$PM_{2.5}$ Airborne Particulates Near Frac Sand Operations

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Abstract **The rapid growth of hydraulic fracturing for oil and gas extraction in the U.S. has led to 135 active "frac" sand mines, processing plants, and rail transfer stations in Wisconsin. Potential environmental health risks include increased truck traffic, noise, ecosystem loss, and groundwater, light, and air pollution. Emitted air contaminants include fine particulate matter ($PM_{2.5}$) and respirable crystalline silica. Inhalation of fine dust particles causes increased mortality, cardiovascular disease, lung disease, and lung cancer. In the authors' pilot study, use of a filter-based ambient particulate monitor found $PM_{2.5}$ levels of 5.82–50.8 µg/m³ in six 24-hour samples around frac sand mines and processing sites. Enforcement of the existing U.S. Environmental Protection Agency annual $PM_{2.5}$ standard of 12 µg/m³ is likely to protect the public from silica exposure risks as well. $PM_{2.5}$ monitoring around frac sand sites is needed to ensure regulatory compliance, inform nearby communities, and protect public health.**

Introduction

Hydraulic fracturing ("fracking") is a process where a mixture of sand, water, and hydrocarbon additives is injected under high pressure into the ground thousands of meters vertically then horizontally to extract oil and gas. The force of injection fractures formations such as the Marcellus Shale, and the sand particles prop open fissures for subsequent oil and gas extraction. Sandstone from upper Midwest formations, including Jordan, Wonewoc, Mt. Simon, and St. Peter Formations contains sand grains that are spherical, of substantial compression strength, and appropriate size (commonly 20/40 mesh, 840–420 µm diameter) for fracking operations. Frac sand mines and processing plants (to remove larger- and smaller-sized particles not used in operations) are concentrated in the upper Midwest but present throughout the U.S. and Canada (Frac Tracker, 2014). Including rail transfer sites, 135 are now active in Wisconsin (Wisconsin Center for Investigative Journalism, 2013; Wisconsin Department of Natural Resources [DNR], 2012; Wisconsin Geological and Natural History Survey, 2013). Rapid proliferation of these facilities—more closely located near population centers than traditional sand and gravel pits—has led to concerns about human exposure to airborne pollutants, notably fine particulates ($PM_{2.5}$, particles with a diameter of 2.5 µm and smaller) and crystalline silica (quartz). To our knowledge, this is the first publication of measured $PM_{2.5}$ concentrations around frac sand facilities.

The Wisconsin Department of Natural Resources does not regulate silica and has required less than 10% of frac sand mines and processing plants to measure the larger PM_{10} fraction of airborne particulates (particles with a diameter of 10 µm and smaller). This size fraction is not as closely associated with human health effects as fine particulates, however, and has a much higher U.S. Environmental Protection Agency (U.S. EPA) ambient limit of 150 µg/m³, compared to 12 µg/m³ for $PM_{2.5}$ (U.S. EPA, 2014).

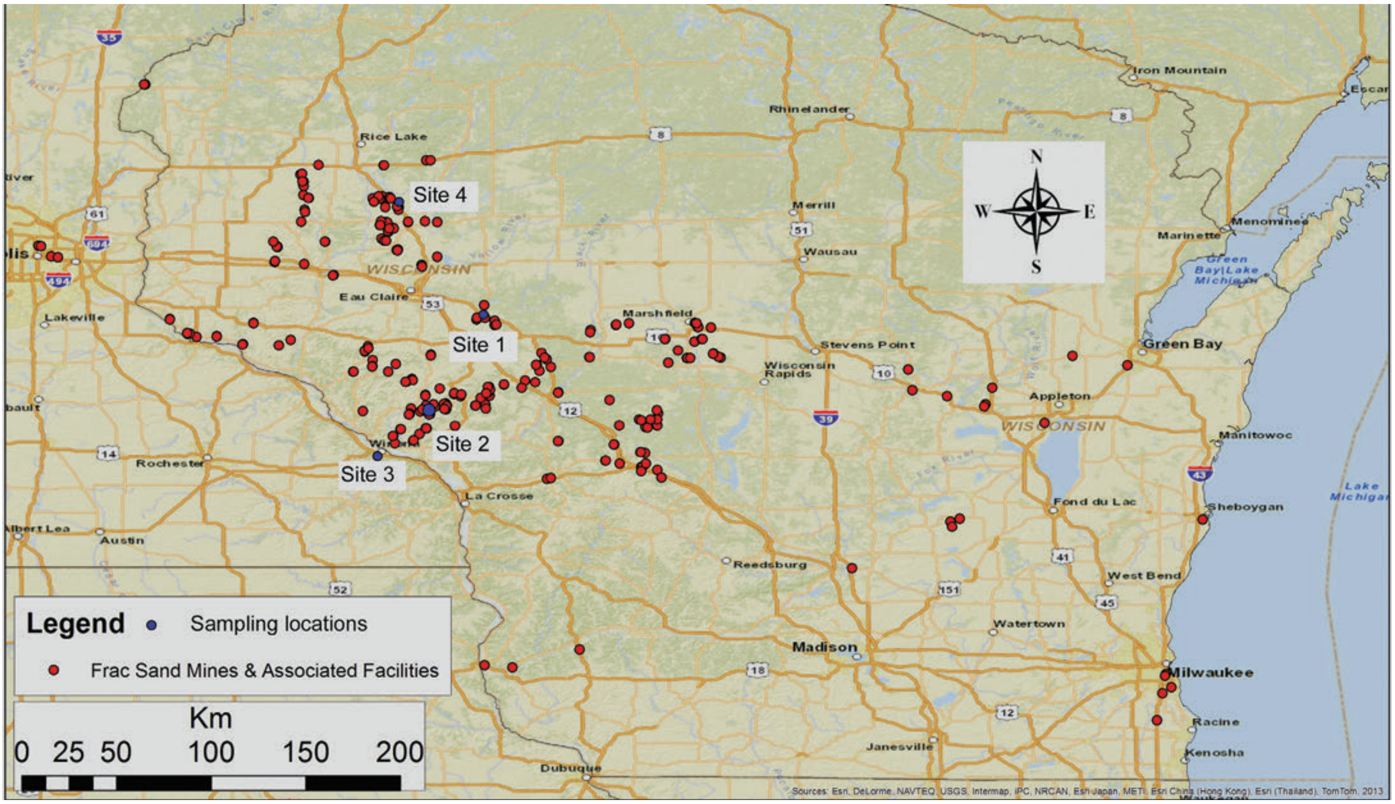
Fine particulates have been identified by U.S. EPA as a cause of cardiovascular and lung disease including lung cancer. Three comprehensive studies of urban air pollution have found that each 10 µg/m³ increase in long-term average $PM_{2.5}$ concentration was associated with

- a 4% to 14% increased risk of death from all natural causes;
- a 6% to 26% increased risk of death from cardiopulmonary/cardiovascular disease (including stroke); and
- an 8% to 37% increased risk of death from lung cancer (Lepeule, Laden, Dockery, & Schwartz, 2012; Martinelli, Olivieri, & Girelli, 2013; Pope et al., 2002).

In recognition of this particulate size toxicity, the U.S. EPA recently reduced the annual $PM_{2.5}$ public exposure standard from 15 to 12 µg/m³.

Crystalline silica (quartz) is a particularly important component of the $PM_{2.5}$ size range and is occupationally associated with silicosis and lung cancer (Collins, Salmon, Brown, FIGURE **1**

Sampling Locations and Wisconsin Frac Sand Facilities



Base map from FracTracker.org.

Marty, & Alexeeff, 2005; Park et al., 2002). "Freshly fractured" silica appears to be two to five times more reactive with animal lung tissue compared to "weathered" silica, though weathering occurs within several days and with exposure to water (Vallyathan et al., 1995). Respirable (PM_4) quartz has recently been measured at levels above occupational standards at hydraulic fracturing sites (Esswein, Breitenstein, Snawder, Kiefer, & Sieber, 2013).

Our examination of Mine Safety and Health Administration inspection reports (www.msha.gov/drs/drshome.htm) found that in 41 measurements of respirable particulates, crystalline silica comprised an average of 14.5%. By enforcing the U.S. EPA $PM_{2.5}$ annual standard of 12 µg/m^3, communities would then be expected to be exposed to a maximum of 12 µg/m^3 x 14.5% = 1.74 µg/m^3 crystalline silica, about half of the 3 µg/m^3 standard now used by California, New Jersey, and Minnesota (Collins et al., 2005); New York, Texas, and Vermont have more stringent standards (Wisconsin Department of Natural Resources, 2011).

Statistically verified public health effects from long-term exposure to fine particulates including silica would likely require decades of surveillance and costly "federal reference method (FRM)" particulate monitors. The rapid proliferation of frac sand plants and corresponding public concern, however, as well as the dearth of available ambient particulate air quality monitoring, mandate systematic new efforts to quantify public health risks. To address this imminent need for data, our pilot study focused on 24-hour "snapshots" of $PM_{2.5}$ concentrations around frac sand plants in Wisconsin and Minnesota. Shared interest in this topic has led to collaborations with environmental science faculty at the University of Wisconsin–Stout and the University of Iowa Environmental Health Sciences Research Center.

Methods

Four sampling sites of convenience in Wisconsin and Minnesota were chosen based on proximity to frac sand operations and protection of monitors on private property (Figure 1). Six nominal 24-hour ambient air samples were collected with an SKC DPS (deployable) sampler using the $PM_{2.5}$ sampling head (Patterson et al., 2010). Sampling conditions included calm and high wind flow, rain, and snow, at distances of 30–1,300 m from operations (Table 1). PVC filters were weighed pre- and post-exposure six times using a Mettler Toledo AT261 DeltaRange balance. Field blanks accompanied the DPS sampler and demonstrated no net mass changes. Filter conditioning was considered unnecessary after filters showed no mass changes after several days in desiccators or humidified chambers. DPS flow rate was calibrated to 10 L/min using a field rotameter. The $PM_{2.5}$ sample inlet was mounted 2 m high and away from buildings and trees as described in U.S. EPA sampling protocol (U.S. EPA, 2007).

Airborne $PM_{2.5}$ concentrations were calculated as follows:

$$PM_{2.5}\ (\mu g/m^3) = (\text{Filter mass}_{end} - \text{Filter mass}_{start})/(\text{Sample duration} * \text{Flow rate})$$

Sample standard deviations (*SD*) were calculated as follows:

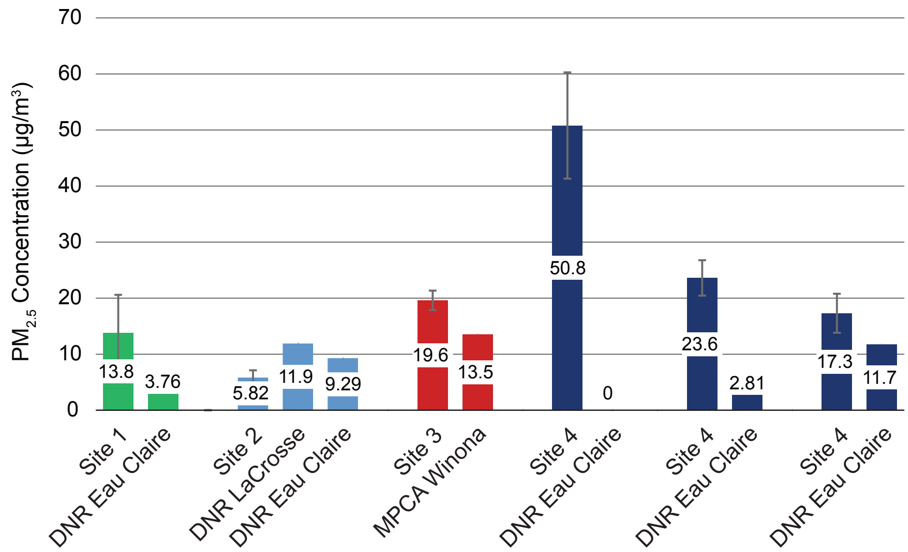
$$s.d._{sample} = \left(\sqrt{s.d.^2_{pre\text{-}weight} + s.d.^2_{post\text{-}weight}}\right) / (\text{Sample duration} * \text{Flow rate})$$

Temperature, humidity, wind speed and wind direction, and GPS coordinates were also recorded at each site.

Measured $PM_{2.5}$ concentrations were compared to the nearest Wisconsin Department of Natural Resources (DNR, 2014) and/or Minnesota Pollution Control Agency (MPCA, 2014) reported $PM_{2.5}$ levels, matched hour-for-hour to sampling times.

FIGURE **2**

Six Measured and Simultaneous Department of Natural Resources (DNR)-Reported Regional $PM_{2.5}$ Concentrations at Four Frac Sand Sites



$PM_{2.5}$ = particulate matter ≤2.5 µm in diameter; MPCA = Minnesota Pollution Control Agency. Error bars represent mean +/- *SD*.

Results

$PM_{2.5}$ levels of the six samples ranged from 5.82 to 50.8 µg/m^3 (Table 1). One location (site 4) that was sampled three times on different days had threefold different levels (50.8 vs. 17.3 µg/m^3). This observation is consistent with increased precipitation and wind speed causing lower levels of $PM_{2.5}$. Extent of frac sand facility activity also appears to affect measured fine particulates, with lowest levels near a small inactive mine (site 2, Table 1).

Five of the six samples had $PM_{2.5}$ levels higher than corresponding DNR or MPCA regional background levels. Variability among sample sites, between measured and DNR/MPCA reported values, and standard deviations from multiple filter weighings within measurements are visible in Figure 2.

Discussion

The U.S. EPA regulates ambient $PM_{2.5}$ both as the three-year annual average level of 12 µg/m^3 to protect against long-term health effects as well as the 98th percentile level of 35 µg/m^3 to protect against short-term effects (U.S. EPA, 2009). Our limited data set found that five of the six samples were above the 12 µg/m^3 average value (Table 1) and the 98th percentile value for the three site 4 measurements was 49.7 µg/m^3, higher than the U.S. EPA value of 35 µg/m^3.

Higher wind conditions (site 1), heavy snowing (site 3), and heavy rain conditions (site 4 on May 19–20, Table 1) may have contributed to lower $PM_{2.5}$ levels. The site with the smallest, inactive mine (site 2) had the lowest $PM_{2.5}$ concentration. Measured fine particulate levels are likely due to a combination of regional pollution, car and diesel truck exhaust, local industrial pollution, and frac sand particulate emissions.

Results from our study are limited due to the small sample size, and longer-term sampling both at the same site and across sites is needed to better establish chronic exposure levels of $PM_{2.5}$ to residents, workers, and commuters around frac sand sites. Colocation and testing of direct-reading instruments with U.S. EPA FRM instruments would provide options for testing of air quality by local health departments using less-expensive and easy-to-interpret instruments. We are currently testing the TSI DustTrak 8520 and 8530 aerosol monitors (battery-operated, portable light-scattering laser photometers) used extensively in particulate measurement (Chang et al., 2001; Kim, Magari, Herrick, Smith, & Christiani, 2004) as well as the Dylos DC1100 consumer air monitor. These, along with the SKC DPS, are being tested against Andersen dichotomous filter-based FRM monitors in control and frac-sand ambient environments.

Conclusion

With rapidly increasing frac sand mining, processing, transportation, and use in hydraulic fracturing, health departments and elected officials face unanswered questions about potential health risks. This research, together with other data of a similar nature we have collected, is suggestive of an increase of ambient $PM_{2.5}$ levels as a result of these activities. We propose the establishment of longer-term $PM_{2.5}$ monitoring with both direct reading and FRM particulate samplers, as well as silica-specific monitoring efforts, to ensure regulatory compliance, inform nearby communities, and protect public health.

TABLE **1**

Locations, Sampling Times, and Measured $PM_{2.5}$[a] Concentrations Near Frac Sand Mines and Processing Plants

Location	Date	Time	$PM_{2.5}$ (µg/m³ +/- *SD*)	Coefficient of Variation	Field Notes
Site 1	April 19–20, 2013	13:30–14:00	13.8+/- 6.79	49%	30 m from enclosed conveyor. Windy/snowing (4/19), clear/slight wind (4/20).
Site 2	July 13–14, 2013	0:00–0:00	5.82+/-1.30	22%	~1000 m from small inactive mine. One hour light rain.
Site 3	January 17–18, 2014	20:46–18:57	19.6+/-1.74	8.9%	500 m from inactive plant. Heavy snow.
Site 4	August 3, 2013	12:00–17:47	50.8+/-9.48	19%	200 m and 1300 m from two active plants. Sampled 347 min.
Site 4	November 22–23, 2013	15:09–16:44	23.6+/-3.16	13%	200 m and 1300 m from two active plants.
Site 4	May 19–20, 2014	16:50–17:15	17.3+/-3.48	20%	200 m and 1300 m from two active plants. Heavy rain on May 19.

[a]$PM_{2.5}$ = particulate matter ≤2.5 µm in diameter.

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mental Health Specialist/Registered Sanitarian (REHS/RS) exam, there are 15 Environmental Public Health Online Courses totaling over 45 hours of training on the South Central Public Health Partnership Web site. For NEHA members there are now more than 300 hours of courses and presentations available online through NEHA e-Learning.

ACTION ITEM: Seek out a new training opportunity to deepen your knowledge or sharpen your skills. Below are links to some of the training opportunities described above.

- IFPTI Fellowship in Food Protection Program: www.ifpti.org/fellowship
- CDC EHTER Ops Course: https://cdp.dhs.gov/training/program/hh
- Toastmasters International: www.toastmasters.org
- FDA ORAU: www.fda.gov/Training/ForStateLocalTribalRegulators/ucm119016.htm
- Environmental Assessment of Foodborne Illness Outbreaks: www.cdc.gov/nceh/ehs/eLearn/EA_FIO/index.htm
- Environmental Public Health Online Courses: www.cdc.gov/nceh/ehs/eLearn/EPHOC.htm
- NEHA e-Learning: www.nehacert.org

Build Your Credentials

Top-notch professionals know that credentials give them credibility with the people they work with. NEHA offers several environmental health credentials including the REHS/RS, the Healthy Homes Specialist (HHS), the Certified Professional-Food Safety (CP-FS), and the new Certified in Comprehensive Food Safety (CCFS) credential.

Every environmental health professional working independently in the field should hold the REHS/RS credential. It reflects demonstrated knowledge of the full range of environmental health issues that one might encounter in the course of one's career. Even in states where an REHS/RS is not required to practice, it is the recognized standard for our profession.

Additional credentials beyond the REHS/RS are important to demonstrate in-depth knowledge of particular areas of practice. In states that require an REHS/RS to practice, these credentials identify one as someone who is motivated to do more than the minimum that is required of them.

ACTION ITEM: Earn a new credential. Credentials are evidence of demonstrated knowledge of a particular area of environmental health and one's commitment to excellence.

For information on NEHA credentials, go to www.neha.org/professional-development/credentials.

Seneca, a first-century Roman philosopher, famously said, "Luck is what happens when preparation meets opportunity." What are you doing to prepare for your next career opportunity?

Bob Custard

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