NIOSH OIL & GAS EXTRACTION SAFETY & HEALTH RESEARCH

Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing

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Disclaimer: The findings and conclusions in this presentation have not been formally disseminated by NIOSH and should not be construed to represent any agency determination or policy.

CDC Workplace Safety and Health NIOSH

- O&G Safety & Health Field Research
- Lack of information: diversity, magnitude of potential chemical exposures to workers
- Unknowns: work practices, products, formulations, equipment, where chemical exposures most likely to occur
- Emphasis Upstream E&P, H&S: S & h
- Better understand the h aspects of O&G

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NIOSH OIL & GAS EXTRACTION SAFETY & HEALTH RESEARCH

NIOSH Field Effort to Assess Chemical Exposure Risks to Gas and Oil Workers

Background

There is a lack of existing information regarding the variety and magnitude of chemical exposure risks to oil and gas extraction workers. To determine if risks are present, NIOSH wants to develop partnerships with the oil and gas extraction industry to identify, characterize and (if needed) control workplace chemical exposures. This work will occur as part of the NIOSH Oil and Gas Extraction Safety and Health Program, which seeks to prevent injuries and illnesses among oil and gas extraction workers. Strategic objectives include identifying possible exposures, determining risk, and preventing chemical exposures to workers involved in oil and gas extraction industry.

Purpose

The goals of this NIOSH field effort include: 1) identifying processes and activities where chemical exposures could occur; 2) characterizing potential exposures to vapors, gases, particulates and fumes (e.g., solvents, diesel particulate, crystalline silica, acids, metals, aldehydes, and possibly other chemicals identified during the study); 3) depending on results of the field effort, recommending safe work practices and/or proposing and evaluating exposure controls (to include engineering controls, substitution, and personal protective equipment).

Crewmember at hydraulic fracturing operations. *Image courtesy of Jeff Swensen for the New York Times.*

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Who Can Participate

Workers, managers, supervisors, and health and safety professionals involved in oil and gas drilling and servicing operations are encouraged to participate in the field effort.

Floorcrew on drilling platform. *Image courtesy of Eric Esswein, NIOSH.*

Benefits of Participation

Companies can leverage the industrial hygiene expertise of a NIOSH field research team to help identify if chemical exposure risks are present or absent, and based on results of field studies, prioritize and control potential workplace chemical exposures at their worksites. Data and results collected by NIOSH in the field effort will be communicated to the company in letter format. Become involved with NIOSH and be seen as a leader in occupational safety and health in the gas and oil industry.

Note: This Field Research Effort will be fully funded by NIOSH; there is no cost to participate. NIOSH is a part of the Centers for Disease Control and Prevention (CDC). NIOSH is federal agency responsible for conducting research and providing guidance related to occupational health and safety. NIOSH is not a regulatory agency. Federal regulations provide for trade secret protection for participating companies.

How to Become Involved

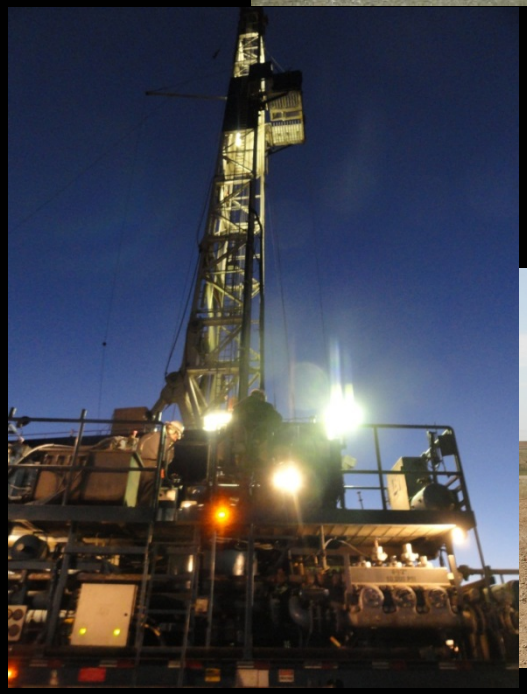
To learn more about the Field Effort to Characterize Chemical Exposures in Oil and Gas Extraction Workers, contact Eric Esswein, CIH, at (303) 236–5946, or submit inquiries electronically or by mail to: eje1@cdc.gov or Eric Esswein, NIOSH, Denver Federal Center, P.O. Box 25226 Denver, CO. 80225

Sand truck operator at hydraulic fracturing operations. *Image courtesy of Eric Esswein, NIOSH.*

Web search: NIOSH Field Effort, Oil and Gas

Gen'l Overview Oil and Gas E & P:

1. Site preparations
2. Drilling and casing well
3. Completions
4. Flowback
5. Production



Oil and Gas E & P

Completions (hydraulic fracturing)

Slurry sand (or other proppant), water
and treatment chemicals injected down the well bore

High pressure (8-9000 psi) slurry forced through well casing holes (perforations)

Pressurized slurry creates fractures in the hydrocarbon bearing strata, proppant maintains the space in the fractures allowing gas and oil to enter well bore.

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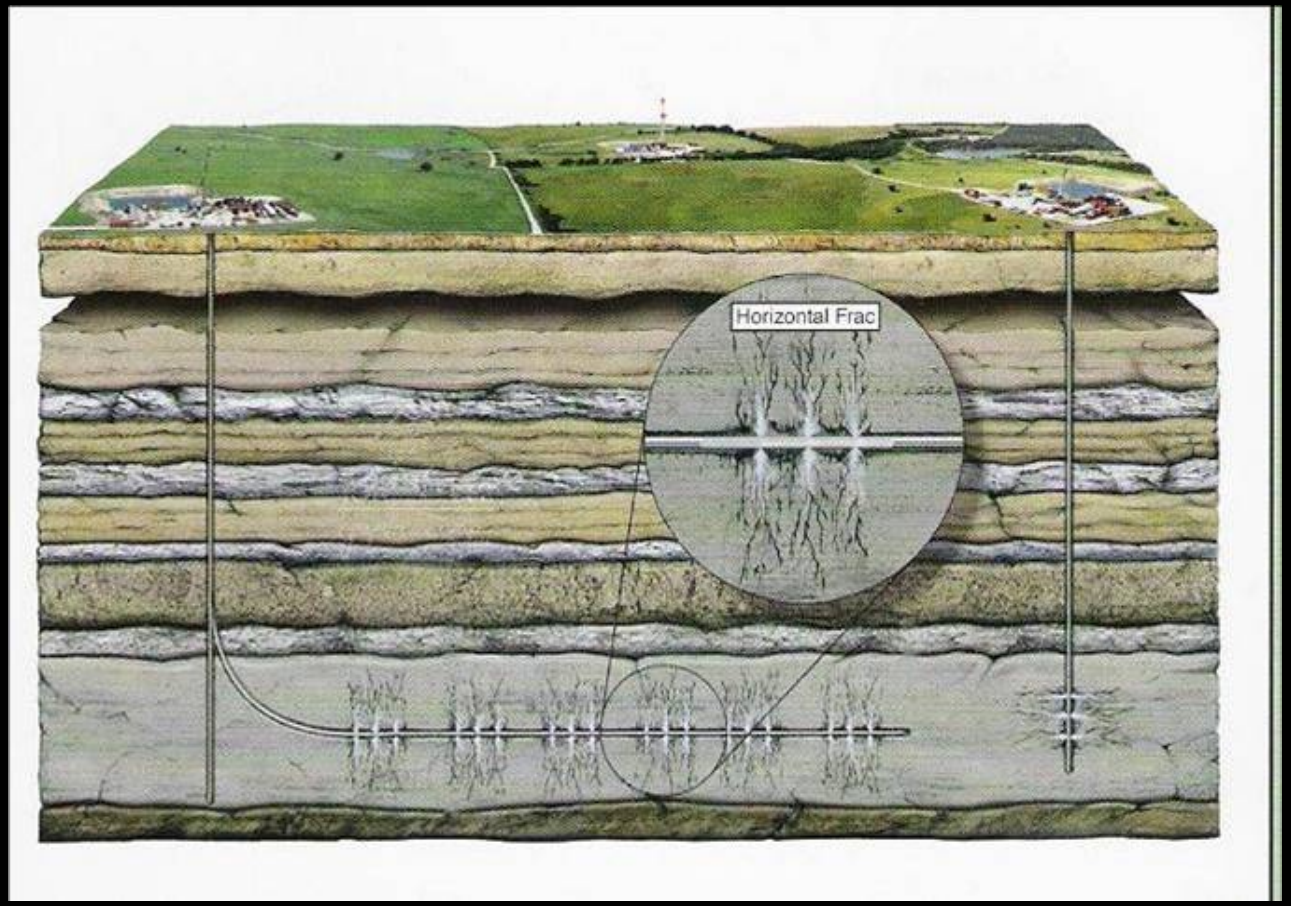
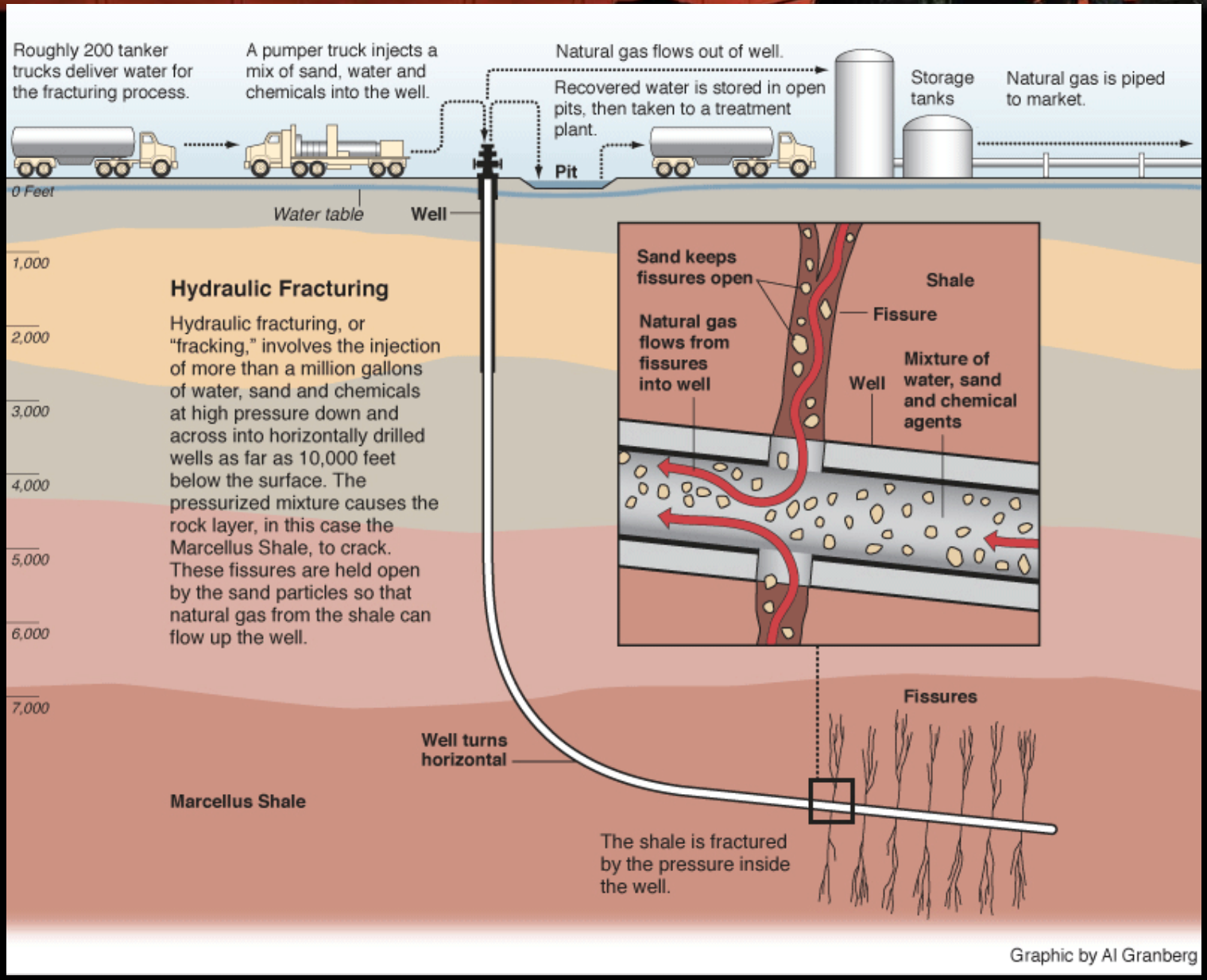




Source: http://www.propublica.org/special/hydraulic-fracturing-national

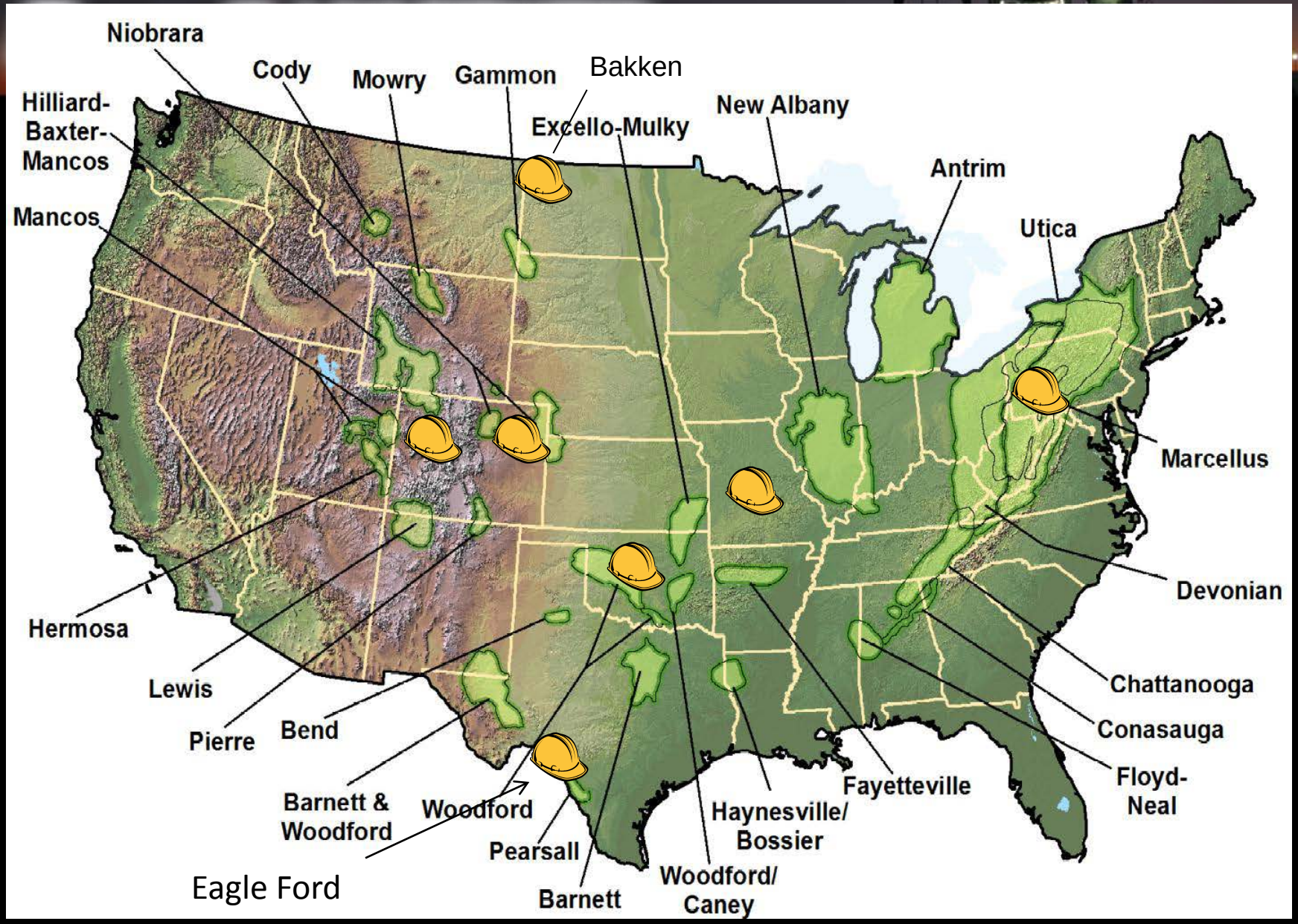
E&P Potential Chemical Exposures

- Gases (H_2S)
- Volatile organic compounds (NBTEX)
- Acid (HCL), Caustic (NaOH)
- ➢ Respirable crystalline silica (quartz)
- Diesel particulate (DPM)
- Biocides (glutaraldehyde)
- Metals (Pb)
- Radioactive materials (U, Th, Ra)

Not an inclusive list

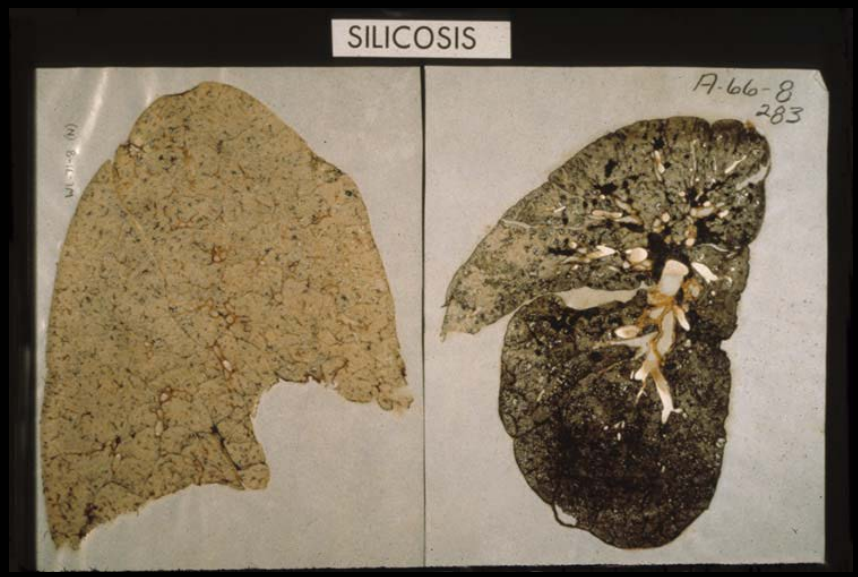
2010-2011 Field Work

- 11 sites, 5 states
- CO (7 sites), AR, PA, TX, ND
- Winter, spring, summer
- Elevation: 300 – 5000 ft.
- Single stage refracs, multi stage, zipper fracs
- Slickwater & gel fracs
- Focus: respirable crystalline silica


Niobrara
Cody
Mowry
Gammon
Bakken
Hilliard-
Baxter-
Mancos
Excello-Mulky
New Albany
Antrim
Mancos
Utica
Marcellus
Devonian
Hermosa
Lewis
Chattanooga
Pierre
Bend
Conasauga
Floyd-
Neal
Fayetteville
Barnett &
Woodford
Woodford
Haynesville/
Bossier
Pearsall
Eagle Ford
Barnett
Woodford/
Caney

Silica (Quartz)

- SiO_2 (silicon dioxide= silica, quartz)
- Silicosis, lung Ca, crystalline silica
- ≈100 – 160 deaths per year U.S.
- Affects to other organs
- Preventable

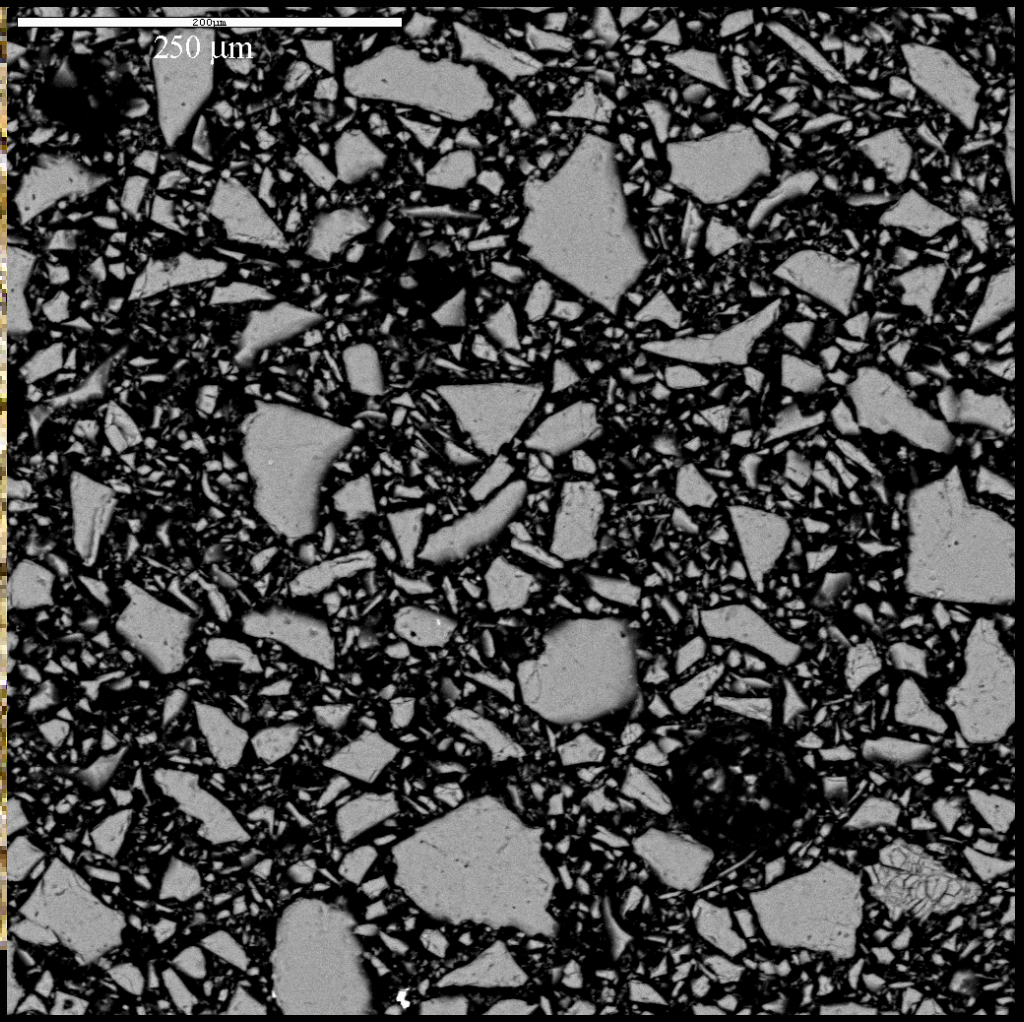


Silicosis: associated with sand use

- Sand = proppant
- Millions of pounds per well
- Various shapes and sizes
- Virtually 100% silica

Sand

Respirable Silica (Quartz)



SEM image courtesy: Geoff Plumlee, Ph.D.
Research Geochemist, Environment and Human Health U.S. Geological Survey, 2011

Where Can Silica Exposures Occur?

Sandmover

Sand refill truck

Blender hopper

Dragon tail

Sand truck refilling sand mover, pressurization of sand mover causes dust to be released from thief hatches

During sand loading operations

Hot loading 2011

Sand transfer operations

- Pressurization of sand mover = silica ejected from fill nozzles

When silica-containing dusts are visible, workplace overexposures are likely

Sand dust on equipment evidence of ?

Sand transfer operations – silica

Multiple sandmovers delivering sand to transfer belt, increased sand handling means increased airborne dusts

Sand transfer operations – silica

Multiple sandmovers delivering sand to transfer belt

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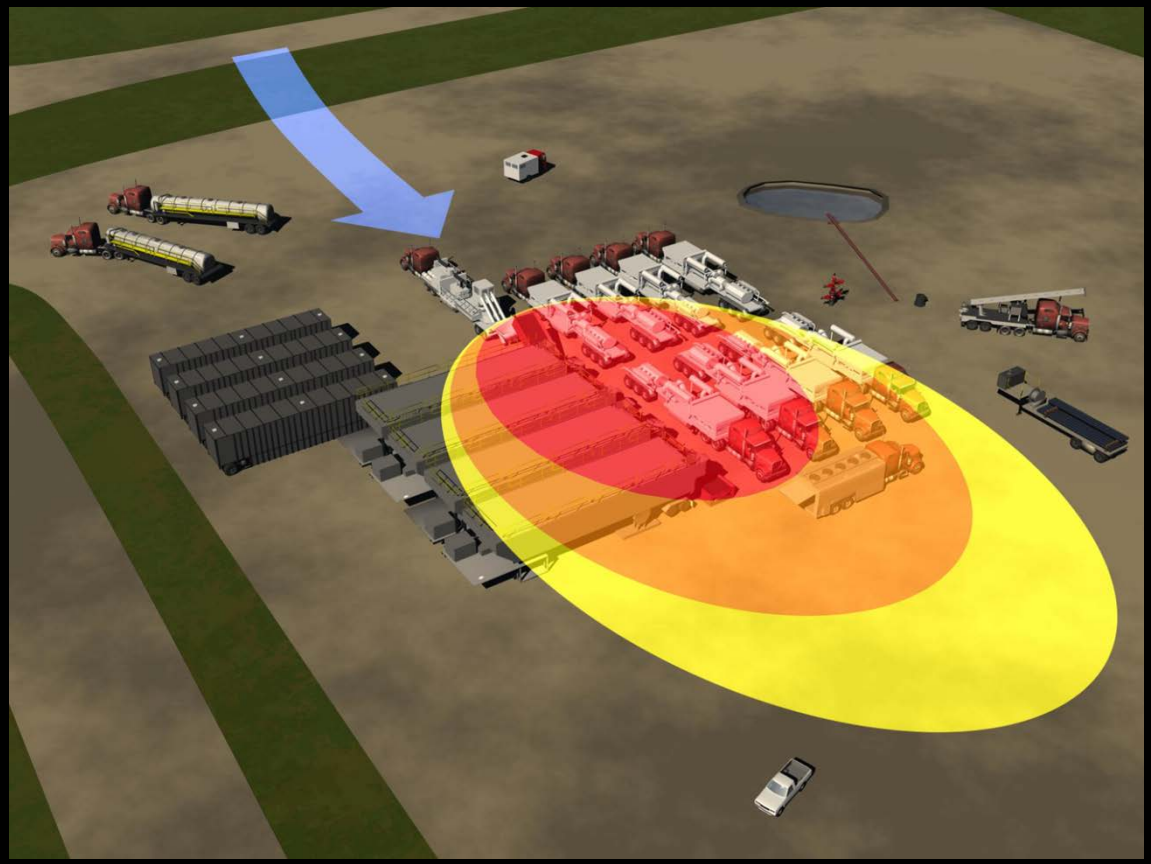
Not moving sand

Operating



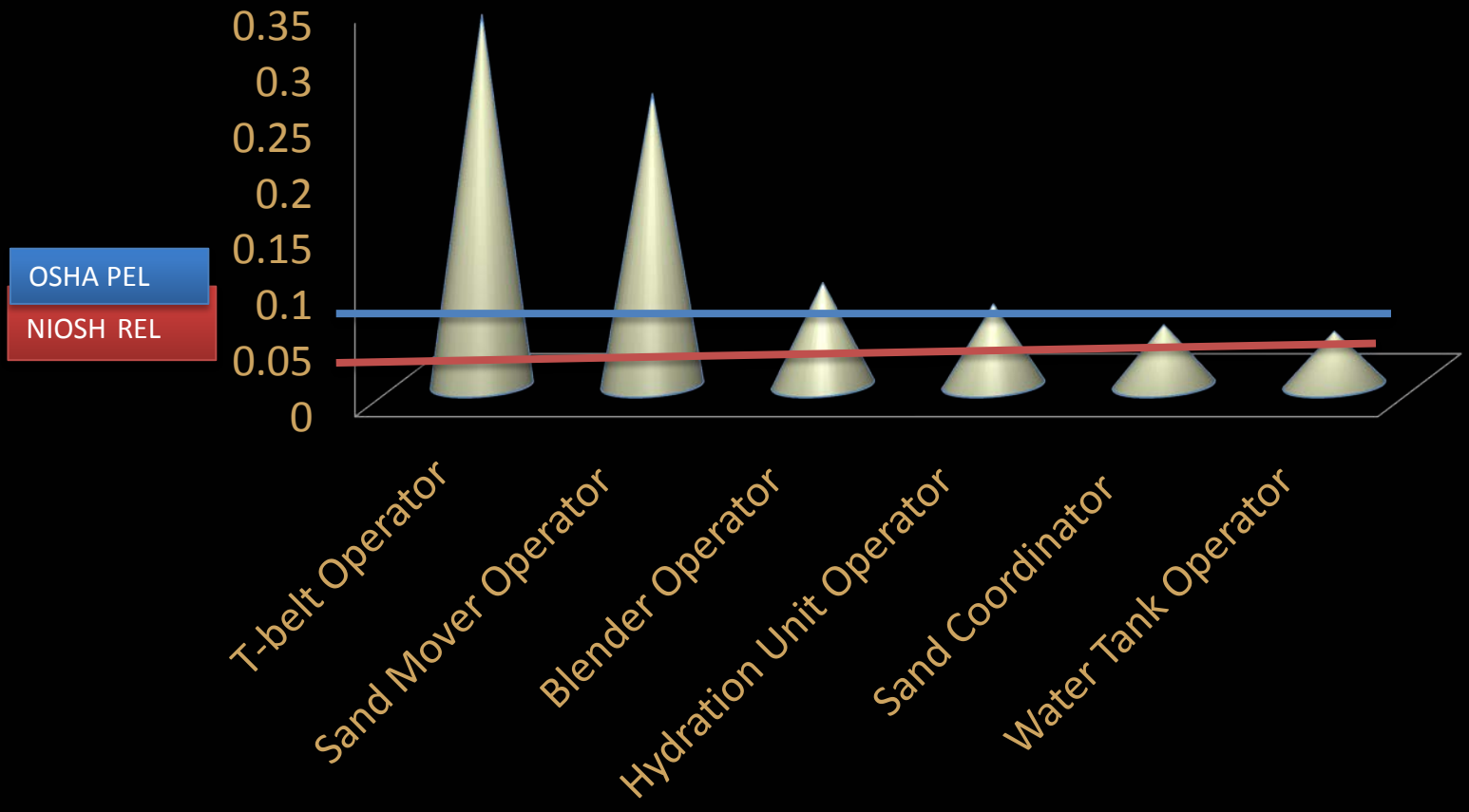
Wind transport of sand dust: exposure risks for workers farther afield

Image: Ken Strunk, NIOSH

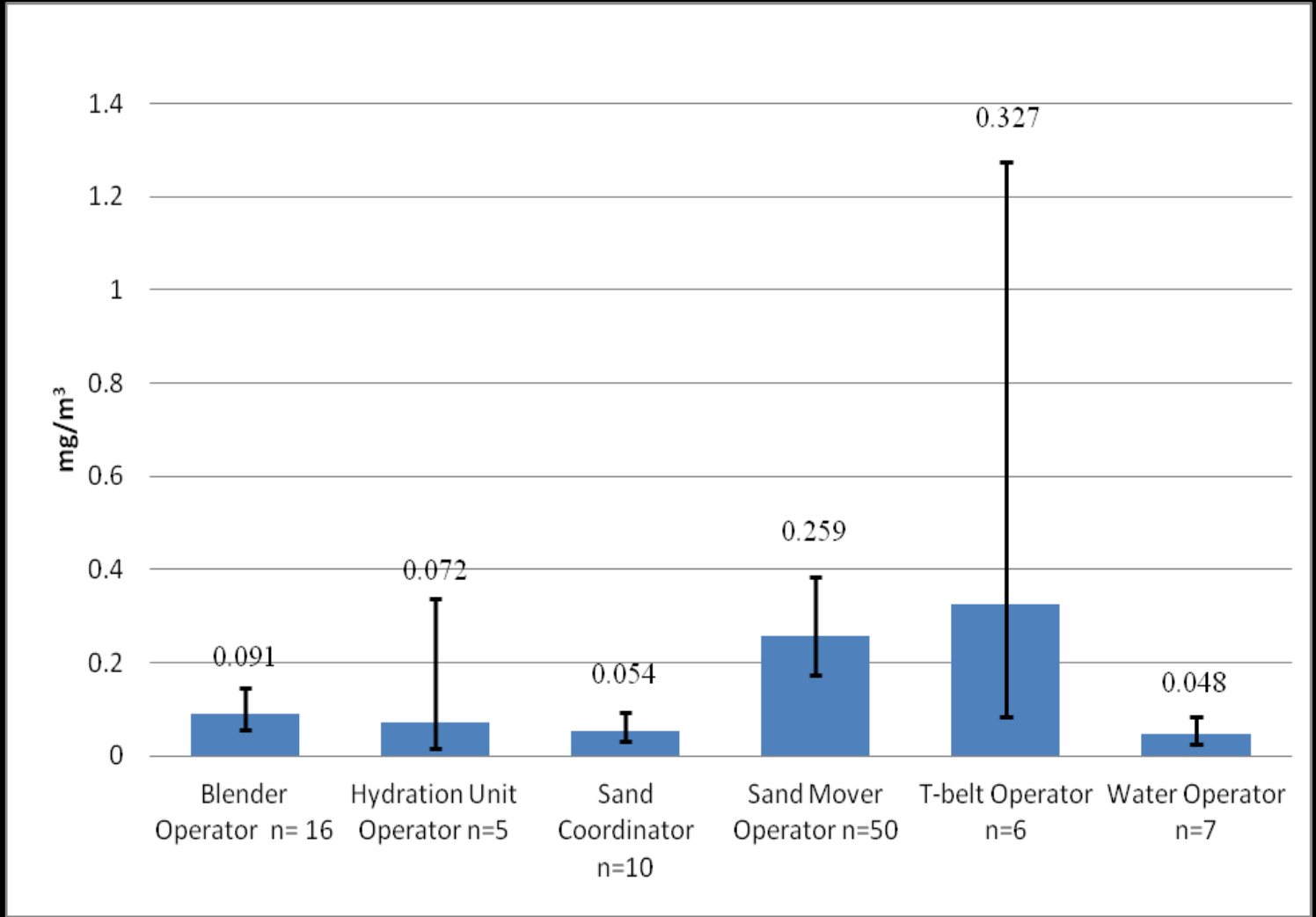
Respirable Silica Results by Location

Site	> ACGIH TLV*	> NIOSH REL*	> OSHA PEL*	Total # samples
A	24 (92.3%)	19 (73.1%)	14 (53.9%)	26
B	16 (84.2%)	14 (73.7%)	12 (63.2%)	19
C	5 (62.5%)	5 (62.5%)	4 (50.0%)	8
D	19 (90.5%)	14 (66.7%)	9 (42.9%)	21
E	25 (92.6%)	23 (85.2%)	18 (66.7%)	27
F	4 (40%)	1 (10%)	0	10
Total	93 (83.8%)	76 (68.5%)	57 (51.4%)	111

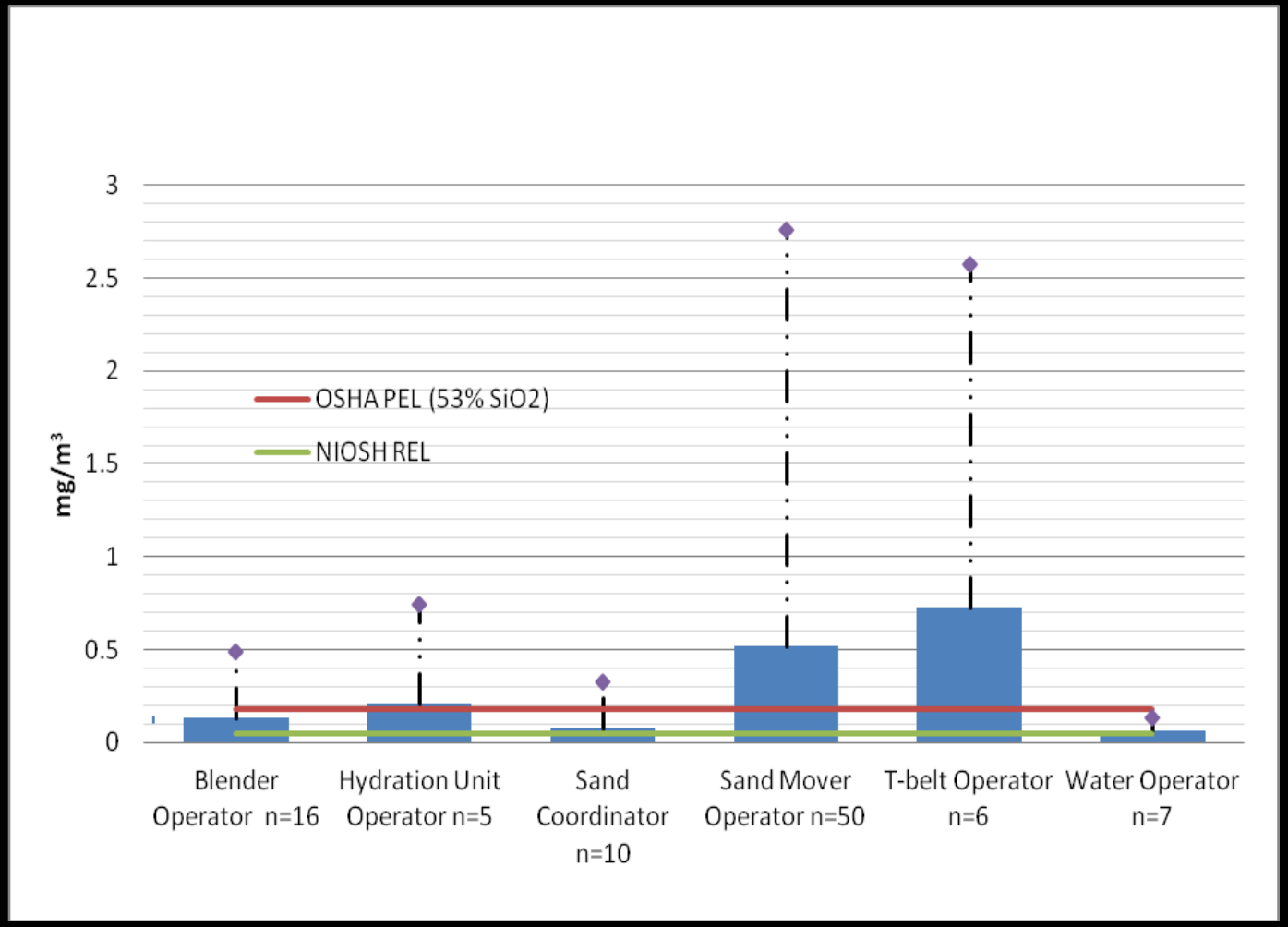
Relative comparisons, geometric means (mg/m³) by job title



Comparisons, respirable silica GMs(mg/m³), 95% confidence intervals for job titles with 5 or more samples



Arithmetic means, maximum values, comparisons to an OSHA PEL, NIOSH REL



NIOSH REL mean severities, job titles

Job Title	Total # of samples	Arithmetic Mean	Arithmetic Std. Deviation	Min	Max	Median
Blender Operator	16	2.58	0.59	0.14	9.70	2.03
Chemical Truck Operator	3	3.32	1.63	0.80	6.38	2.78
Fueler	2	0.85	0.17	0.68	1.02	0.85
Hydration Unit Operator	5	4.28	2.79	0.18	14.92	0.88
Mechanic	3	1.20	0.39	0.46	1.76	1.38
Operator, Data Van	1	0.86	---[2]	0.86	0.86	0.86
Pump Truck Operator	1	0.42	---	0.42	0.42	0.42
Q.C. Tech	1	0.26	---	0.26	0.26	0.26
Roving Operator	4	0.52	0.24	0.12	1.18	0.39
Sand Coordinator	10	1.60	0.57	0.34	6.52	1.22
Sand Truck Driver	1	0.82	---	0.82	0.82	0.82
Sandmover Operator	50	10.44	1.59	0.14	55.10	7.62
T-belt Operator	6	14.55	7.57	0.30	51.40	9.06
Water Tank Operator	7	1.23	0.34	0.38	2.72	1.12
Wireline Operator	1	0.14	---	0.14	0.14	0.14
Total	111	6.45	0.93	0.12	55.10	2.18

Occupational Exposure Criteria

Respirable silica (quartz)

ACGIH TLV : 0.025 mg/m^3 TWA

NIOSH REL: 0.05 mg/m^3 TWA

OSHA: $\frac{10\ mg / m^3}{(\%\ silica + 2)}$ Resp. dust containing silica

How much respirable crystalline silica is the NIOSH REL?

Photo: Geoff Plumlee, USGS

NIOSH REL = 0.05 mg/m^3 TWA

0.05 mg/m^3 = 50 micrograms (µg) mg/m^3

1 m^3 of air = 1,000 liters

Normal breathing rate (moderate work, 1 work day) = 10 m^3 (10,000 liters of air)

50 micrograms x 10 m^3 = 500 µg's

8 Primary Points of Dust Generation

1. Release from thief hatches, sand movers
2. Transfer belt under sand movers
3. Site traffic
4. Sand dropping in blender hopper
5. Release from T-belt operations
6. Release from “dragon tail”
7. Dust ejected from fill ports on sand movers
8. “Pig Pen” effect

Eight (8) primary points of dust release or generation from completions equipment or workplace operations

1) Dusts ejected from thief hatches on top of the sand movers during refilling operations

2) Dust ejected and pulsed through side fill ports on the sand movers during refilling operations

3) Dust generated by on-site truck vehicle traffic including sand trucks and crew trucks, the release of air brakes on sand trucks, and by winds

4) Dust released from the transfer belt under the sand movers

5) Dusts created as sand drops into, or is agitated in the blender hopper and on transfer belts

6) Dust released from operations of transfer belts between the sand mover and the blender

7) Dust released from the top of the dragon's tail on sand movers

8) Dust deposited on and released from workers coveralls







Hierarchy of Controls

- Eliminate
- Substitute
- Engineering Controls
- Administrative Controls
- Personal Protective Equipment

Control of Dust Generation

1. Prevention through Design (PtD)
2. Remote operations (if feasible)
3. Substitution (ceramic vs. sand)
4. Implement Engineering Controls (ventilation)
5. Passive enclosures
   - ✓ Stilling (staging) curtains, skirting, shrouding
6. Minimize distance that sand falls
7. End caps on fill nozzles
8. Use amended water for site dust control
9. Clothes cleaning booths for workers
10. Effective respiratory protection program

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Communicate the Risk

- Signage
- Effective Haz. Comm.
- Include in JSA's
- Periodic training
- Effective respiratory program
- Medical monitoring

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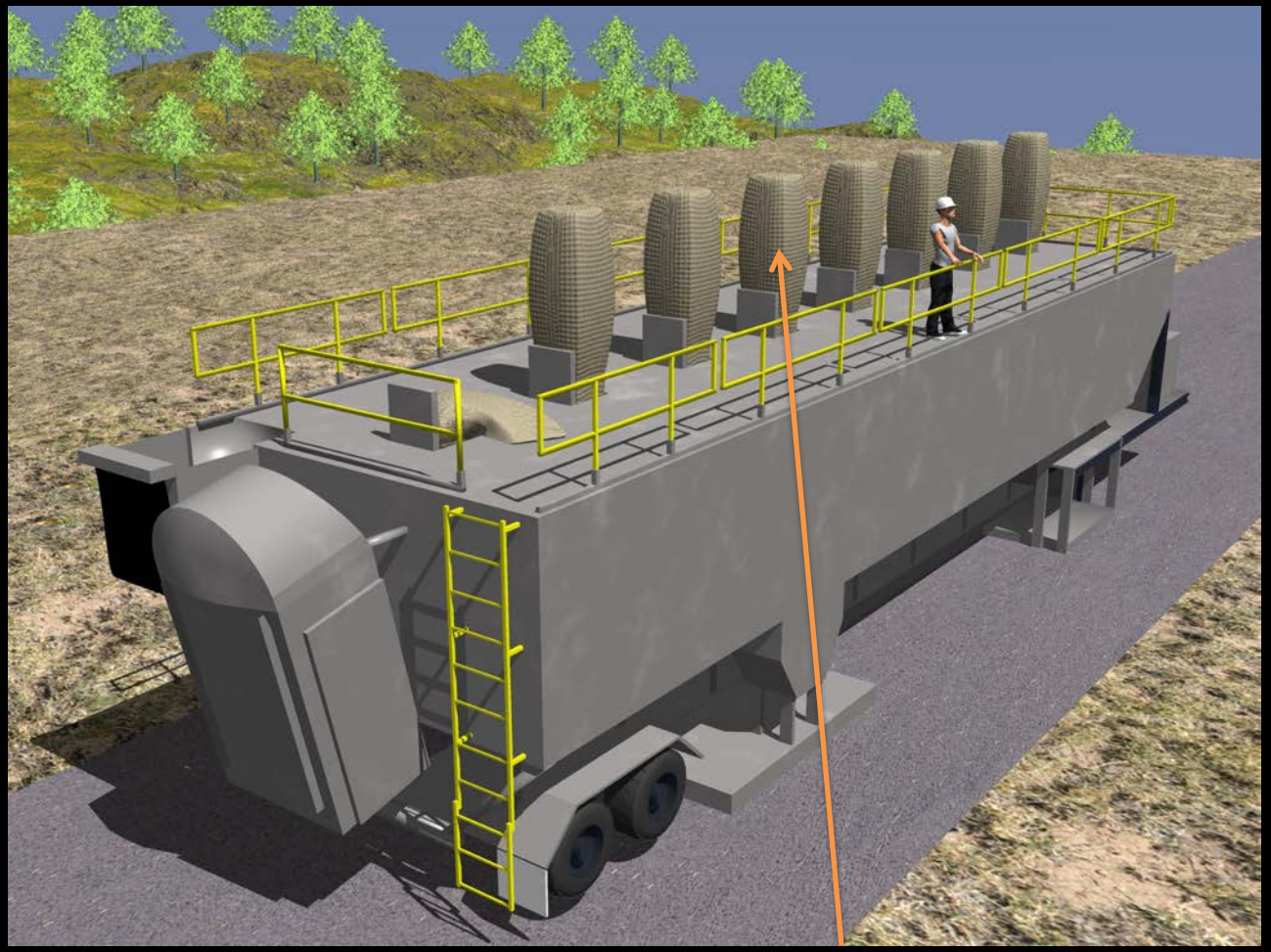
Controls research: NIOSH mini baghouse retrofit assembly

- ✓ Conceive
- ✓ Invent
- ✓ Design, fabricate
- ✓ Proof of concept
- ✓ Refine design
- ✓ Field trials
- ✓ License
- ✓ Patent pending
- Manufacture
- Distribute

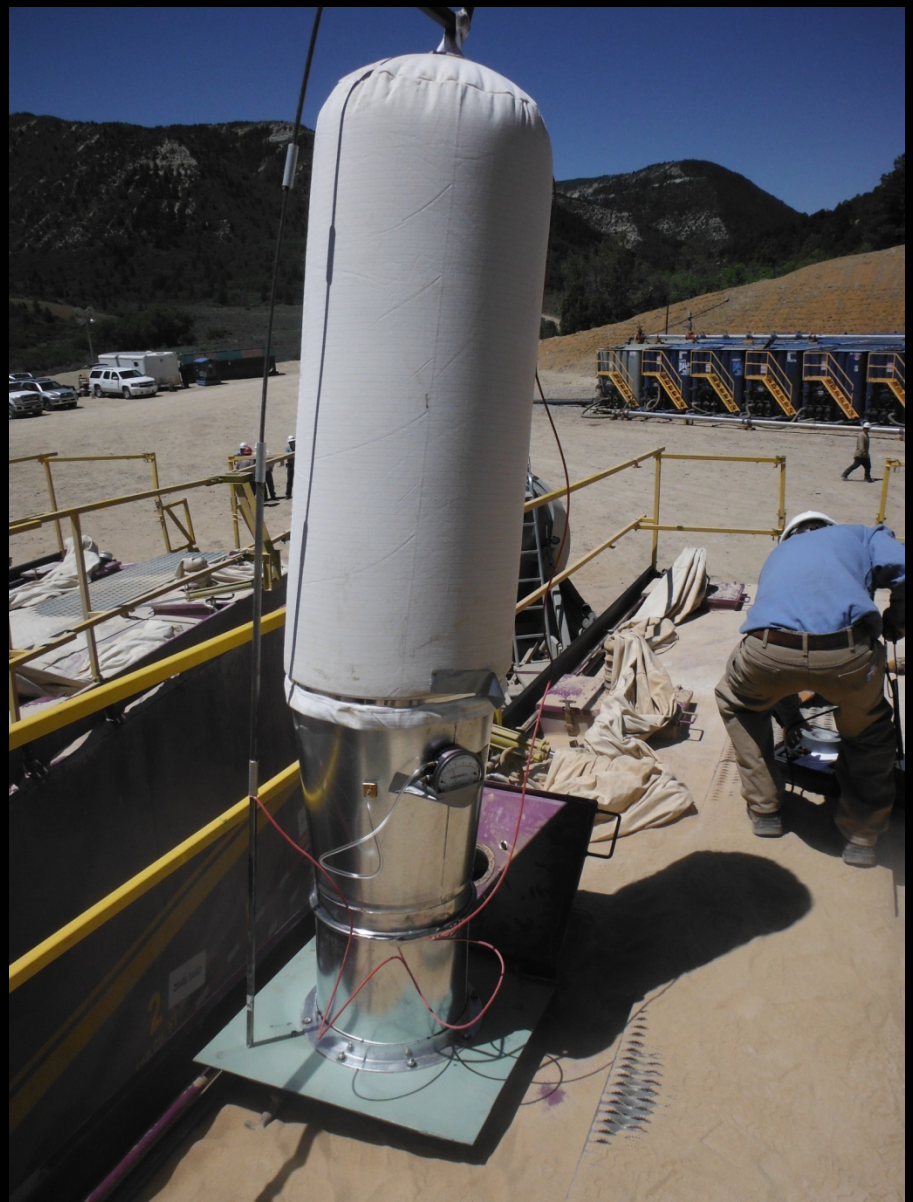
Proposed Controls



mini-baghouse retrofit assembly

Image: Ken Strunk, NIOSH

Mini Baghouse Retrofit Ass'y.



- ✓ Proof of concept evaluation, June 2012
- ✓ Patent pending

November, 2013

4 days, field evaluations

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Controlled vs. Uncontrolled

No control

Control

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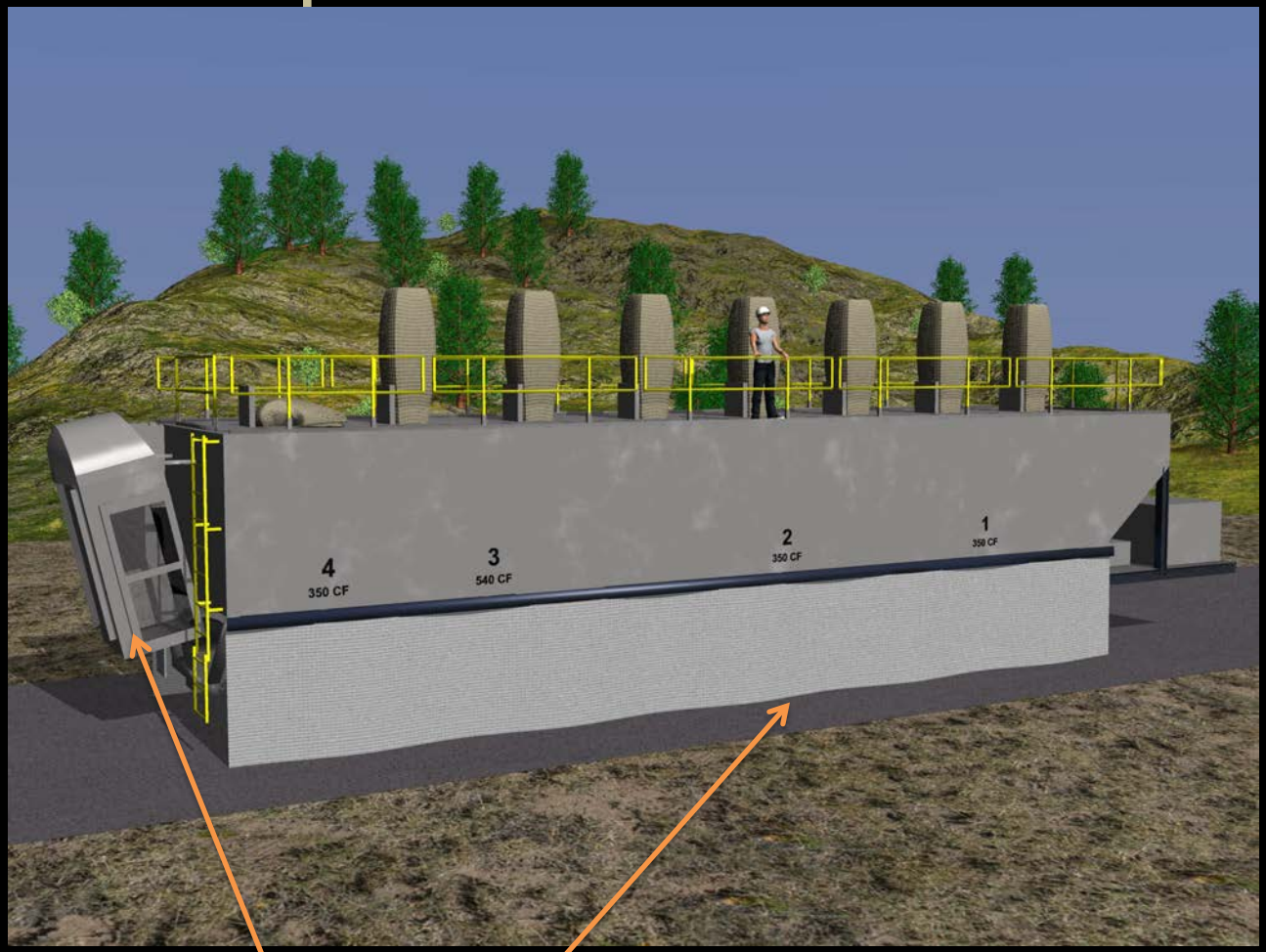
Control

No control

Control

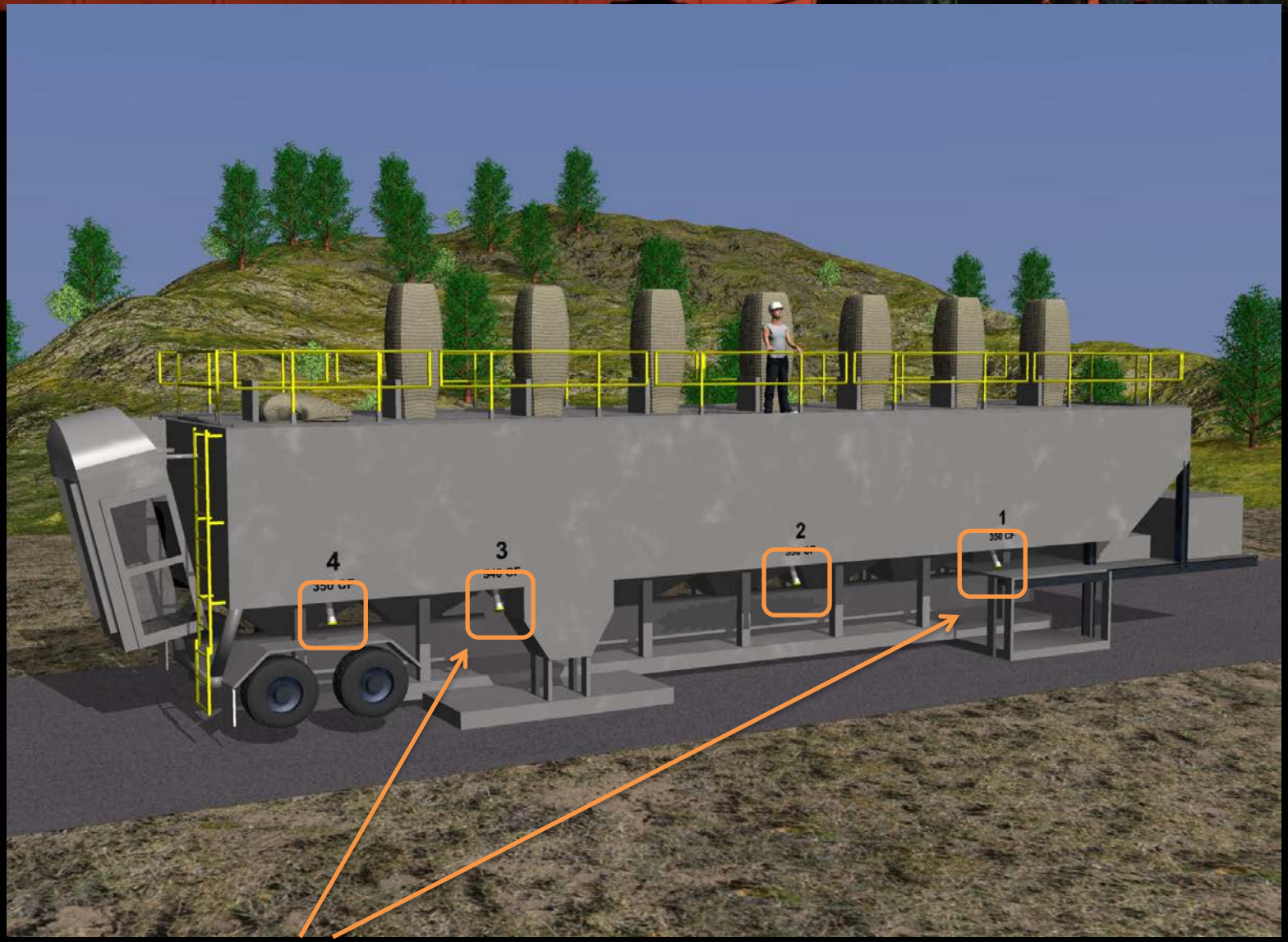
4 bins filled simultaneously

Proposed Controls



enclosure, skirting

Image: Ken Strunk, NIOSH



end caps on fill nozzles

Image: Ken Strunk, NIOSH

Research dissemination

- Well Servicing Magazine, *Understanding Silica Exposures and Controls Sept-Oct, 2013*
- Jour. Occ. Env. Hlth, *Occupational Exposure to Respirable Crystalline Silica during Hydraulic Fracturing, July, 2013*
- AIHA Synergist: *Keeping Up with the Oil and Gas Rush* June/July 2013
- Respirable Crystalline Silica Video, November, 2013
- Conference, webinar presentations (not complete list)
  - PA., Shale Summit, December, 2013
  - AIHA Fall Conference October, 2013
  - Association Env. Geologists, Sept. 2013
  - SPE Webinar, June, 2013
  - Proppant Summit, May ,2013
  - HSE for Unconventional Oil and Gas, April, 2013
  - Indiana S&H Conference March, 2013

RRT Take Aways

- Respirable crystalline silica: occupational health hazard for completions crews
- Freshly fractured quartz: more toxic
- Silica exposures ≥ MUC for certain respirators
- Numerous point sources of silica dust generation
- Respiratory protection program failures

RRT Take Aways

- Drilling, Completions and Servicing
  - Different risks
- Ask Respiratory health questions
  - Resp. Sx?
  - Do you work around frack sand and diesel exhaust?
  - Do you know the hazards of silica?
  - Do you wear a respirator, why?
  - Do you understand controls?

Controls

- Simple controls
  - effective hazard communication,
  - administrative controls,
  - close thief hatches,
  - employ stilling/staging curtains
  - end caps on fill nozzles,
  - dust control at worksite,
  - < 15 psi during sand fills,
  - correct respirator use
- More involved:
  - Contract out dust control
  - Development, implementation of engineering controls,
  - reconfiguration of sand movers,
  - integrate Prevention through Design (PtD)

Questions?

Photo: Soutpansburg range, South Africa James Mitchell