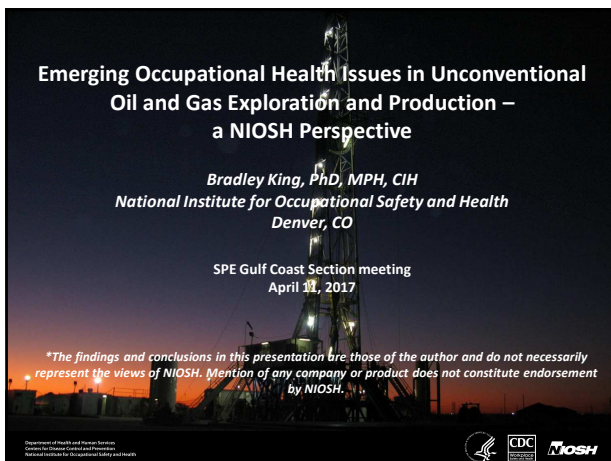




Emerging Occupational Health Issues in Unconventional Oil and Gas Exploration and Production – a NIOSH Perspective

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National Institute for Occupational Safety and Health
Denver, CO

SPE Gulf Coast Section meeting
April 11, 2017

**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.*

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NIOSH OIL & GAS EXTRACTION SAFETY & HEALTH RESEARCH

NIOSH

- Part of the Centers for Disease Control & Prevention (CDC)
- Research-focused, not regulatory
- Created an Oil and Gas Sector Program in 2007
 - Epi/Surveillance
 - Exposure Assessment
 - Engineering Controls
 - Communications



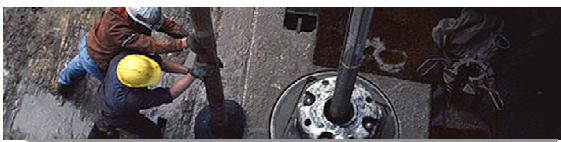
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National Occupational Research Agenda (NORA) Oil and Gas Extraction Sector Council



A national partnership effort to define and conduct priority occupational safety and health research

www.cdc.gov/niosh/nora/councils/oilgas

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Health Hazard: Respirable Crystalline Silica (RCS) during Hydraulic Fracturing

RCS Exposures

- 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

¹ Esswein, Breitenstein, Snawder, et al., Occupational Exposures to Respirable Crystalline Silica in Hydraulic Fracturing Jour. Occ. Env. Hyg. Vol. 10, Issue 7, May, 2013

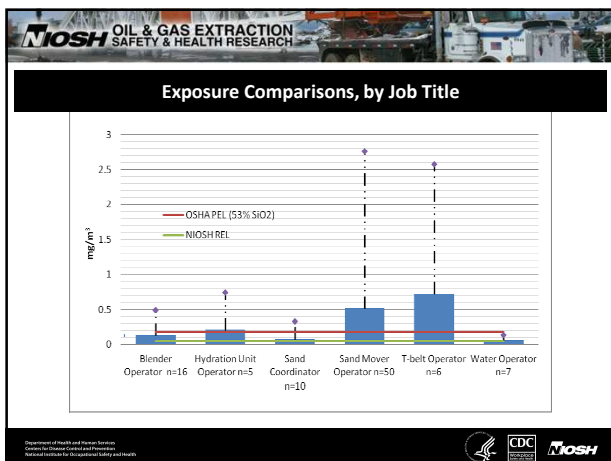
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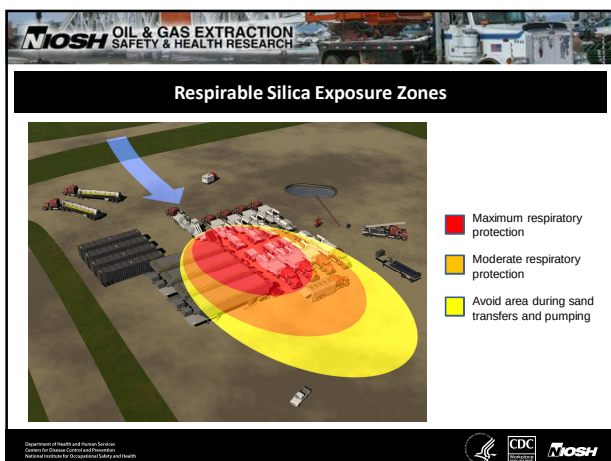
Study Results, by location

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
G**	0	0	0	8
Total	93 (78%)	76 (64%)	57 (48%)	119

* Number of samples/% ** Composite of 2 locations

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Elimination, Substitution, Engineering Controls

Examples of controls being developed by Industry

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

National STEPS Network: Emerging Issues Focus Group
May 11, 2016

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NIOSH-developed Engineering Control

NIOSH Mini baghouse retrofit assembly

2012 2013 2015

Features

- ✓ Highly effective
- ✓ Inexpensive
- ✓ "bolt-on"
- ✓ Uses pneumatic energy
- ✓ In-field retrofit

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NIOSH-developed Engineering Control

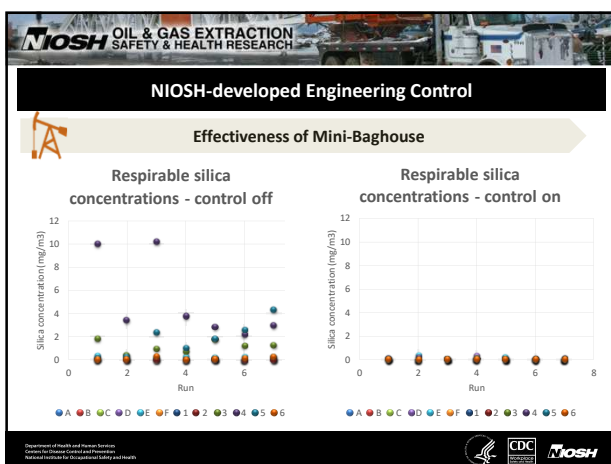
Effectiveness of Mini-Baghouse

Respirable silica concentrations - control off

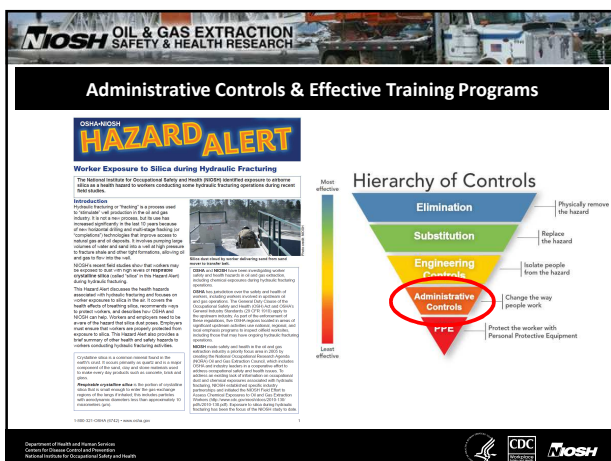
Respirable silica concentrations - control on

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Continuing Questions about...

- Reliance on personal protective equipment (PPE) (i.e., respiratory protection) rather than engineering controls
- Increased quantities of proppant used
- Extent of use of controls by smaller and mid-size operations
- Introduction of 'microproppant'

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Health Hazard: Hydrocarbon Gases and Vapors during Manual Tank Gauging

 **Opening Thief Hatch**



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2010–2014 Hydrocarbon Related Worker Fatalities

9 fatalities identified where inhalation of volatile hydrocarbons was a possible contributing factor:

- 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

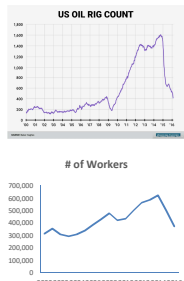
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Why did we see the surge in this 4 year period?

- Increases in:
 - Number of wells drilled
 - Number of workers employed upstream
 - Production of oil
- Crude oil from tight shales often lighter, more volatile product
- New storage tanks subject to EPA's 2012 New Source Performance Standards (NSPS 0000)
- Use of traditional work practices (i.e., manual gauging and thiefing)



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Exposure Assessments Locations

- Fayetteville Shale-Dry Gas
- Marcellus-Wet and Dry Gas
- Utica Shale-Wet Gas
- DJ-Oil and Gas
- Piceance-Oil and Gas
- San Juan-Oil and Gas
- Jonah-Oil and Gas
- Bakken-Oil



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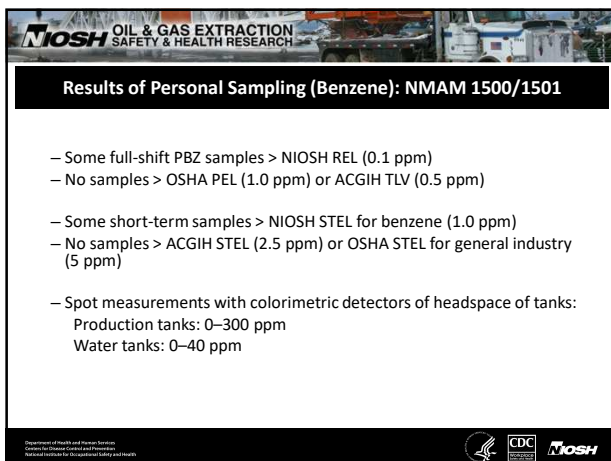
Exposure Assessments Methods

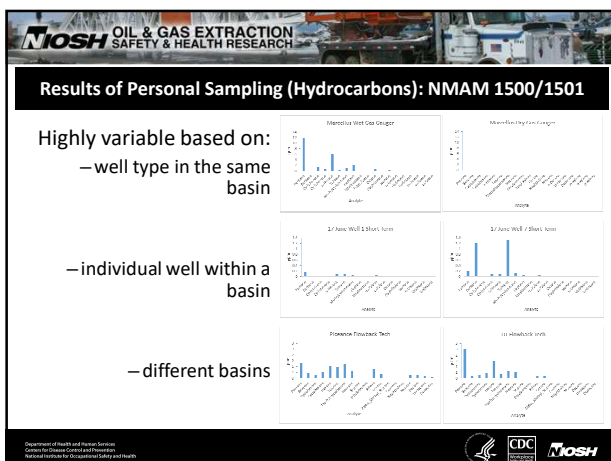
- Standard Industrial Hygiene Methods
 - NMAM (1500, 1501, 1550) and OSHA Methods (PV2010)
 - Personal and Area Samples (Full-shift, short term)
- Direct Reading Methods
 - Real Time Instruments, Meters and Monitors
 - Video Exposure Monitoring (FLIR GF 320)
- Whole air sampling
 - Evacuated containers (Entech Bottle-Vac)
 - Sample bags
- Real-time GC as well as GC/MS analysis

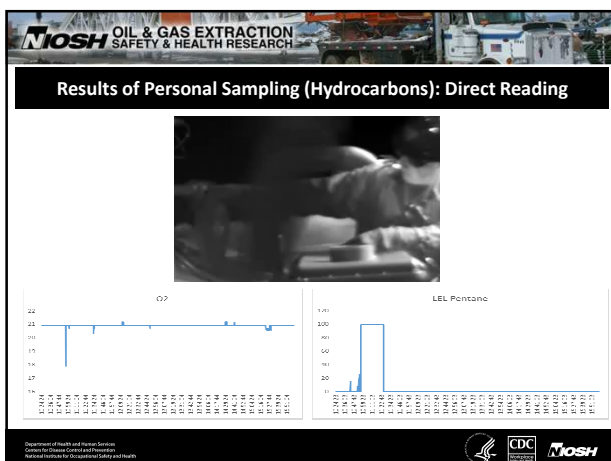


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Results of Grab Samples 0.5 Meters Above Hatch			
Analyte	Concentration Range	IDLH (ppm)	Severity
Methane	0-88,000 ppm	5000	0-17
Ethane	200-188,000 ppm	3000	0.1-63
Propane	64-240,000 ppm	2100	0-114
Isobutane	35-21,664 ppm	1800	0-12
n-Butane	100-110,000 ppm	1860	0-60
Isopentane	0-14,000	1400	0-10
n-Pentane	0-100,000	1500	0-67
C1-C5 (Total)	800-640,000	-	-

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OIL & GAS EXTRACTION SAFETY & HEALTH RESEARCH			
Results of Grab Samples 0.5 Meters Above Hatch			
Analyte	Concentration Range (ppm)	IDLH (ppm)	Severity
Benzene	ND-338	500	0-0.67
Toluene	ND-82	800	0-0.03
Ethylbenzene	ND-26	500	0-0.15
Xylenes	ND-40.5	900	0-0.2

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OIL & GAS EXTRACTION SAFETY & HEALTH RESEARCH			
Results of PBZ Grab Samples When Hatch Opened			
Gas or Vapor	Concentration Range (IDLH)	Vapor	Concentration Range (IDLH)
Methane	ND-5979 ppm (5000)	Benzene	ND-280 ppm (500)
Ethane	ND-24,818 ppm (3000)	Toluene	ND-129 ppm (800)
Propane	ND-41,435 ppm (2100)	Ethylbenzene	ND-55 ppm (500)
i-Butane	ND-3793 ppm (1800)	Xylenes	ND-84 ppm (900)
n-Butane	ND-19,336 ppm (1860)		
i-Pentane	ND-2990 ppm (1400)		
n-Pentane	ND-3385 ppm (1500)		

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Assessment Results

- Traditional IH sampling methods:
 - exposure hazards of concern for benzene and other gas and vapors may be present
- Direct reading instruments:
 - short-term hazardous atmospheres (flammable atmospheres, low oxygen, high levels of VOCs) can occur when tanks opened
- Standard methods are not always adequate to evaluate very high but very brief exposures**

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Factors that may *increase* worker exposure to hydrocarbon

- Produced Fluid and Reservoir Characteristics
 - Condensate and lighter crude (versus heavy crude)
 - High temperature fluids
 - High production volumes/early in production
- Operational and Task-related Factors
 - Tanks not isolated prior to opening hatch
 - Interconnected tanks (tank batteries)
 - Working around separators/enclosed spaces
- Environmental Factors
 - Higher temperatures
 - Weather inversions
 - Wind direction/low speed



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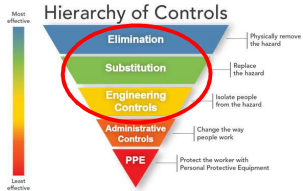
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Elimination, Substitution, Engineering Controls

Develop alternative tank gauging procedures so workers do not have to routinely open hatches

- Remote tank gauging and sensing
- LACT units

Hierarchy of Controls



Success Story: [BHP Billiton](#)

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Administrative Controls & Effective Training Programs

- Hazard communication
- Reduce times workers must manually gauge tanks
- Stand upwind and to side of open hatch
- Use multi-gas meters correctly



Hierarchy of Controls



Most effective
Least effective

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

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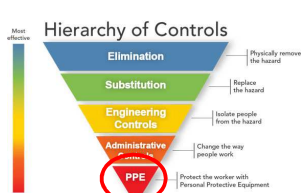
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Proper Respiratory Protection



Hierarchy of Controls



Most effective
Least effective

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

- Utilize supplied air respirators for environments with oxygen deficiency and high low-molecular weight hydrocarbon concentrations

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Future Directions for NIOSH Research in the Oil and Gas Extraction Industry

- Acute exposure hazards (VOC exposures, flammability hazards) during handling of crude, produced water, etc.
- Flowback (VOCs, aldehydes, alcohols, BTEX)
- Drilling (VOCs, diesel particulate matter [DPM], silica)
- Servicing operations (NORM, VOCs, DPM)
- Evaluation of controls
- Long term evaluation: NIOSH Mini Baghouse Retrofit Assembly
 - Long term goal: licensing, adoption

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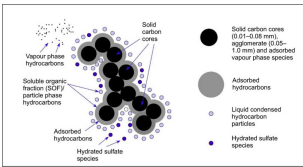
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Health Hazard: Diesel Particulate Matter

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
- The adsorbed compounds comprise 15–65% of the total particulate mass and include compounds which may be carcinogenic.



The diagram illustrates the structure of Diesel Particulate Matter (DPM). It shows a central 'Solid carbon core' (black circle) with a size range of 0.01–0.08 μm. Surrounding this core are 'Vapour phase hydrocarbons' (small blue dots), 'Solid carbon cores agglomerates (0.1–1.0 μm) and adsorbed vapour phase species' (larger black circles), 'Soluble organic fraction (SOF) particle phase hydrocarbons' (small grey circles), 'Adsorbed hydrocarbons' (small blue dots), 'Liquid condensed hydrocarbon particles' (small grey circles), and 'Hydrated sulfate species' (small blue dots).

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Health Hazard: Diesel Particulate Matter

Health Effects from DPM exposure

- Eye, nose, throat irritation
- Exacerbation of pre-existing respiratory conditions: bronchitis, asthma, etc.
- Headaches, dizziness
- Cardiovascular disease
- Cancer

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Upcoming NIOSH Journal Article: Diesel Particulate Matter

Combination of data from 2008–2012

- 103 full shift air samples
 - 48 Personal Breathing Zone
 - 55 Area
 - Analysis by NMAM 5040
 - DPM as elemental carbon by Thermal Optical Analysis
- States: CO, ND, NM, TX
- Site types
 - Completions Hydraulic Fracturing (56/103 or 54%)
 - Drilling (31/103 or 30%)
 - Servicing (16/103 16%)



The photograph shows an oil and gas extraction site with several drilling rigs and equipment. A red truck is visible in the foreground, and the background shows a hilly landscape under a clear sky.

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Conclusions

1. 10% (5/48) PBZ samples, > 20 $\mu\text{g}/\text{m}^3$ as EC
2. 31% (17/55) area samples > 20 $\mu\text{g}/\text{m}^3$ as EC
3. Proximity, #'s of sources, equipment configuration, weather conditions were determinants of exposures
4. Most non-road diesel equipment: at least Tier 1 and Tier 2 EPA diesel emission standards
5. No statistically significant difference GMs: PBZ vs. area...some degree of homogenous risk for DPM exposure?

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HAZARD ALERT: Fatalities Associated with Fires and Explosions

- 85 Fatalities from 2005–2015
 - 28 Fatalities from Hot Work
 - On production sites and at maintenance shops
 - Welding, cutting, grinding, propane torch
 - Storage tanks, tanker/vacuum trucks, heater-treaters, flowlines from wellhead
 - General maintenance and repairs

Source: NIOSH FOG Database.
Infographic: http://nationalstepsnetwork.org/pdf/HotWork_Hazard_Alert_Final_9-28-16.pdf

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

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- Belinda Johnson
- Bradley King
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- Sophi Ridl
- John Snawder
- Julie Toseski (visiting scientist)

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