What we can (and can’t) see can hurt us (depending on the exposure): NIOSH Worker Exposure Assessments for Silica, VOCs and Benzene

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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.
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What do we really know about OGE worker health and safety risks?
NIOSH Oil and Gas Safety and Health Research Program

- Safety
- **Health (NIOSH Field Effort... began in 2010)**

1. Need to understand: scope, diversity, magnitude of occupational health exposure risks (if any)

2. Variables: site conditions, work practices, products, formulations, equipment, where health risks are most likely to occur

3. **Traditional emphasis:** upstream oil and gas OHS: S & h

4. **Research the little h aspects of O&G S & H**
Why $S$?

- **Standards:** OSHA 1910, 1926, EPA,
  - ANSI/ASSE, API-RPs, State-based oil and gas commissions etc.

- **Severity:** injury/accident outcomes

- **Surveillance:** fatality, recordable, injury rates tracked & compiled (OSHA, BLS, ISN, PEC)

- **Significance:** ratings, contracts
Why little h?

**S (outcomes)**
- You can **see** them
- Fatality
- Recordable injury
- Immediate
- Acute
- Severe
- Knowable
- Familiar
- Soon and certain

**h (outcomes)**
- Often can’t see, **hidden**
- Illness
- Latent effects exposures
- Delayed
- Chronic
- Mild
- Unknown
- Obscure
- Long and latent
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).

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.

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 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.

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: ejel@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.
Challenges

• Obtain industry partners
• Access small companies
  – little OH&S expertise
  – highest fatality rates
• Interact with a dynamic workforce
  – tough to reach/track
  – young, transient workforce
• Connect with large numbers sub-contractors
• Understand rapidly evolving technologies
  – Drilling, completions, servicing
Evaluation of Worker Exposures

OGE workers have risks for exposures to multiple chemical hazards

Drilling  Completions  Production, servicing
How to Do It?

1. Partner with industry
2. Understand process operations
3. Preliminary survey: identify potential hazards
   • Do worker’s report health symptoms?
4. Quantitative exposure assessments
5. Interpret sampling results; communicate results
6. Determine controls, if needed
7. Re-evaluate to determine effectiveness of controls
Hiding in Plain Sight?

What is the most commonly found mineral in the earth's crust? It occurs in igneous, metamorphic and sedimentary rocks.
NIOSH Respirable Crystalline Silica (RCS) Field Study, 2010-2011

- 11 sites, 5 states
- Winter, spring, summer
- Elevation: 300 – 5,000 ft.
- Silica sand, resin coated and ceramic
Silica Exposures at Hydraulic Fracturing Sites Exceed OELs\(^1\)

<table>
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<th>Site</th>
<th>&gt;ACGIH TLV</th>
<th>&gt;NIOSH REL</th>
<th>&gt;OSHA PEL</th>
<th>Total # Samples</th>
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<td>4 (50.0%)</td>
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<tr>
<td>D</td>
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<td>93 (83.8%)</td>
<td>76 (68.5%)</td>
<td>57 (51.4%)</td>
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8 main sources of respirable crystalline silica release

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.
Goal: eliminate silica aerosol release from thief hatches

Control: NIOSH Mini-baghouse retrofit assembly

Rendering: Mr. Kenneth Strunk, NIOSH
40/70 mesh **before** sand transfer

Collected by NIOSH mini baghouse **after** released through thief hatches
Method 1: Resuspension of bulk dust. Collection: MOUDI Model M110R rotating impactor, analysis for aerodynamic mass and size distribution.

Laboratory procedure:
1) bulk dust particles re-suspended, acoustical generator
2) airborne dust sampled using micro-orifice uniform deposition impactor™ (MOUDI™) size selective sampler

Greatest mass of silica particles average 1.75 microns (µm)

Mass Geometric Mean = 1.75 µm
Mass Geometric SD = 2.4
Method 2: Analysis of bulk dust sample by scanning electron microscope (SEM).

Particle size distribution, silica dust

Laboratory procedure:
1) bulk dust placed in crucible w/IPA, sonicated, filtered onto PC filter
2) Sample placed onto carbon-taped stub and carbon coated
3) Analysis by SEM

72.4% of particles
> 0.5 < 5 µm
Sample contained a wide range of particle sizes from 0.1 µm to 7 µm.
ISO/CEN/ACGIH sampling conventions for inhalable, thoracic, and respirable aerosol fractions (source: Lidén and Harper, 2007)
Impact: NIOSH Silica Exposure Assessment Study

- First study to quantify silica exposure risks during hydraulic fracturing
- JOEH article most downloaded of 2013-15, cited > 60 times
- Industry formed silica focus workgroup
- Hazard Alert widely disseminated
- Worker hazard awareness
- New, improved controls implemented

NIOSH mini baghouse retrofit assembly
Hiding in Plain Sight?

First discovered by Michael Faraday in 1825 from an oily film deposited from the gas used for lighting.
Worker Exposures to Benzene and Volatile Organic Compounds During Flowback Operations

Flowback tank gauging

Production tank gauging
Exposure Assessments: Flowback and Production Tank Gauging

- 6 well sites in CO, WY, 2013
- > 20 well sites in PA, AR, CO, 2015
- Operations: flowback, production watch, water transport
- Occupations: Flowback Leadman, Production Watch, Water Management, Water Haulers
- Full-shift and short-term sampling for VOCs
- Spot measurements, real-time, direct-reading instruments
Flowback Findings

• Benzene, VOCs
  – Flowback tanks: 0-250 ppm; VOCs 0 ->20,000 ppm
  – Production tanks: 0 -300 ppm; VOCs 0->20,000 ppm
  – Produced water tanks: Benzene 0-1,430* ppm; other VOCs 0->10,000 ppm

• Release of flammable gas/vapor when tank hatches are opened > 99% LEL

*Benzene concentration may have exceeded instrument limits other results: LEL = 40%  O₂ = 16%
Full-shift personal breathing zone benzene measurements (n=35)*

* $p < 0.05$ (Student’s t test) gaugers vs. non-gaugers

>5 fold difference

Worker gauging flowback tanks
Patterns of Exposure: Spatial Variation

Worker did not consistently gauge standing atop tank, gauging from ladder platform: risks for higher concentrations

- 149 ppm Benzene at 18 inches above hatch
- 1.2 ppm Benzene at 54 inches above hatch
What you can’t see...
Patterns of Exposure: Temporal Variation

• Worker gauging once per hour:
  – Peak VOC = 537 ppm; TWA VOC = 5.89 ppm; TWA PBZ Benzene = 0.23 ppm
Flammable/Explosive Hazards

Direct reading instruments showed many instances of short term excursions measuring > 40% of the Lower Explosive Limit (LEL)

– especially while drilling plugs and during snubbing

– measured near areas of flowback tanks, separators, and tank batteries
Why were exposures elevated among workers gauging tanks?

Headspace pressure and VOCs build up in tank before dumping to the combustor (emission control), separator dumps product to tank. Risks for exposures: opening hatches to gauge tank.

Plume is emitted after hatch is opened.
Conclusions: Tank Gauging

1. Very high concentrations of VOCs/Benzene can occur after hatches are opened
   a) Separator dumps enhance risks if hatch is opened
2. Benzene exposures exceeded NIOSH exposure limits
3. None of 35 full shift samples exceeded OSHA PEL
   a) Small study
4. Flammable/explosive hazards exist when tank hatches are opened
5. Additional field research needed, fully characterize risks for exposure, variety of basins
Communication results

OSHA/NIOSH Hazard Alert: Worker Exposures to Silica during Hydraulic Fracturing

Occupational Exposures to Respirable Crystalline Silica during Hydraulic Fracturing, JOEH

Evaluation of Some Potential Chemical Exposure Risks during Flowback Operations, JOEH
What else?

- Well servicing opns:
  - Concentrated VOCs,
  - Flammable hazards,
  - Benzene, $\text{H}_2\text{S}$
  - TENORM?

- Drilling:
  - Drilling fluids,
  - Dry products (mixing house),
  - Diesel particulate,
  - $\text{NO}_x$, NO, CO
  - flammable hazards?

- Pigging, wire line,
- pipefitting, fluids transfer
  - VOCs, CO, $\text{H}_2\text{S}$,
  - Benzene
  - Welding fume
  - Explosive residues?