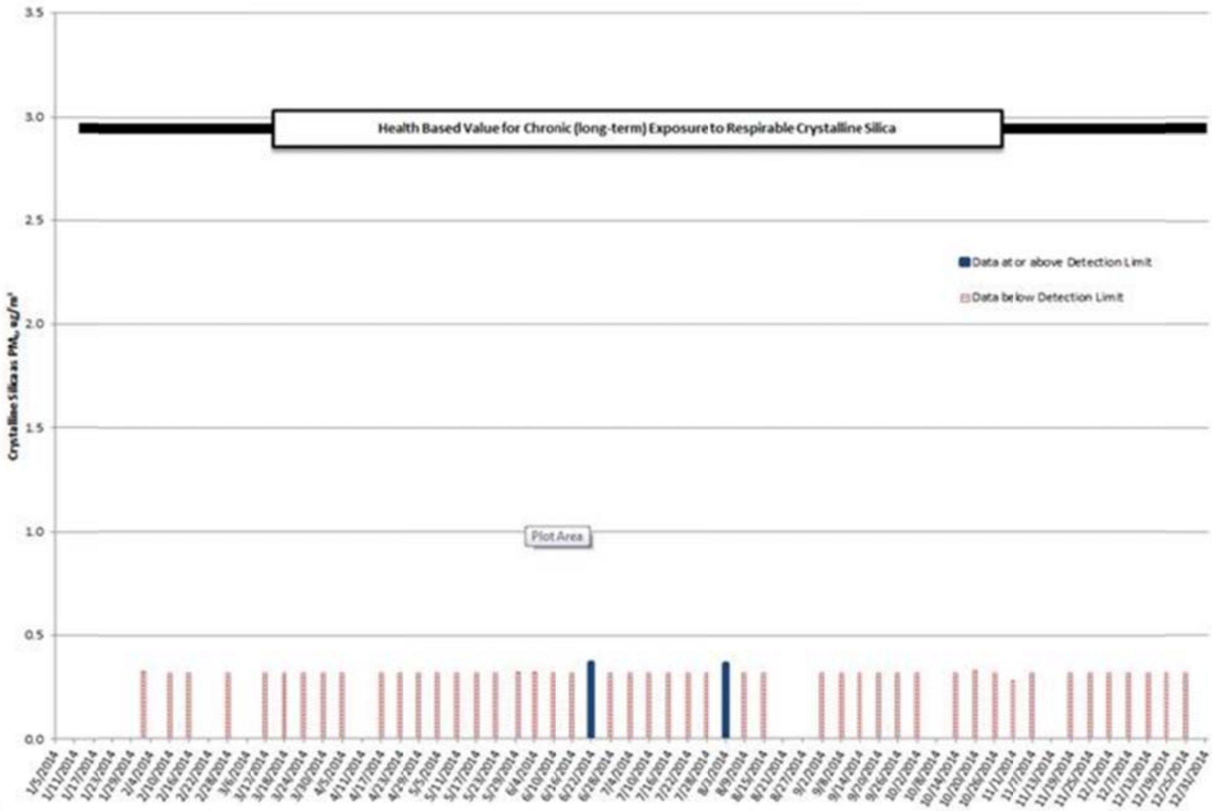
This table shows the sampling location, number of samples taken, and results from each of the six industrial sand facilities, and the control area of Cataract Green. Results indicate levels of RCS at industrial sand facilities were similar to Cataract Green, suggesting these facilities do not generate large quantities of RCS.

The data compiled in the sampling studies at the four Wisconsin facilities indicate the PM4 crystalline silica concentrations at industrial sand operations are within the range of local background concentrations, and demonstrate these operations are not responsible for generating hazardous levels of particulates in the local or regional ambient air.

Dust Generated by Transportation of Sand

A small number of individuals have raised concerns that dust blowing from trucks hauling sand could be a source of hazardous respirable silica particles along transportation routes. Those concerns prompted authorities from MPCA to conduct ambient air monitoring along a busy truck route in Winona, Minnesota. MPCA concluded dust from hauling industrial sand near the air monitoring location was not a threat to public health. MPCA data showed RCS levels were too low to be detected on 95 percent of the days sampled. (See Figure 11.) When air monitors did detect dust, it was in concentrations near 15 percent of the chronic health benchmark of 3 µg/m^3 used by MPCA.[35]

Figure 11
RCS Levels in Dust Along a Truck Route in Winona, Minnesota

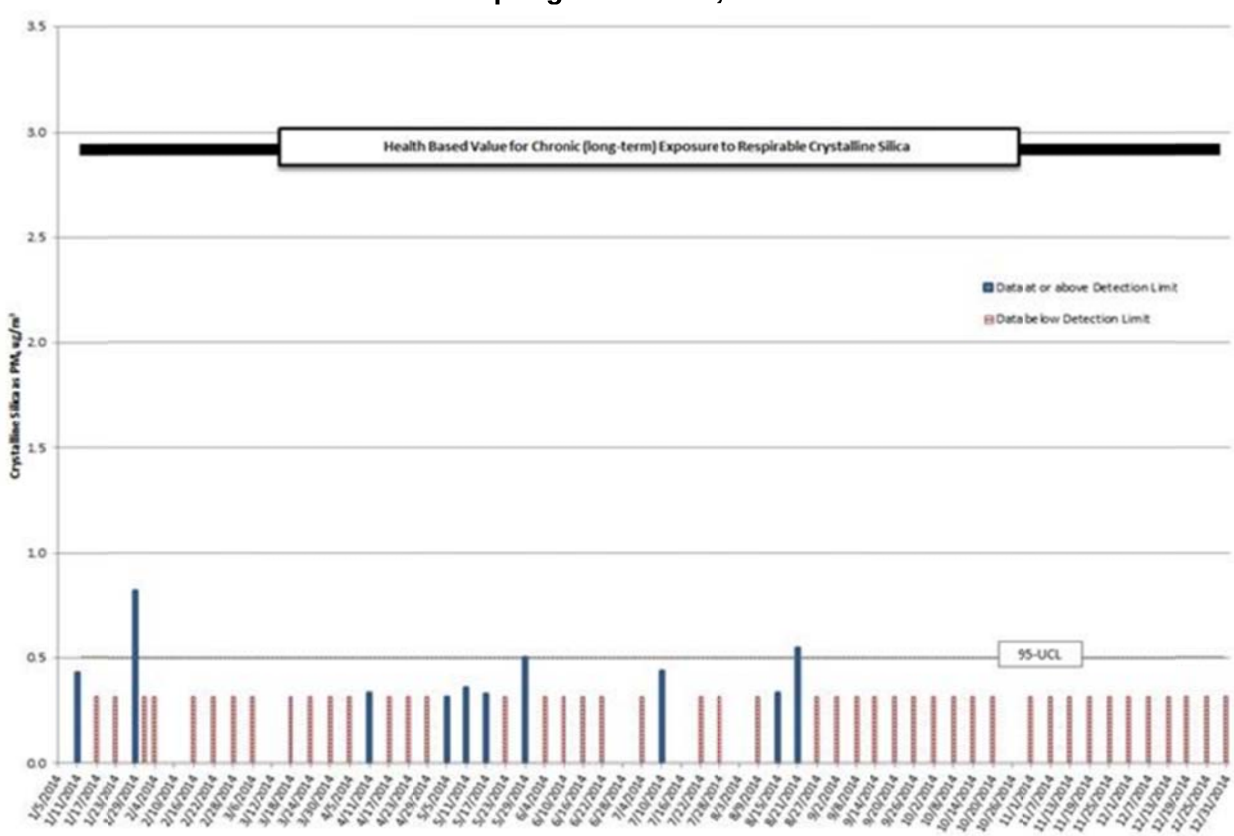


MPCA data from Winona, Minnesota indicate only two days (blue) of 61 days sampled had any detectable amount of RCS, meaning levels of RCS were so low in Winona they could not be detected on 96.8 percent of the days sampled. Additionally, when RCS was detected, it was approximately 10 percent of the California and Minnesota health-based limits.

MPCA conducted sampling near the town of Stanton, Minnesota as a control/reference site to compare against RCS levels it recorded in Winona. Stanton does not have industrial silica sand facilities or haul routes used to move sand, but it does have other sources of RCS, such as farm fields and unpaved roads. The air monitor installed in Stanton detected RCS on in nine of the 33 24-hour samples taken, and the RCS levels were higher than the concentrations found in Winona, despite the fact Stanton has no industrial sand facilities.[36,37] (See Figure 12.)

These findings led MPCA to conclude, “Airborne silica is a fairly ubiquitous pollutant and is not unique to silica sand mining and processing facilities.”

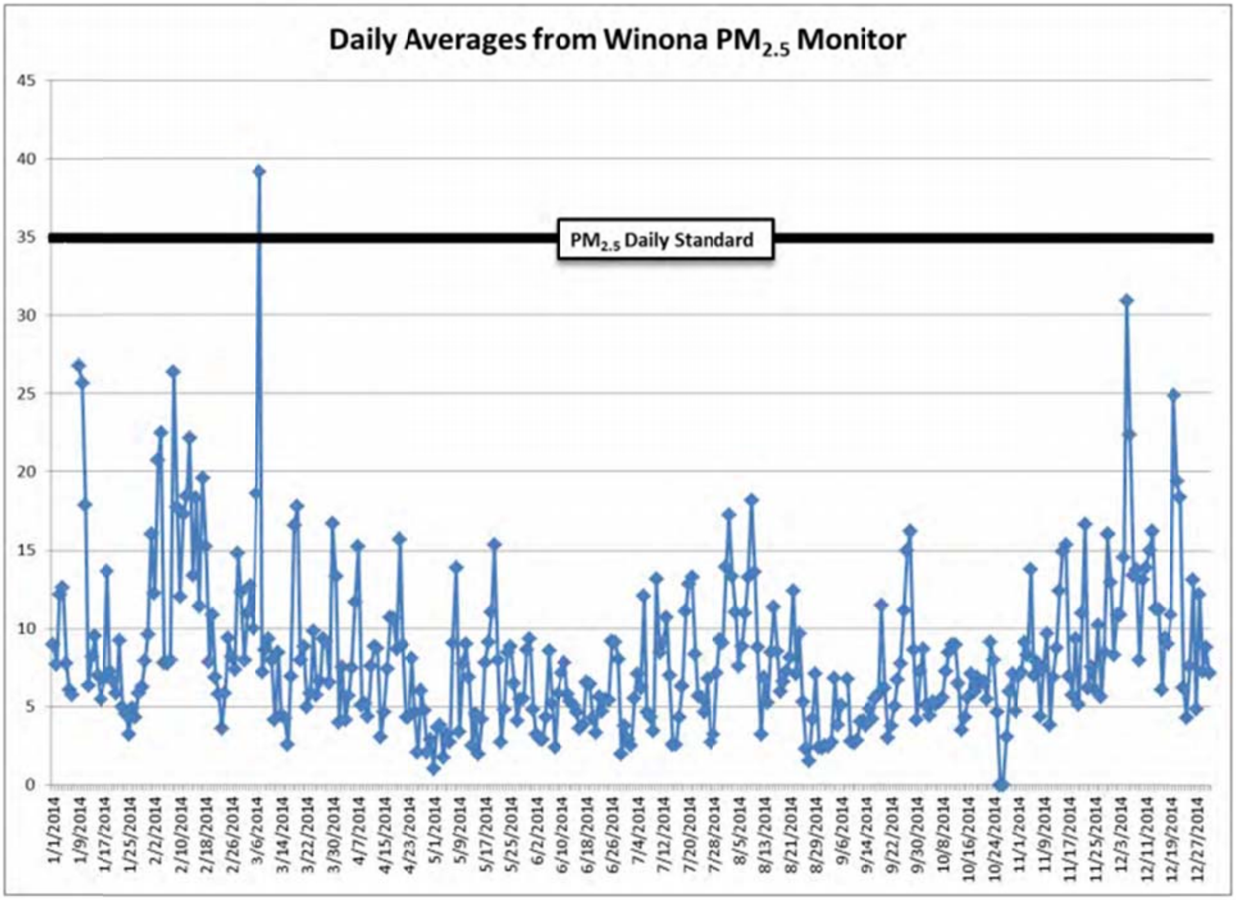
Figure 12
RCS Sampling in Stanton, Minnesota



Despite having no industrial sand facilities near Stanton, Minnesota, concentrations of RCS were higher in this area than near the frac sand haul route in Winona, Minnesota. Levels of RCS in Stanton were likely due to agricultural activity or unpaved roads, and none of the sample days indicate RCS concentrations that could potentially result in negative health impacts.

PM2.5 concentrations measured by MPCA in Winona were also lower than levels considered dangerous by USEPA. (See Figure 13.) Of all the days sampled, only one 24-hour sample exceeded the National Ambient Air Quality Standards (NAAQS) for PM2.5, and even this reading MPCA attributed to a weather pattern that affected much of the central and eastern United States, not industrial sand mining. MPCA did not conclude fine particle pollution associated with silica sand operations caused the exceedance in Winona.[38]

Figure 13
Daily PM2.5 Concentrations in Winona, Minnesota



Concentrations of PM 2.5 in Winona Minnesota were below the daily standard on all but one of the days sampled. MPCA attributed this outlier to a regional weather pattern and not industrial sand mining.

MPCA also conducted air monitoring at the Titan Lansing transload facility, where sand is processed and loaded into rail cars, located in North Branch, Minnesota, to assess the effect of sand processing and transportation on air quality.[39] Respirable crystalline silica (PM4) was monitored at the northwest and south sides of the Titan Lansing Transload fence line at a one-in-six-days frequency. Monitoring began at the site in January 2013 and was ongoing at the time this study was written.

MPCA reports the data collected indicated RCS values were lower than the RCS health-based value and did not suggest any exceedances of ambient air quality standards. The data indicate levels of RCS too low to be detected on most days sampled, and the data show no days on which PM2.5 or PM10 standards were exceeded.[40]

In summary, Part 2 presents the findings of several studies assessing the impact of industrial sand facilities on air quality in Minnesota and Wisconsin. Each of these studies has found industrial sand facilities have not generated hazardous concentrations of silica dust, and none of the operations studied exceeded health standards established by California and Minnesota.

Additionally, concentrations of RCS measured near these facilities have been similar to, and sometimes lower than, concentrations of silica dust in "control" areas where there are no industrial sand facilities, and concentrations of PM10 and PM2.5 were consistent with regional background concentrations.

Part 3

Understanding the Limitations of Research by Walters *et al*. and Dr. Crispin Pierce

Opponents of industrial sand mining frequently cite an article published in the *Journal of Environmental Health* titled "PM 2.5 Airborne Particles Near Frac Sand Operations," which they allege support their position that industrial sand facilities are negatively affecting air quality.[41,42]

> "PM 2.5 Airborne Particles Near Frac Sand Operations," for which Dr. Crispin Pierce served as faculty advisor, suffers from serious limitations that compromise the study and render the data collected of little or no use.

This article, which is formally credited to Walters *et al.*, is largely the result of work by Dr. Crispin Pierce, a professor of public health at the University of Wisconsin, Eau Claire, who served as faculty advisor for the article. We refer to this as the "Pierce article" due to his role as faculty advisor on this project.

While the Pierce article was published in a peer-reviewed academic journal, it suffers from serious limitations that compromise the study and render the data collected of little or no use in furthering the understanding of the impact of industrial sand facilities on air quality.

The article contains highly misleading statements that are demonstrably false. The Institute for Wisconsin's Health Incorporated (IWHI), a non-profit, non-partisan organization that conducted an extensive Health Impact Assessment of the potential health impacts of industrial sand mining in Western Wisconsin, concluded this about the Pierce article:

> It should be noted that researchers have conducted additional community-level ambient air quality monitoring for PM2.5 in western Wisconsin in the vicinity of industrial sand facilities. [Pierce], et al. (2015) measured PM2.5 at four industrial sand sites, collecting a total of six measurements ranging in length from approximately 6 hours to 25 hours in length.
>
> The equipment and methods used in this study did not meet the EPA Federal Reference Method for ambient air data collection, and not all samples represented a full 24-hour average. In addition, wind direction, wind speed, and distance to other possible particulate sources were not published as part of this study. Based

> on these deviations from approved air monitoring standards and the partial nature of the dataset, the research team did not find the study contributed to understanding of the issue.[43]

The limitations of the research methods utilized by Pierce prompted the Wisconsin Department of Natural Resources to issue the following criticism of his work:

> While the data from studies like Dr. Pierce's are of interest, the conclusions drawn are uncertain and of limited value due to the very limited sample sizes, and the fact that they employ non-federally approved sampling methodologies.[44]

> The Pierce article should not be considered of equal quality to the research done by scientists at MPCA, WDNR, or ACT.

Stakeholders in discussions of the air quality effects of frac sand mining are often directed to Pierce's work without being told of its significant flaws. The Pierce article should not be considered of equal quality to the research done by scientists at MPCA, WDNR, or ACT. Below we explain the limitations of Pierce's work, which ultimately does not make a serious contribution to scientific understanding of this issue.

Equipment Shortcomings

Air sampling is a delicate process. USEPA certifies only certain sampling equipment capable of accurately measuring concentrations of fine particles. Using the proper equipment is essential to obtaining quality, scientific data. None of the air sampling equipment used in the Pierce article, *PM 2.5 Airborne Particles Near Frac Sand Operations*, was USEPA-certified.

Instead of using EPA-certified Federal Reference Method (FRM) samplers, non-EPA certified filter-based, direct-reading samplers were used to conduct the analysis. Although these samplers are sometimes used by the U.S. Army to take quick measurements of particulate matter levels, they are not the industry standard used by environmental health professionals and thus are the incorrect equipment if reliable and relevant data are desired.

Despite the known limitations of the equipment, no easily understandable disclaimer was made in the journal article to give readers an accurate understanding of the margin of error in data collection or the uncertainties of the study. Although the article included consideration of the statistical uncertainty of the data collected, those uncertainties were presented as a series of complicated statistical calculations. No effort was made to present the uncertainties in a way the general public could reasonably be expected to understand.

The Pierce article also misleadingly asserts that direct-reading instruments can be co-located with EPA-certified FRM instruments, giving local governments and health departments a less-expensive, easy-to-interpret option for testing air quality. This assertion is inaccurate and misleading because it assumes the measurements from such instruments can be calibrated to correspond with the results obtained using USEPA FRM equipment. No evidence is offered to support this assertion.

It is highly unlikely such calibration is possible. Direct-reading instruments, such as the handheld TSI DustTrak 8520 and 8530 units, are unable to distinguish between water vapor and particulate matter in the air. These instruments cannot provide reliable data on PM2.5, because factors such as humidity can affect the accuracy of the readings. Dr. Pierce was aware of this fact but did not disclose the limitation in his article.[45]

If local governments purchase these less-expensive monitors, they will be no more capable of obtaining quality data than if they had purchased no monitors at all. Local officials must be aware of the shortcomings of this equipment to avoid spending limited resources on monitors that cannot properly detect small PM2.5 particles.

Faulty Methodology

In science, methodology is like a recipe for cooking: If the proper procedures are not followed, the results do not turn out well. In science, following the proper methods is not simply beneficial – it is absolutely essential to gathering data that are scientifically valid, because using flawed methodology will lead to obtaining flawed results.

> Pierce failed to follow well-established methods for sampling air quality.

Pierce failed to follow well-established methods for sampling air quality. The study did not include both upwind and downwind measurements, too few samples were collected, and some of the samples were not even 24-hours in length. Additionally, wind direction, wind speed, and distance to other possible particulate sources were ignored. All of these factors result in flawed and inappropriate data.

Upwind and Downwind Sampling

As noted in Part 2, upwind and downwind measurements are important because they act as before and after pictures. No upwind measurements were taken by Pierce during any of the six samples taken to compare with the downwind measurements taken. As a result, there are no "before and after pictures," making it impossible for this study to determine the contribution of industrial sand facilities to PM2.5 concentrations.

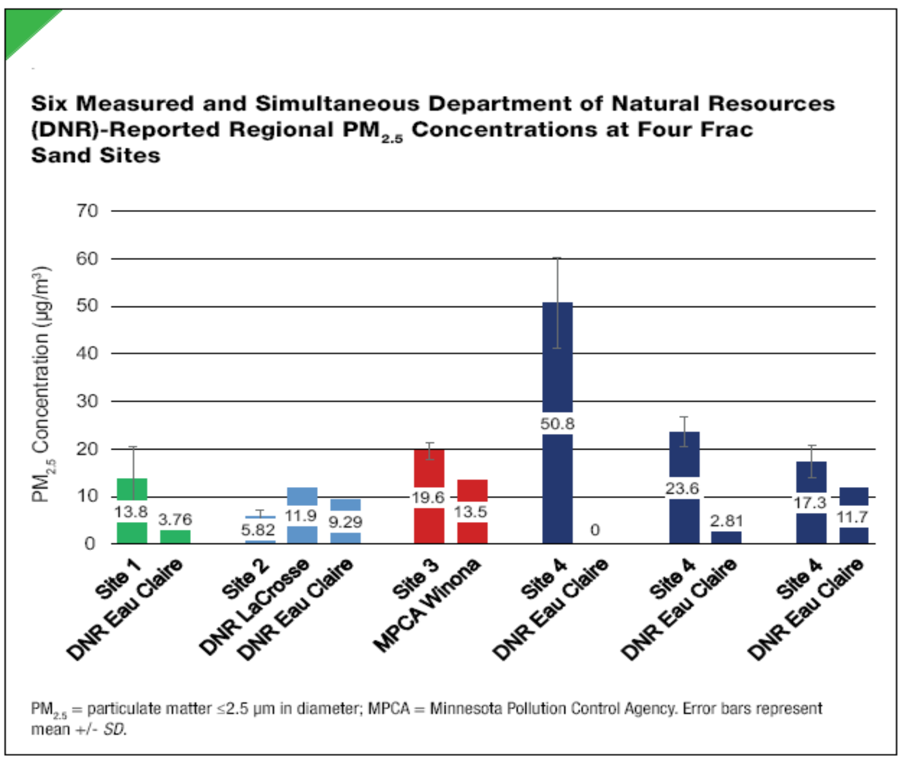
Pierce did not publish wind direction data relative to the position of the industrial sand facility, meaning the particulates could have come from other, nearby sources. As discussed above, levels of particulate matter are influenced by several factors at regional and local scales including local traffic and dust blowing from farm fields. Without taking these factors into account by observing upwind and downwind measurements, the study shows only "after" shots obtained with inappropriate equipment with no context or background data.

Not Enough Samples

Whereas the data reported by ACT and MPCA represent 2,936 24-hour samples at multiple locations in Wisconsin and Minnesota and years of sample data collected at the Titan Transloading station, the Pierce work reported on six samples at four locations. Only one of these locations, site 4, had multiple samples taken. (See Figure 13.)

Additionally, although the abstract of the study claims six 24-hour samples were taken near industrial sand facilities, the PM2.5 sample measuring 50.8μg/m^3 taken at Site 4 was taken over just six hours. This may explain why PM2.5 concentrations were higher during this sampling period than during the 24-hour samples.

Figure 13
Just Six Data Samples Collected at Four Locations

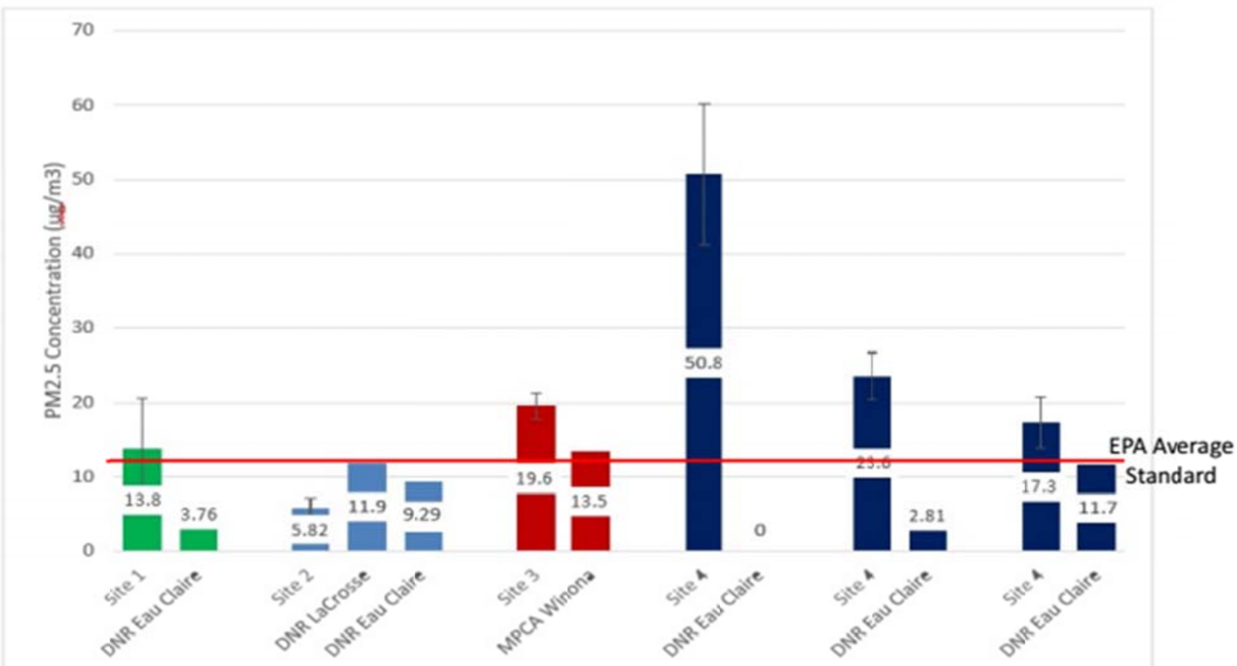


This chart shows the six data samples collected at four locations. USEPA FRM standards require samples be taken over a three-year period to draw accurate conclusions about air quality. The number of samples collected in the Pierce study constitutes only a tiny fraction of the required sampling days needed to draw scientific conclusions. Additionally, the sampler located at Site 4 collected data for only six hours. It is not a 24-hour sample and should not be compared with the rest of the data obtained.

USEPA regulates ambient PM2.5 as the three-year annual average level of 12 µg/m3, to protect against long-term health effects, and the 98th percentile level of 35 µg/m3, to protect against short-term effects.[46] Determining whether the PM2.5 annual average of 12 µg/m3 has been exceeded requires three years of data. Pierce routinely shows the graph below with the annual PM2.5 average superimposed on his six-sample data taken over periods of 24 hours or less. (See Figure 14.)

Pierce intentionally places the USEPA line on his graph to suggest these facilities are having adverse impacts on public health. In fact, his data are woefully insufficient to support that conclusion.[47]

Figure 14
Pierce Routinely and Misleadingly Superimposes
EPA Three-Year Standard on his 24-Hour Data



Three years of complete data using FRM equipment are required to determine regulatory compliance with the PM10 and PM2.5 annual ambient air quality standards.[48] Without this data, comparing 24-hour measurements to the annual standard is highly misleading, inappropriate, and causes people to become unnecessarily alarmed. *Source*: See, for example, Crispin Pierce, “What’s in the Air Around Frac Sand Plants,” Winchester Academy, February 25, 2015, https://www.youtube.com/watch?v=2P9s7k6RBs4, at approximately the 44-minute mark.

No Literature Review of PM2.5 Data Near Sand Plants

In addition to the limitations presented above, the Pierce article failed to conduct a literature review—which examines the results of similar studies to provide context for a new study—of the PM2.5 data and PM4 data collected near industrial sand plants with which to compare his results. Conducting such a literature review is standard practice for scientific papers, and the failure of the Pierce article to include a review of the best-available scientific data shows sloppiness at best, and scientific incompetence at worst.

The studies conducted by MPCA or ACT were not mentioned in Pierce's article. In fact, the Pierce article claims to be the first publication, to the authors' knowledge, measuring PM2.5 concentrations near frac sand facilities, claiming, "To our knowledge, this is the first publication of measured PM2.5 concentrations around frac sand facilities."[49]

This claim is demonstrably false. Several studies, including those conducted by MPCA and ACT, were published before Pierce's paper. It is also an irresponsible claim, needlessly alarming people when studies using EPA-certified equipment and methodologies clearly show frac sand facilities do not jeopardize air quality and present hazards to the public health.

Concluding Remarks

In the Health Impact Assessment cited earlier, the Institute for Wisconsin's Health concluded the health of people living near industrial sand facilities was threatened by stress and anxiety caused by the fear that those facilities could compromise public health and hurt property values. Stress and anxiety can cause irritability, anxiety, depression, headaches, and insomnia. It can also raise the risk of hypertension, heart attacks, and strokes, and increase incidences of heartburn or acid reflux. People under chronic stress are more susceptible to viral illnesses like influenza and the common cold.[50]

The alarming—yet scientifically baseless—conclusions reached by Pierce are likely to cause stress and anxiety in people living near industrial sand plants. The flawed methodology and shrill tone of Pierce's work is likely to be a greater public health hazard than industrial sand operations themselves.

> When improper equipment and methods are used for air quality monitoring, such "research" is a detriment to all stakeholders.

Although the authors of the Pierce article stated they wanted to help local health departments and elected officials gain clarity on unanswered questions about the potential health risks of frac sand mining, processing, transportation, and use in hydraulic fracturing, the flawed methodologies and improper equipment they used have produced the opposite result.

As air quality has become an issue of concern in areas near sand facilities, local governments have sought ways to measure potential emissions from sand facilities. Because of limited resources, these local governments may be tempted to use non-EPA certified equipment not capable of taking accurate readings. Pierce's article could have had a silver lining if it had cautioned these against purchasing this equipment because of its unreliability. Instead, the alarming tone of this research will serve only to make people more fearful of industrial sand mining operations, even though the research is not credible. Local governments would be wise to understand the limitations of this research and take the results with a grain of sand.

Air monitoring is critical to understanding the impact of industrial sand facilities, and nothing in this *Policy Study* in intended to downplay the importance of monitoring. Proper air monitoring is crucial for policymakers and local citizens. But when improper equipment and methods are used, such "research" dilutes the results of properly conducted monitoring programs and is a detriment to all stakeholders.

Part 4
Sandstone Cementation as a Potential Source of RCS

Examining a potential reason why frac sand mining does not generate large quantities of harmful particles

Studies by MPCA and ACT have found low concentrations of RCS near industrial silica sand facilities, with RCS concentrations far lower than levels established by California and Minnesota health officials. Here, we examine a possible reason *why* these operations are not significant sources of RCS.

The silica sand found in Illinois, Iowa, Minnesota, and Wisconsin is especially valuable as frac sand because the small particles of crystalline silica don't easily fragment when they are being fractured from larger grains of sand. Handling the frac sand at mines and processing facilities is unlikely to cause it to chip into particles of respirable size.

> Handling the frac sand at mines and processing facilities is unlikely to cause it to chip into particles of respirable size.

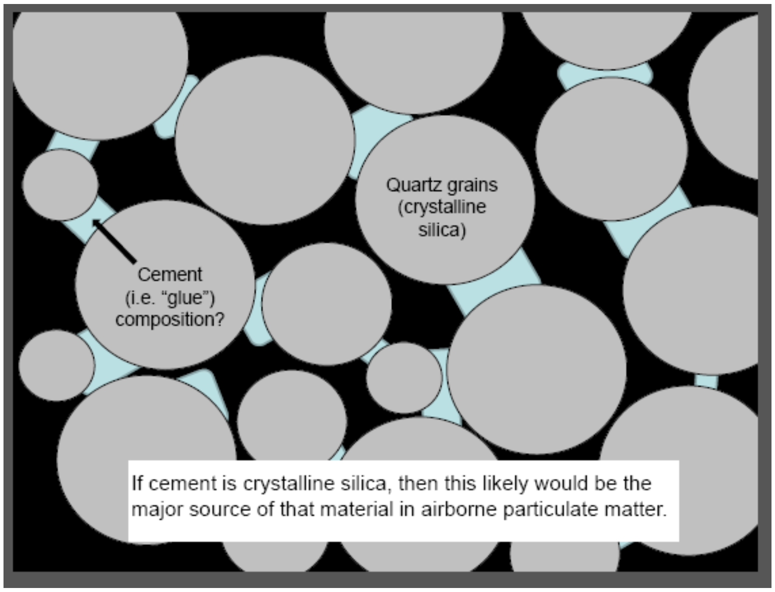
The smallest grain size of frac sand that satisfies specifications set by the American Petroleum Association is 105 microns—more than 40 times larger in diameter and more than 70,000 times larger in mass than a respirable 4-micron particle. The extraction, screening, and drying processes used in frac sand mining and processing do not impose the energy needed to fragment the crystalline silica grains to form PM4 particles.[51]

To have high concentrations of RCS, there must be a source of the small particulate material. If frac sand does not become fragmented during the mining process, another potential source of RCS is the "cement" holding sand particles together within the sandstone formation. (See Figure 15.) If the cement material has high concentrations of crystalline silica, it could be a potential source of small particles of silica dust, which makes studying the composition of the cement an important part of assessing potential risk.

The Department of Geology at the University of Wisconsin-Eau Claire studied the cement in the Jordan and Wonewoc Sandstone formations, two formations used extensively as a source of frac sand in Wisconsin and Minnesota. These formations are prized for frac sand due to their ultra-pure composition; round, high-strength grains; and weak cementation. The study sought to determine if the cement in these formations contained high levels of silica cement.

This study has yet to be submitted to a peer-reviewed journal, and it is important to remember the results provided are preliminary insights. However, the study can still provide valuable insight into the composition of cement material in the sandstone formations used for industrial silica sand mining in the upper Midwest.[52]

Figure 15
Makeup of a Sandstone Formation

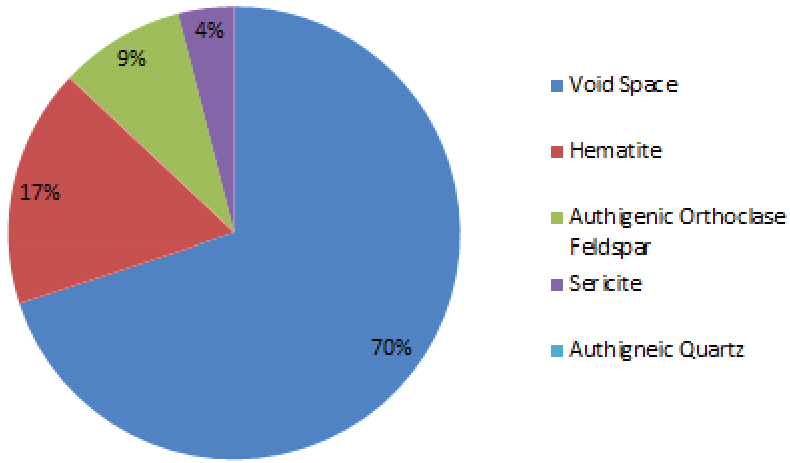


Think of the sand grains as bricks, and the entire sandstone as a wall. The “mortar” or cement holds the sand grains together. If this cement is silica-based it could potentially be a source for respirable crystalline silica.

Petrographic analyses of the Wonewoc Formation show the cement is composed largely of pore space (empty space between sand grains), hematite, authigenic orthoclase feldspar, and small amounts of sericite. (See Figure 16.) The samples studied contained very small amounts of authigenic quartz, which could potentially be a source of respirable crystalline silica. On the pie graph below, the amount of authigenic quartz does not register because it is less than 1 percent of the material identified in the pore spaces.

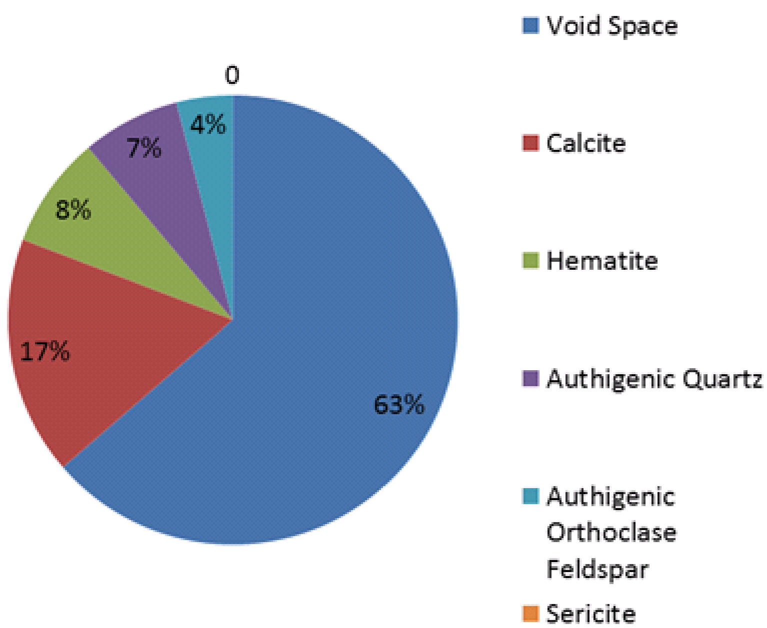
The composition of the space between sand grains was similar in the Jordan Formation, where pore space constituted the majority of the space between sand grains, followed by calcite, hematite, authigenic quartz, authigenic feldspar, and sericite. (See Figure 17.) The larger concentrations of authigenic quartz in the Jordan Formation come from samples that were obtained in the upper Jordan Formation near Arcadia, Wisconsin, where quartz, which is composed of silica, makes up a greater share of the cement. However, because silica is so strong, these silica-rich zones cannot be broken apart into useful frac sand grains, and rock from this area is treated as waste rock at industrial sand facilities in Wisconsin.[53]

Figure 16
Composition of the Wonewoc Sandstone



Nineteen samples were collected and analyzed in the Wonewoc Formation. Void space constituted 70 percent of the interstitial space, hematite 17 percent, authigenic orthoclase feldspar 9 percent, sericite 4 percent, and authigenic quartz less than 1 percent.[54]

Figure 17
Composition of the Jordan Sandstone



Interstitial spaces (spaces in between sand grains) are occupied by voids, calcite, sericite, authigenic orthoclase feldspar, and hematite. After analyzing 30 samples in the Jordan Formation, Mahoney et al found these spaces contained void space (63%), calcite (17%), hematite (8%), authigenic quartz (7%), authigenic orthoclase feldspar (4%), and sericite (<1%).

The lack of authigenic quartz in the cement samples implies the respirable particulate matter generated from the industrial sand mining process should have low concentrations of crystalline silica, which is good news for environmental and public health. The UW Eau Claire authors of this study have stated more samples are needed to conduct statistical analysis on these data.

Part 5
Conclusion

As industrial sand mining became more prevalent in Wisconsin and other states in the Upper Midwest in response to the demand for frac sand, so too did concerns about the effects the industry might have on the environment and human health. An initial lack of information exacerbated those concerns, and much misinformation persists to be cited in the public debate.

This *Policy Study* examined the best available scientific data collected by state agencies and nationally respected air monitoring scientists using EPA-certified equipment and sampling methodologies. Each of these studies has found industrial sand facilities do not contribute hazardous levels of respirable crystalline silica or particulate matter (PM) pollution, and therefore do not pose a threat to human health or the environment.

> This *Policy Study* examined the best available scientific data collected by state agencies and nationally respected air monitoring scientists using EPA-certified equipment and sampling methodologies.

Non-scientific studies using uncertified equipment and flawed methods have served only to create confusion regarding the effect of industrial sand facilities on the environment. Those reports have made people unnecessarily anxious and fearful about the effect these facilities may have on their families, their health, and their home values. It is our hope that this *Policy Study* will alleviate some of those fears.

This concludes The Heartland Institute's six-paper series on the environmental, economic, and social impacts of industrial sand mining. We thank those of you who have provided insights and assistance through the writing process, and especially thank you for reading these papers. We hope you found them informative and not too longwinded, and we look forward to working with you on these important issues in the future.

# # #

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