NIOSH Research of Occupational Exposures in the Upstream Oil and Gas Industry

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Health Effects Institute’s Energy Research Program:
Research Planning to Understand Population-Level Exposures Related to Development of Oil and Natural Gas from Unconventional Resources

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*The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of NIOSH. Mention of any company or product does not constitute endorsement by NIOSH.*
Upstream Oil and Gas Research: Epidemiology

Number and Rate of Fatal Work Injuries

Note: Fatality counts from BLS Census of Fatal Occupational Injuries. Worker Estimates from BLS Quarterly Census of Employment and Wages. Rate per 100,000 workers per year. Includes NAICS 211, 213111, 213112..
Fatalities in Oil and Gas (FOG) Database

NIOSH database that collects detailed information about oil and gas worker fatalities in the U.S.

Includes

Fatal events to U.S. oil and gas extraction workers:
- Onshore
- Offshore
- All NAICS (O&G related)
- Motor vehicle incidents
- Non-traditional commuting
- Cardiac events

Excludes

Midstream, downstream, non-fatal injuries

Data Sources

OSHA case files, media, crash reports, autopsy reports, industry partners

Limitations

Roadway motor vehicle fatalities, chronic illness
## Fatalities in FOG by Event Type, 2014–2016

**Event type**
- How fatality occurred
- Event type similar to OIIICS
- Initial event
- One per fatality

★ 15 cardiac events with no identified work exposure are not included in these data

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>53</td>
</tr>
<tr>
<td>Contact injuries</td>
<td>46</td>
</tr>
<tr>
<td>Explosion (combustion) or fire</td>
<td>28</td>
</tr>
<tr>
<td>Exposure</td>
<td>17</td>
</tr>
<tr>
<td>Falls</td>
<td>14</td>
</tr>
<tr>
<td>Electrocution</td>
<td>10</td>
</tr>
<tr>
<td>Explosion (pressure)</td>
<td>9</td>
</tr>
<tr>
<td>Cardiac event: possible work exposure</td>
<td>7</td>
</tr>
</tbody>
</table>

*5 undetermined and/or un-coded cases not reported
Upstream Oil and Gas Research: Industrial Hygiene

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).

www.cdc.gov/niosh/docs/2010-130/
• Systematically evaluated occupational exposures at hydraulic fracturing sites ¹
  – 11 sites in 2010–2011
  – Sand mover operators/T-belt operators
    • Exposures can be 10–50 times greater than occupational exposure limits

### Study Results, by location

<table>
<thead>
<tr>
<th>Site</th>
<th>&gt; ACGIH TLV*</th>
<th>&gt; NIOSH REL*</th>
<th>&gt; OSHA PEL*</th>
<th>Total # samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>24 (92.3%)</td>
<td>19 (73.1%)</td>
<td>14 (53.9%)</td>
<td>26</td>
</tr>
<tr>
<td>B</td>
<td>16 (84.2%)</td>
<td>14 (73.7%)</td>
<td>12 (63.2%)</td>
<td>19</td>
</tr>
<tr>
<td>C</td>
<td>5 (62.5%)</td>
<td>5 (62.5%)</td>
<td>4 (50.0%)</td>
<td>8</td>
</tr>
<tr>
<td>D</td>
<td>19 (90.5%)</td>
<td>14 (66.7%)</td>
<td>9 (42.9%)</td>
<td>21</td>
</tr>
<tr>
<td>E</td>
<td>25 (92.6%)</td>
<td>23 (85.2%)</td>
<td>18 (66.7%)</td>
<td>27</td>
</tr>
<tr>
<td>F</td>
<td>4 (40%)</td>
<td>1 (10%)</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>G**</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>93 (78%)</td>
<td>76 (64%)</td>
<td>57 (48%)</td>
<td>119</td>
</tr>
</tbody>
</table>

* Number of samples/%  ** Composite of 2 locations
Exposure Comparisons, by Job Title

- OSHA PEL (53% SiO2)
- NIOSH REL

<table>
<thead>
<tr>
<th>Job Title</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blender Operator</td>
<td>n=16</td>
</tr>
<tr>
<td>Hydration Unit Operator</td>
<td>n=5</td>
</tr>
<tr>
<td>Sand Coordinator</td>
<td>n=10</td>
</tr>
<tr>
<td>Sand Mover Operator</td>
<td>n=50</td>
</tr>
<tr>
<td>T-belt Operator</td>
<td>n=6</td>
</tr>
<tr>
<td>Water Operator</td>
<td>n=7</td>
</tr>
</tbody>
</table>
On-Site Dust Control

- Changes in proppant storage/handling/delivery
- Ceramic proppant
- Coated/treated sand proppant
- Portable baghouse
- Dust collectors with filters
- Personal decontamination booth

Hierarchy of Controls

- Elimination: Physically remove the hazard
- Substitution: Replace the hazard
- Engineering Controls: Isolate people from the hazard
- Administrative Controls: Change the way people work
- PPE: Protect the worker with Personal Protective Equipment

Examples of controls being developed by Industry

National STEPS Network: Emerging Issues Focus Group
Administrative Controls & Effective Training Programs

OSHA-NIOSH Hazard Alert

Worker Exposure to Silica during Hydraulic Fracturing

The National Institute for Occupational Safety and Health (NIOSH) identified exposure to airborne silica as a health hazard to workers conducting some hydraulic fracturing operations during recent field studies.

Introduction

Hydraulic fracturing or ‘fracking’ is a process used to ‘stimulate’ oil production in the oil and gas industry. It is not a new process, but its use has increased significantly in the last 10 years because of new horizontal drilling and multi-stage fracking (or ‘completions’) technologies that improve access to natural gas and oil deposits. It involves pumping large volumes of water and sand into a well at high pressure to fracture shale and other tight formations, allowing oil and gas to flow into the well.

NIOSH’s recent field studies show that workers may be exposed to dust with high levels of respirable crystalline silica (called ‘silica’) in this Hazard Alert during hydraulic fracturing. This Hazard Alert discusses the health hazards associated with hydraulic fracturing and focuses on worker exposures to silica in the air. It covers the health effects of breathing silica, recommends ways to protect workers, and describes how OSHA and NIOSH can help. Workers and employers need to be aware of the hazard that silica dust poses. Employers must ensure that workers are properly protected from exposure to silica. This Hazard Alert also provides a brief summary of other health and safety hazards to workers conducting hydraulic fracturing activities.

OSHA and NIOSH have been investigating worker safety and health hazards in oil and gas extraction, including chemical exposures during hydraulic fracturing operations. OSHA has jurisdiction over the safety and health of workers, including workers involved in upstream oil and gas operations. The General Duty Clause of the Occupational Safety and Health Act and OSHA’s General Industry Standards (29 CFR 1910) apply to the upstream industry. As part of the enforcement of these regulations, NIOSH regions located in areas of significant upstream activities use national, regional, and local emphasis programs to inspect oilfield workers, including those that may have ongoing hydraulic fracturing operations.

NIOSH made safety and health in the oil and gas extraction industry a priority focus area in 2005 by creating the National Occupational Research Agenda (NORA) Oil and Gas Extraction Council, which includes OSHA and industry leaders as a cooperative effort to address occupational safety and health issues. To address an existing lack of information on occupational dust and chemical exposures associated with hydraulic fracturing, NIOSH established a cooperative industry partnership and initiated the NIOSH/NIOSH Oil & Gas Study to Assess Chemical Exposures among Oil and Gas Industry Workers (www.cdc.gov/niosh/docs/2010-130/pdf/2010-130.pdf). Exposure to silica during hydraulic fracturing has been the focus of the NIOSH study to date.

O N I O S H

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

1-800-321-Osha (6742) • www.osha.gov

Hierarchy of Controls

Elimination

Substitution

Engineering Controls

Administrative Controls

Physically remove the hazard

Replace the hazard

Isolate people from the hazard

Change the way people work

Protect the worker with Personal Protective Equipment

Most effective

Least effective

Silica dust cloud by worker delivering sand from sand mover to transfer belt.
Health Hazard: Hydrocarbon Gases and Vapors during Manual Tank Gauging and Sampling
9 fatalities identified where inhalation of volatile hydrocarbons was a possible contributing factor\(^2\):

- 2010 (1); 2012 (1); 2013 (1); 2014 (6)
- North Dakota (3); Colorado (3); Texas (1), Oklahoma (1); Montana (1)
- All occurred at crude oil (production) tanks:
  - tank gauging (4)
  - sampling by pumpers/truckers (5)
  - working alone or not being observed (9)
- In at least one case:
  - victim sought medical evaluation for health effects (dizziness, disorientation, etc.) experienced during prior gauging activities

\(^2\) NIOSH Science blog: [https://blogs.cdc.gov/niosh-science-blog/2015/04/10/flowback-3/]
Results of Personal Sampling (Hydrocarbons): Direct Reading
## Results of PBZ Grab Samples When Hatch Opened

<table>
<thead>
<tr>
<th>Gas or Vapor</th>
<th>Concentration Range (IDLH)</th>
<th>Vapor</th>
<th>Concentration Range (IDLH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>ND–5,979 ppm (5,000)</td>
<td>Benzene</td>
<td>ND–280 ppm (500)</td>
</tr>
<tr>
<td>Ethane</td>
<td>ND–24,818 ppm (3,000)</td>
<td>Toluene</td>
<td>ND–129 ppm (800)</td>
</tr>
<tr>
<td>Propane</td>
<td>ND–41,435 ppm (2,100)</td>
<td>Ethylbenzene</td>
<td>ND–55 ppm (500)</td>
</tr>
<tr>
<td>i-Butane</td>
<td>ND–3,793 ppm (1,800)</td>
<td>Xylenes</td>
<td>ND–84 ppm (900)</td>
</tr>
<tr>
<td>n-Butane</td>
<td>ND–19,336 ppm (1,860)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i-Petane</td>
<td>ND–2,990 ppm (1,400)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n-Pentane</td>
<td>ND–3,385 ppm (1,500)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IDLH = immediately dangerous to life or health
Develop alternative tank gauging procedures so workers do not have to routinely open hatches

- Remote tank gauging and sensing
- LACT units
• Reduce times workers must manually gauge tanks
• Use multi-gas meters correctly
• Hazard communication
Proper Respiratory Protection

- Utilize supplied air respirators for environments with oxygen deficiency and high low-molecular weight hydrocarbon concentrations
Health Hazard: Hydrocarbon Gases and Vapors during Fluid Transfer

- 440–550 parts per million of hydrogen sulfide
- >100% lower explosive limit for methane
- < 19.5% oxygen concentration
Utilize vent lines to direct hydrocarbon gases and vapor away from the work zone and potential ignition sources.
Health Hazard: Diesel Particulate Matter

What is Diesel Particulate Matter?

• Complex aerosol: gases, respirable particulates, > 40 potentially toxic compounds

• Solid elemental carbon (EC) core with hydrocarbons, S, NOx adsorbed onto core

• Respiratory and cardiovascular health effects; carcinogen
Health Hazard: Diesel Particulate Matter

Combination of data from 2008–2012\(^3\)

- 103 full shift air samples
  - 48 Personal Breathing Zone
  - 55 Area

- Site types
  - Completions Hydraulic Fracturing (56/103 or 54%)
  - Drilling (31/103 or 30%)
  - Servicing (16/103 16%)

Conclusions: Diesel Particulate Matter

• 10% (5/48) PBZ samples, > 20 µg /m³ as EC

• 31% (17/55) area samples > 20 µg /m³ as EC

• Proximity, #’s of sources, equipment configuration, weather conditions were determinants of exposures

• No statistically significant difference geometric means of PBZ vs. area results...some degree of homogenous risk for DPM exposure?
### On-going Exposure Assessments: Well Drilling Processes

#### What We Sampled
- Vapors and emissions from diesel based mud
- Hydrocarbon gas and vapors from the well/production zone
- Combustible gas/vapors, CO, H₂S, Oxygen
- Total hydrocarbons
- Respirable particulates
  - Diesel particulate matter (DPM)
  - Silica, cement, dust
- Special treatment chemicals

#### Where We Sampled
- Personal breathing zone samples on workers
  - Shakerhands/Mudmen
  - Motormen
  - Roughnecks/Floorhands
  - Derrickhands
- Areas around the site
  - Over mud tanks
  - In the mixing room
  - Over/around shakers
  - In the trip room
  - Processing solids
Questions? Bradley.King@cdc.hhs.gov

Alice Hamilton, M.D.
Mother of U.S. Occupational Medicine
1869–1970

NIOSH Project Researchers

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