

The University of Iowa EHSRC Project on Proppant Sand Mining

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Professor Peter Thorne
Mr. Jeff Falk

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Acknowledgements - Our Team

- Exposure Science:
 - Tom Peters, Patrick O'Shaughnessy, Ryan Grant (student), Jeff Falk, Ralph Altmaier
- Toxicology and Risk Assessment:
 - Peter Thorne, Andrea Adamcakova-Dodd, Jeffrey Stolwijk (student)
- Community Engagement:
 - Edith Parker, David Osterberg, Nancy Wyland, Liz Swanton (student)
- Partners
 - Trempealeau County, WI
 - Winneshiek County, IA
 - Allamakee County, IA



Fracking is a game changer

- Unconventional oil and gas production (UOGP) (a.k.a. hydraulic fracturing, fracking)
- New technology allows gas extraction from deep shale deposits through deep horizontal drilling down 9,000 ft.
- Fissures in shale formations are created by high pressure injection of a “fracking fluid” through which natural gas flows into a well
- These fissures are held open by crystalline silica sand injected with the fracking fluid (up to 15%)
- Currently no hydraulic fracturing operations in IA, WI, MN
- Mining operations are moving to the upper Mississippi River valley to extract Proppant (Frac) sand



Source of Frac Sand

UOGP has reduced the reliance of the U.S. on coal and foreign oil for power generation, but has issues for health and the environment



Source: Energy Information Administration



Crystalline Silica “Proppant” Sand

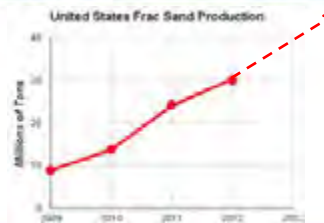
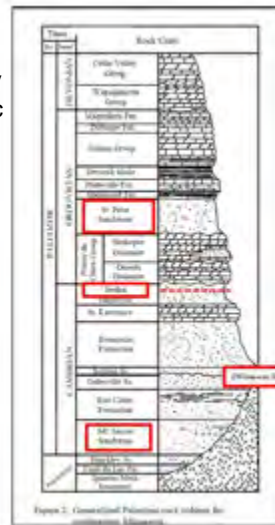
- Proppant sand props open the fissures in shale.
- Silica = silicon dioxide (SiO₂)
 - Amorphous
 - Crystalline
 - Rhombohedral crystals
 - Mohs hardness=7
 - Very resistant to crushing
- Source is certain sandstone formations
- Data are limited but perhaps 30 million tons were mined in 2012



Image: http://apps.startribune.com/blogs/user_images/sand2.JPG



Stratigraphy of Paleozoic rock in SE Minnesota showing favorable Frac Sand layers (in red)



Sources: MDNR and MGS
<http://geology.com/articles/frac-sand/>



Frac Sand Mining - Environmental Health Issues

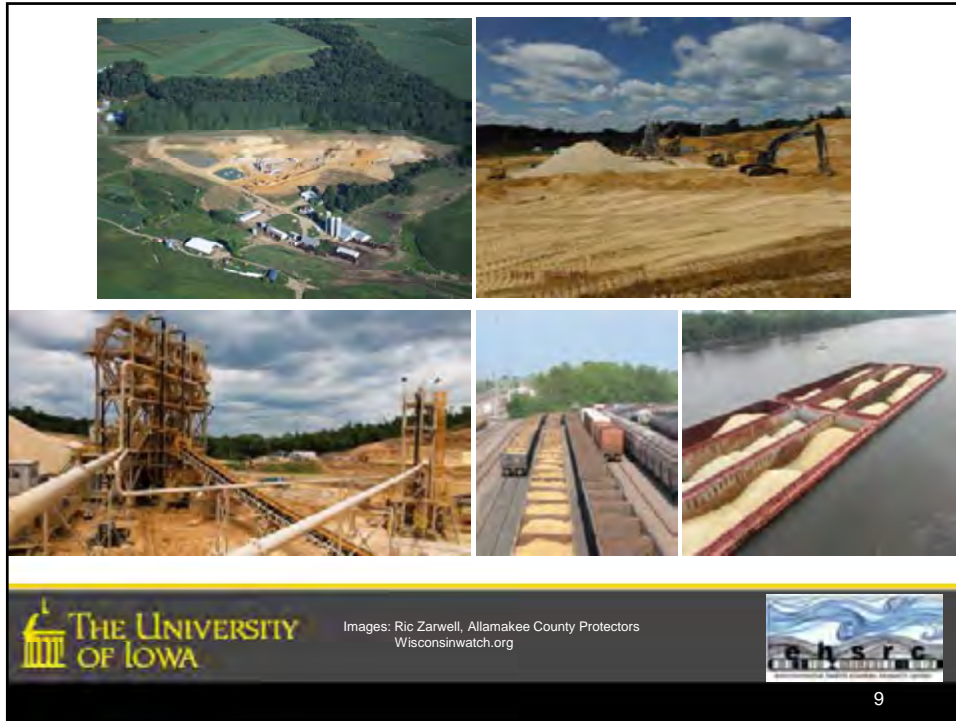
- Environmental degradation
 - water contamination
 - habitat loss
 - lost tourism revenue
 - social discord
 - loss of aesthetic beautiful
- Truck/rail/barge traffic
 - Diesel exhaust
 - Noise, light pollution
- **Airborne particulate matter**
- **Airborne crystalline silica**



Respirable Crystalline Silica Causes Severe Occupational Pulmonary Diseases



- Silicosis – lung fibrosis, restrictive breathing, shortness of breath, weakness, weight loss
- COPD (including bronchitis, emphysema)
- Lung cancer
 - Known human carcinogen – IARC, NTP
 - Potential occupational carcinogen - NIOSH



Images: Ric Zarwell, Allamakee County Protectors
Wisconsinwatch.org



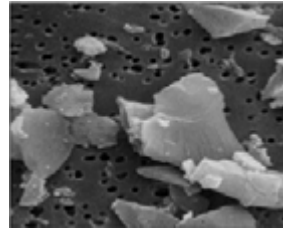
Particulate Matter (PM) Federal Regulations

- Clean Air Act (community health)
 - All particle types
 - PM₁₀ → PM smaller than 10 μm
 - <150 μg/m³ over 24-hr
 - PM_{2.5} → PM smaller than 2.5 μm
 - <12 μg/m³ annual avg; <35 μg/m³ over 24-hr
 - Only measured in 8 locations in Iowa
 - State issues permits to ensure compliance
- MSHA and OSHA (occupational health)
 - Respirable (~PM₄)
 - Particles that enter the deep lung
 - All particle types and specific compounds

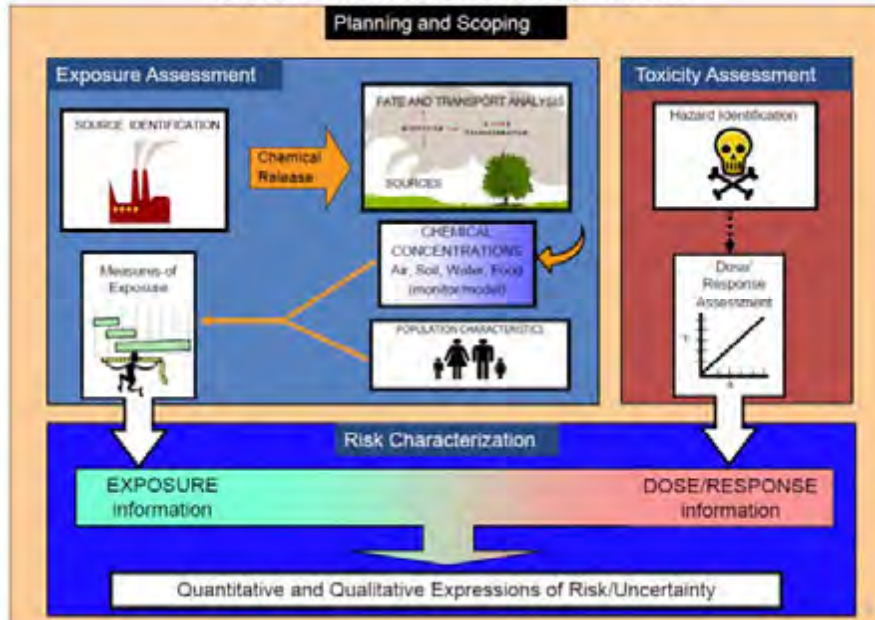


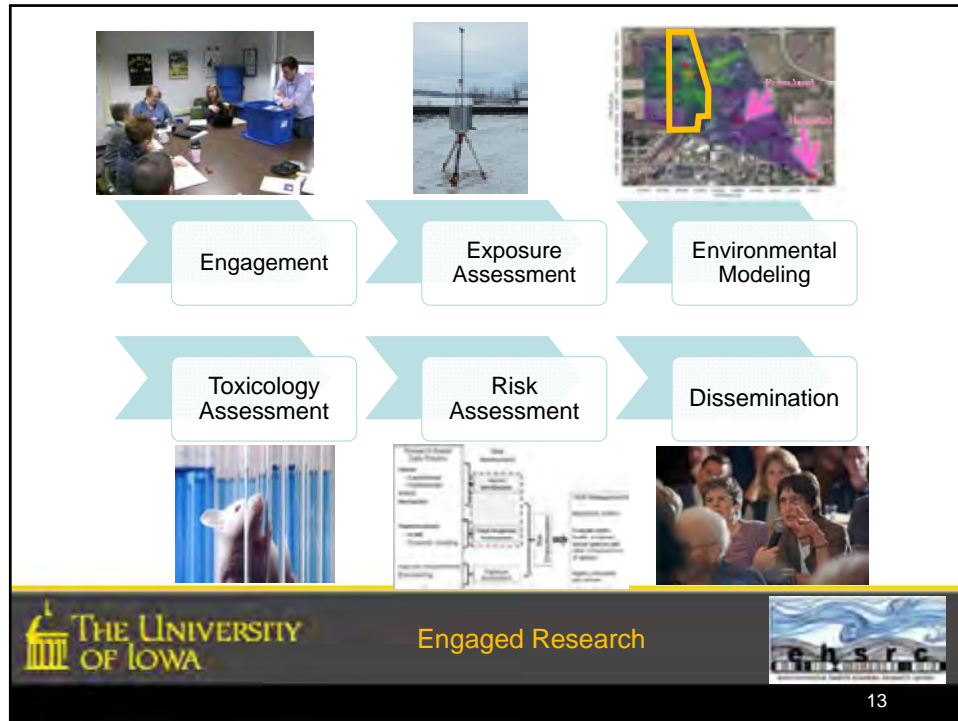
Respirable Crystalline Silica

- Specific component of PM of concern for mining of sand
 - Silicosis & lung cancer hazard
- Regulatory levels
 - OSHA standards
 - PM₄ - 100 µg/m³
 - Protect workers
 - State standards (MN, CA)
 - PM₄ - 3 µg/m³
 - Protect everyone, including vulnerable populations



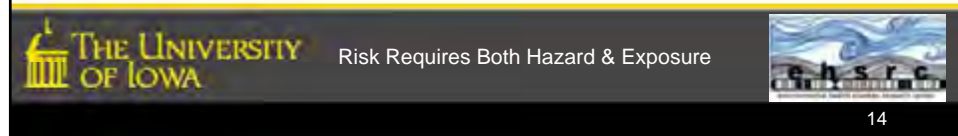
Human Risk Assessment Process





Study Questions

1. Is particulate matter from sand mining operations **hazardous**?
2. What are community **exposures** to PM and respirable crystalline silica?
3. What are **risks** of developing adverse health effects from inhalation of particulate matter from a sand mine?



Is PM from sand mining operations hazardous?

- Collected sand types
 - Unprocessed sand from mine
 - Processed frac sand
- Characterize physicochemical properties
 - Size distribution
 - Composition
- Evaluating toxicity
 - Cell testing
 - Inhalation toxicology testing

Sand Types

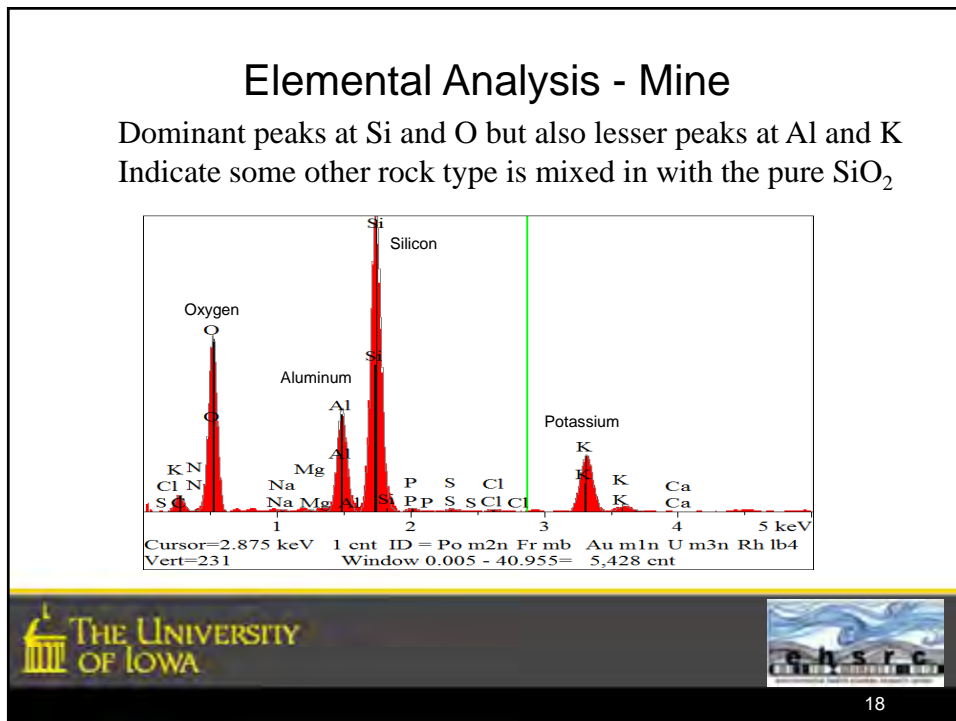
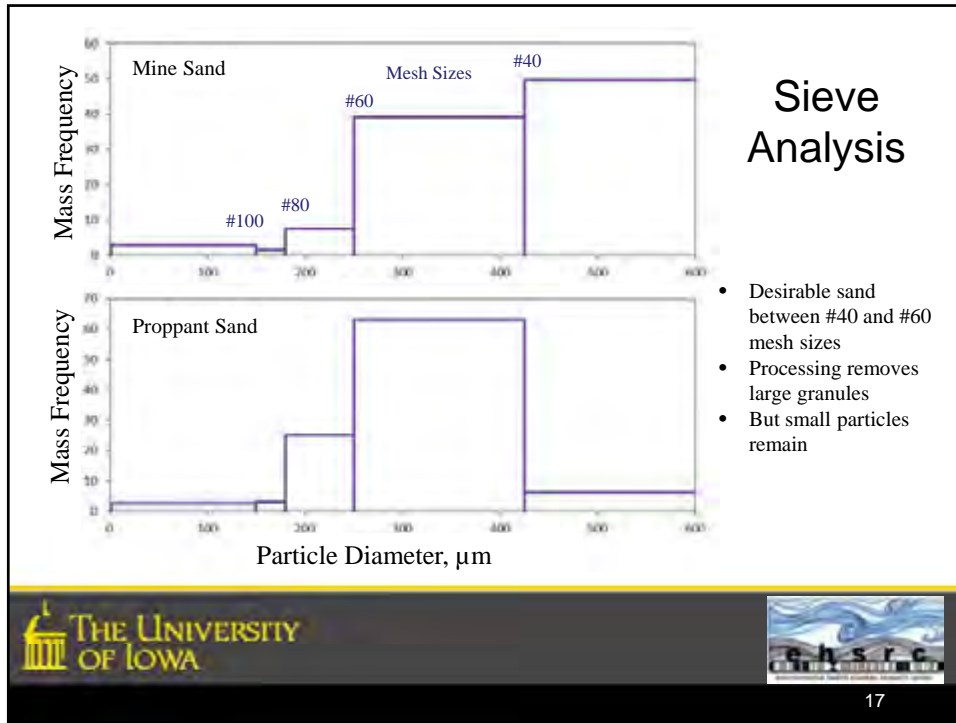
Mine sand processed to leave certain size particles deemed best for use as a proppant in fracturing

Mine Sand



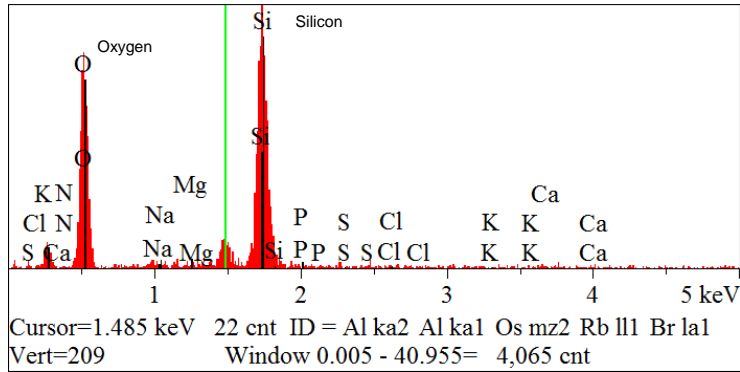
Proppant Sand



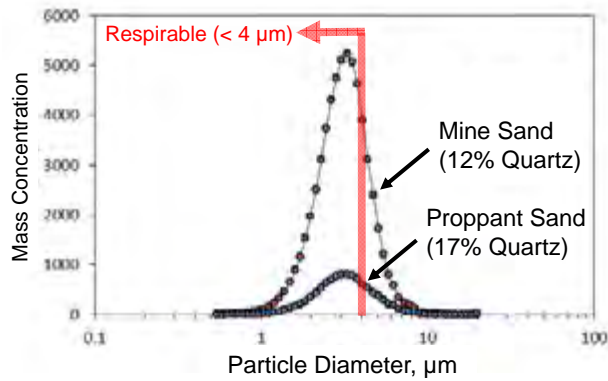


Elemental Analysis - Proppant

Dominant peaks at Si and O indicate crystalline silica, SiO₂



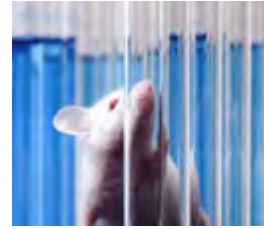
Simulation in Laboratory



- Sand dropped from 1 meter
- Respirable (PM₄) particles released, although less for proppant
- PM₄ is 10% - 20% Quartz, the dominant form of crystalline silica in these samples

Inhalation Toxicology Studies

- Hypothesis (based on our cell culture studies):
 - Proppant sand has lower toxicity than MinUSil and produces less inflammation and fibrosis
- Subchronic inhalation exposure to raw proppant sand
 - Male and female C57Bl/6 mice
 - Pos. control = Min-U-Sil 5 (97% $5 \mu\text{m}$, 99.3% SiO_2)
 - Neg. control = Sham exposure, air only
- Outcomes
 - Biological: Cytotoxicity, inflammation, oxidative stress, fibrosis, histopathology
 - Physiological: Weight gain, pulmonary mechanics, behavioral changes



Work to be completed by March 2016



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What are community exposures to airborne respirable dust and crystalline silica?

- Three approaches to the assessment
 - Filter-based sampling
 - Atmospheric dispersion modeling
 - Air monitoring with direct-reading instruments



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PM₄ Filter-based Sampling



Wind Speed &
Direction
Sensors

Cyclone
Sampler
Under
Rain Cover

Air Pump
& Data
Storage

- Collects respirable sand
 - Less than 4 μm in diameter
- Sampled 17 homes in Trempealeau Co, WI
 - 48 hrs minimum for silica detection
 - < 0.5 miles from active sand operation
- Analyzed filters for:
 - Mass (gravimetrics)
 - Crystalline silica (XRD)

Measured Concentrations

- Respirable dust mass concentration
 - N = 17
 - Mean = 9.1 $\mu\text{g}/\text{m}^3$
 - St Dev = 2.6 $\mu\text{g}/\text{m}^3$
 - Min = 6.0 $\mu\text{g}/\text{m}^3$
 - Max = 15 $\mu\text{g}/\text{m}^3$
- Respirable crystalline silica concentration
 - Detected quartz on 7 of 17 samples (2% to 4% of mass)
 - All values < 0.4 $\mu\text{g}/\text{m}^3$
 - Value of concern in CA and MN is 3 $\mu\text{g}/\text{m}^3$

Atmospheric Dispersion Modeling

- Processing plants with sand piles and sand mines
- AERMOD – EPA tool for short-range, steady-state dispersion modeling

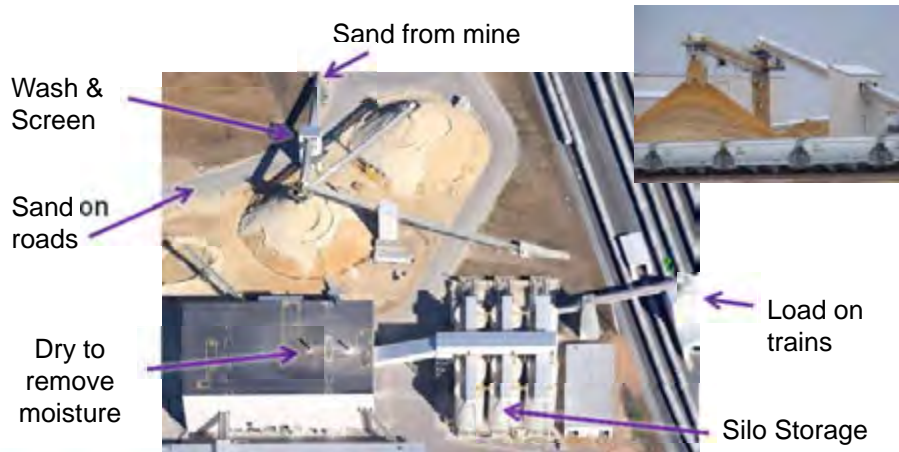


Chippewa Falls, WI sand transport facility



Image: Google Earth

Sand Processing Emission Sources



Chippewa Falls, WI sand transport facility

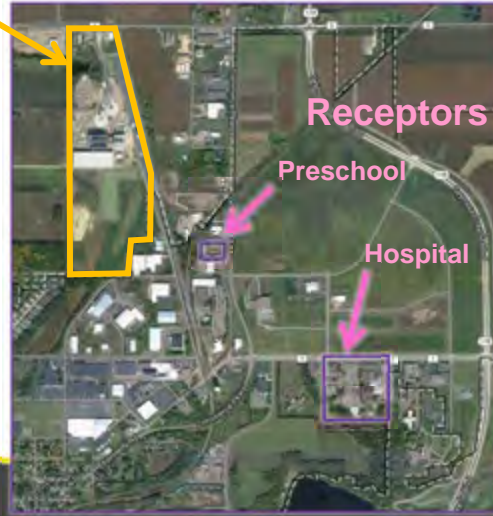
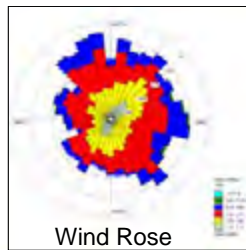


Image: Google Earth

Model Inputs and Receptors

Processing Plant Property Line

- Model Inputs
 - Dust emission rates for sources
 - Topography
 - Meteorological data



Chippewa Falls, WI sand transport facility

Image: Google Earth

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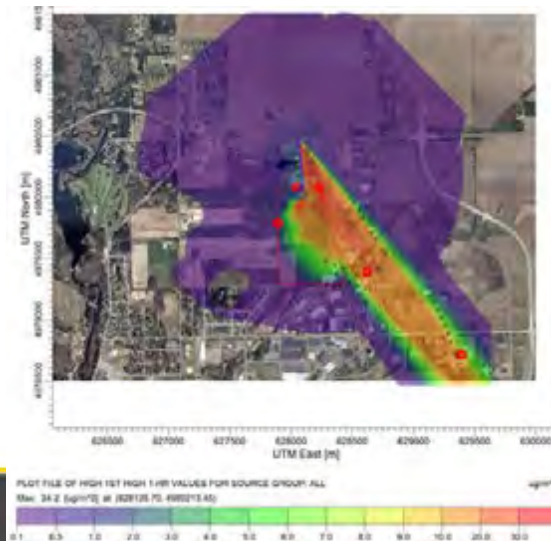
Worst case concentration - 1-hr PM₁₀

Red ~30 $\mu\text{g}/\text{m}^3$

The NAAQS 24-hr PM₁₀ of 150 $\mu\text{g}/\text{m}^3$

Worst case estimate for crystalline silica ~3 $\mu\text{g}/\text{m}^3$ for 1 hr

Assumes all PM₁₀ is respirable and 10% crystalline silica



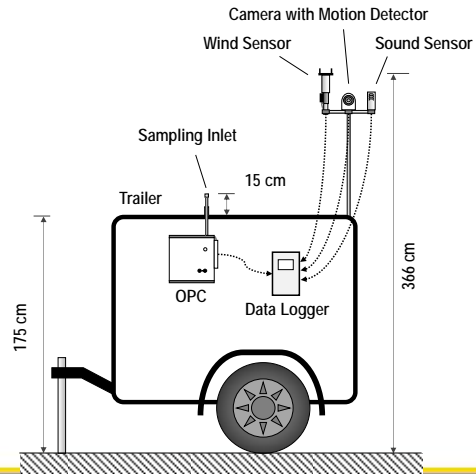
24-hr Averages are much lower than these values

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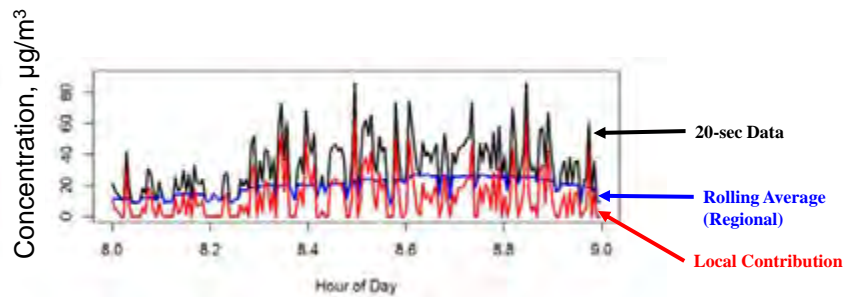


Air Monitoring With Direct-Reading Instruments


- 6 sites < 0.5 mile from active mine
- Data collected every 20 sec
 - Wind, motion, sound
 - PM_{10-2.5} and PM_{2.5}
- Determined local contribution of PM



Air Monitoring With Direct-Reading Instruments



Arcadia, WI



Active Mining

Monitor Location




 

Image: Google Earth 31

Preferred Sands, Blair, WI



Conveyance

Processing

Mine

Transload

Monitor Location to SSE



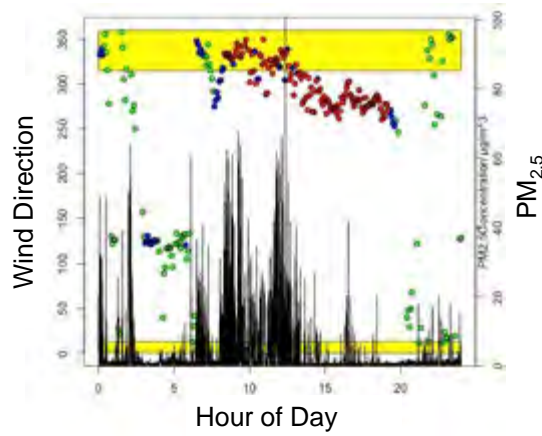
 

Image: Google Earth 32

Example of Data (Preferred Sands, Blair, WI)



Yellow indicates wind direction from facility

Wind speed indicated by color
 - green low
 - red high

- Short duration increase in $PM_{2.5}$ when wind over facility
- But, daily average still lower than EPA regulations



Maximum Local PM Concentrations

	Averaging Time	Arcadia	Blair
Full Days		6	23
$PM_{2.5}$, $\mu\text{g}/\text{m}^3$ (Fine)	24 Hrs	0.5	4.1
	Work Hrs	0.3	3.6
	1 Hr	5.6	18
	5 Min	5.6	110
$PM_{10-2.5}$, $\mu\text{g}/\text{m}^3$ (Coarse)	24 Hr	0.2	18
	Work Hrs	3.5	27
	1 Hr	35	130
	5 Min	160	480

EPA 24-hr $PM_{2.5}$ NAAQS $35 \mu\text{g}/\text{m}^3$

$22.1 \mu\text{g}/\text{m}^3$
 EPA 24-hr PM_{10} NAAQS $150 \mu\text{g}/\text{m}^3$



Dichotomous sampler
 $24\text{-hr } PM_{10} \approx PM_{2.5} + PM_{10-2.5}$



How does our exposure assessment data compare to work of others?

Summary of Monitoring Required by State Agencies

- Wisconsin
 - PM₁₀ monitoring requested by Wisconsin Department of Natural Resources when air permit modeling exceeds a certain threshold
- Minnesota
 - All required monitoring by Minnesota Pollution Control Agency
 - TSP, PM₁₀, PM_{2.5}, and Respirable Crystalline Silica

