NIOSH Field Effort to Assess Chemical Exposures in Oil and Gas Workers: Health Hazards in 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.
Why?

1. NIOSH O&G Safety & Health Program

2. Lack of information: diversity, magnitude of potential chemical exposures to workers

3. Unknowns: work practices, products, formulations, equipment, where chemical exposures most likely to occur

4. Emphasis O&G, H&S: S & h

5. Better understand the h aspects of O&G
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).

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.

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 workplaces. 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, E/O. Box 25226 Denver, CO. 80225

Web search: NIOSH Field Effort, Oil and Gas
How?

1. Develop partnerships with oil and gas industry
   – 5 current MOUs (Producers & Contractors)
2. Review work processes
   – 11 sites, 5 states, 4 seasons, varying climates, elev.
3. Identify potential chemical hazards
4. Characterize risks for exposure
   – exposure assessments
5. Evaluate significance of risks, develop controls
6. Communicate findings
Potential Chemical Exposures

- Silica
- Diesel particulate
- Volatile organic compounds (NBTEX)
- Hydrogen sulfide (H₂S)
- Acid gases (HCL)
- Aldehydes (biocides)
- Metals (Pb)

Not an inclusive list
2010-2011 Field Work

- 11 sites, 5 states
- CO (7 sites), AR, PA, TX, ND
- Winter, spring, summer and fall
  - 30 -113 °F
- Elevation: 246 - 4,813 ft.
- Single stage refracs, multi stage, zipper fracs
- Slickwater & gel
- Silica, resin coated and ceramic
Hydrogen Sulfide (H₂S)

- PEL: 20 ppm (C) 50 ppm (1 x per 8 hr. shift)
- NIOSH: 10 ppm (C) 100 ppm IDLH
- TLV: 1 ppm, 5 ppm (STEL)
Flow back operations, pit aeration

Volatile organic compounds (VOCs)
- Napthalene, benzene, toluene, ethylbenzene, xylenes (NBTEX)
Real-time VOCs at flow-back pond

Isobutylene Concentration

Date Time (2011)
Diesel particulate (DPM)

Photo: courtesy of Jeff Swenson, for the NY Times
Diesel particulate (DPM)
Real time DPM trends, risks

DJ Basin, 2011
- 13 PBZ samples, 3/13 (23%) > 20 µg/m³ time-weighted average
- 4 samples (2 PBZ, 2 area) > 40 µg/m³ TWA
Chemicals transported, contained on site in totes, carboys, etc.
Airborne Aldehydes

- Ground level near “frac” tank: < 0.2 ppm (<0.82 mg/m³)
- Top “frac” tank opening: 0.21 ppm (0.85 mg/m³) *
- Head space: 0.44 ppm (1.76 mg/m³)

* NIOSH Recommended Exposure Limit (REL) glutaraldehyde = 0.2 ppm (0.8 mg/m³) ceiling
Silica (Quartz)

- Silicon (Si) an element
- SiO$_2$ (silicon dioxide = silica, quartz)
- Respirable crystalline silica (fine dusts)
- Exposures regulated by OSHA
- Silicosis, lung cancer
- Occupational hazard of antiquity
- 200 workers deaths per year U.S.

SEM image courtesy: Geoff Plumlee, Ph.D., Heather Lowers, MS, USGS 2011
Sand use

- Completions (hydraulic fracturing)
- Up to 4M lbs. per well
- Proppant
- Various shapes and sizes
- Virtually 100% silica
Sand  Respirable Silica (Quartz)

SEM image courtesy: Geoff Plumlee, Ph.D., Heather Lowers, MS, USGS 2011
Why is silica an occupational health hazard?

- Silicosis
- Occupational Carcinogen
- Incurable
- Irreversible
- Progressive

Photo: Val Vallyathan, Ph.D. NIOSH
Where can exposures occur?

Cementing jobs

If you can see silica containing dust in the air, exposures can be a health risk.
During all sand moving operations

- Sandmover
- Sand refill truck
- Blender hopper
- Dragon’s tail
Respirable Dust containing Silica (Quartz)

Sand truck refilling sand mover, pressurization of sand mover causes dust to be released from thief hatches.
During loading operations
Hot loading
Hot loading, sand transfer operations

- Pressurization of sand mover causes dust to be ejected from fill nozzles
When silica-containing dusts are visible, workplace overexposures are likely.
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, visible dusts suggests workplace exposure risks for RCS
Occupational Exposure Criteria

Respirable dust containing Silica (Quartz)

ACGIH TLV: 0.025 mg/m³ TWA

NIOSH REL: 0.05 mg/m³ TWA

OSHA: 10 mg/m³ Resp. dust dust containing silica ( % silica + 2)

TLV = Amer. Conf. of Gov’t Industrial Hygienists, Threshold Limit Value
REL = NIOSH Recommended Exposure Limit
PEL = OSHA Permissible Exposure Limit
TWA = Time-weighted average
How much respirable crystalline silica is the NIOSH REL?

NIOSH REL = 0.05 mg/m³ TWA

0.05 mg/m³ = 50 micrograms (µg) mg/m³

1 m³ of air = 1,000 liters

Normal breathing rate (moderate work, 1 work day) = 10 m³ (10,000 liters of air)

50 micrograms x 10 m³ = 500 µg’s
Silica Exposures, hydraulic fracturing

DJ Basin, CO (6 sites, 3 days)
- 21 PBZ samples
  - 43% (9/21) > OSHA PEL
  - 71% (15/21) > NIOSH REL
- 2 samples > 20, 29 X PEL
- 2 samples 89, 137 X REL
  - Dust: 17-77% quartz
- Single well, each site
- No hot loading,
- Winter, moderate wind

Fayetteville shale, Arkansas (1 site, 3 days)
- 26 PBZ samples
  - 46% (12/26) > OSHA PEL
  - 81% (21/26) > NIOSH REL
- 31% (8/26) > 10X NIOSH REL
  - 15 - 66 times REL
  - Dust: 36-100% quartz
- Hot loading occurring
- Spring
- Calm winds (1-3 mph)

PBZ = personal breathing zone sample
Silica Exposures, hydraulic fracturing

Marcellus shale, PA (1 site, 3 days)
• 27 PBZ samples
  – 67% (18/27) > OSHA PEL
  – 92.6% (25/27) > NIOSH REL
• 55% (15/27) > 10X NIOSH REL
  – 21,24, 30 times REL
  – dust 30-88% quartz
• Hot loading, multiple wells
• Dusty site conditions
• Summer, calm winds (1-5 mph) winds

DJ Basin, CO (1 site, 3 days)
• 18 PBZ samples
  – 61.1% (11/18) > OSHA PEL
  – 94.4% (17/18) > NIOSH REL
• 44.4 % (8/18) > 10X NIOSH REL
  – 13-44 times NIOSH REL
• Hot loading
• Dusty site conditions
• Summer, gusty winds (5-7 mph) winds
Silica Exposures, hydraulic fracturing

Baaken formation, ND (1 sites, 3 days)
- 11 PBZ samples
  - 0% (11/11) > OSHA PEL
  - 82% (9/11) > NIOSH REL
- 0 > 10X NIOSH REL
- 58% ceramic proppant
- Less hot loading
- Thief hatches kept closed
- Late summer

Eagle Ford Shale, TX (1 sites, 3 days)
- 8 PBZ samples
  - 50% (4/8) > OSHA PEL
  - 62.5% (5/8) > NIOSH REL
- 1 sample > 10X OSHA PEL
- Dust 30-65% quartz
- Hot loading
- Thief hatches kept closed
- No workers atop Sandmasters
- Late summer
- Constant winds
11 Site visits, 116 PBZ samples for silica

- 54 / 116 (47%) > OSHA PEL
- 92 / 116 (79%) > NIOSH REL
- 36 / 116 (31%) > 10 X NIOSH REL

PEL = OSHA Permissible Exposure Limit
REL = NIOSH Recommended Exposure Limit
7 Primary dust generation points

1. Release from top 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’s tail”
7. Dust ejected from fill ports on sand movers
Control of dust generation

1. Prevention through Design (PtD)
2. Remote operations
3. Substitution (ceramic vs. sand)
4. Mini-bahouse, screw augur assemblies
5. Passive enclosures
   ✓ Stilling (staging) curtains
6. Minimize distance that sand falls
7. End caps on fill nozzles
8. Amended water
9. Effective respiratory protection program
NIOSH Mini-baghouse retrofit assembly
Proposed Controls

NIOSH screw augur retrofit assembly
Conclusions

• Respirable crystalline silica: occupational health hazard
• Diesel particulate: likely health hazard
• Silica exposures > MUC for half mask and FF respirators
  • numerous point sources of dust generation
• PPE: workers not clean shaven
• Simple controls:
  • caps on nozzles, dust control for worksite, close thief hatches, shave
• More involved:
  • development of NIOSH controls, reconfiguration of sand movers.
• Prevention through Design (PtD)

MUC = maximum use concentration
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