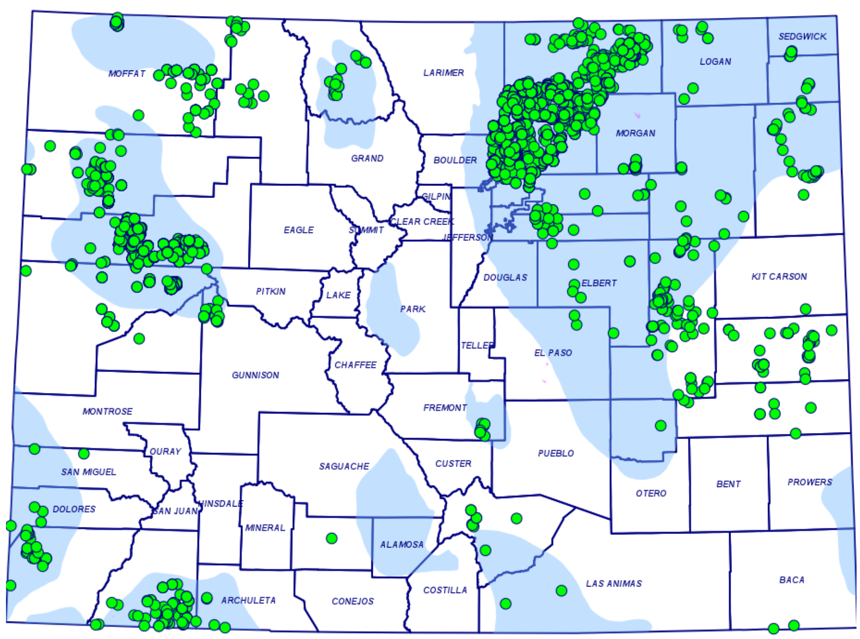
FAQ: Oil and Gas Extraction
Occupational Health and Safety Surveillance

What is hydraulic fracturing?
Hydraulic fracturing, or "fracking" as it is commonly referred, is one of many steps in establishing a productive oil and natural gas well. After a well is drilled, hydraulic fracturing, or completion, is the process whereby large volumes of water, sand, and chemicals are injected at high pressure into the well, creating cracks and fissures in the rock. The proppant, typically sand, holds the fractures open, allowing for more efficient and sustained flow back of gas or oil (2).

Is hydraulic fracturing new technology?
Conventional (vertical) drilling for natural gas has occurred since the 1940s, but the development of horizontal and directional drilling and high volume hydraulic fracturing technologies offer access to natural gas and oil located in "tight shale" layers, which were economically unattractive to drill prior to the past ten to fifteen years (2). This newer unconventional technique involves vertically drilling a well thousands of feet below the surface and then horizontally for up to two miles. An average of 2 to 5 million gallons of a mixture consisting of water and proppant (typically sand) and chemicals are injected into the well at high pressure to fracture the shale rock (3). The wells are now fractured in numerous stages potentially creating additional opportunities for occupational injury and exposure, generating noise, dust, and flowback fluid that returns to the surface following injection.

Where are oil and gas basins located in Colorado?
There are several oil and gas basins in Colorado as indicated by blue on the map to the right (4). The overlying green dots indicate the location of actively permitted wells. Most of the active wells in Colorado are located in Weld, Garfield, Yuma, La Plata, Las Animas, and Rio Blanco counties (5). As of June 2014, there were 52,182 active wells in Colorado (5).



Is it true that the majority of hydraulic fracturing fluid is composed of water?
About 95% of hydraulic fracturing fluid by volume is water, while the remainder is composed of sand (~4.5%) and chemical additives (≤1.0%). The chemical additives can include biocides, breakers, buffers, clay stabilizers, corrosion inhibitors, crosslinkers, foaming agents, friction reducers, gelling agents, iron control agents, pH adjusters, scale inhibitors, solvents, and surfactants. In Colorado, oil and gas operators are required to disclose all chemicals used during the hydraulic fracturing process (with limited exceptions for trade secret chemicals) to an online registry (6).

What is difference between "produced water" and flowback?
Flowback water and sand returns to the surface after injection of hydraulic fracturing fluid into a drilled well. Produced water is the water found in the formation that is freed up with the fracking process. The properties of produced water vary with geologic formation, fracturing fluid composition, and the time since drilling. Some chemicals that are naturally present in the formation can be brought to the surface in the produced water and may also pose a concern. Both produced water and flowback may contain dissolved hydrocarbon gases, water, liquid hydrocarbons, sand, and chemical additives (7). Additionally, it may contain salts, clays, dissolved metal ions, total dissolved solids, and naturally occurring radioactive material.

How many workers are employed in oil and gas in Colorado?
According to the Quarterly Census of Employment and Wages published by the Bureau of Labor Statistics, in 2012 in Colorado there were a combined 24,043 individuals employed in oil and gas extraction (NAICS 211, n=9,152), drilling oil and gas wells (NAICS 213111, n=2,545), and support activities for oil and gas operations (NAICS 213112, n=12,346). This represents a two-fold increase when compared to the same value for 2003 (8).

What risks are workers in unconventional oil and gas exposed to?

Risk for death
In the period spanning 2005 to 2009, the most common fatal events in the oil and gas industry nationally were due to highway crashes (29.3%) and being struck by an object (20.1%) (1, 9). Occupational Safety and Health (OSHA) data indicates that between 2005 and 2013, there were twenty fatalities in Colorado in the oil and gas industry, with the highest numbers in Weld (35%), Garfield (25%), and Rio Blanco (15%) counties (5). Fatalities resulting from motor vehicle crashes are of particular concern, as the national rates in the oil and gas industry are 8.5 times higher than the average for all industries (10).

The national occupational fatality rate for the oil and gas industry was 7 times higher than general industry and 2.5 times higher than the construction industry between 2005 and 2009 (1)

Risk for injury
According to workers' compensation claims data from the Colorado Department of Labor and Employment, in 2012 and 2013, the most common causes of injury among oil and gas workers include strain (35.3%), slip, trips or falls (24.1%), and struck or injured by an object (14.1%) (5). For the same time period in Colorado, the most commonly injured part of the body was the upper extremity (40.6%), followed by the trunk (21.2%) and the lower extremity (17.6%). While the fatality rate is quite high, the recordable injury rate based on 2012 Bureau of Labor Statistics national data is lower

than the overall average for all industries combined (1.5 vs. 3.7, respectively) (5). Discordance between fatality and injury rates is an unusual finding in occupational populations.

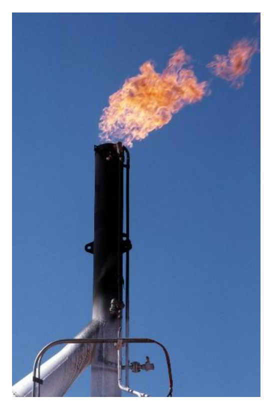
Potentially preventable injuries requiring days away from work nationally in oil and gas for 2010 include being struck by/against an object (35.8%), caught in an object, equipment, material (21.2%), falls on same/lower level (14.6%), overexertion (11.5%), exposure to harmful substance (3.3%), slips or trips (1.3%), or other (10.6%)(1).

Motor vehicle accidents

Development of a well pad requires extensive truck transport of fuel and water to the well development site. Additional visits are required among active well pads during the production and maintenance phases. Nationally, between 2003 and 2009, 202 oil and gas extraction workers died in a motor vehicle crash, accounting for 28% of all oil and gas extraction work-related fatalities and was the leading cause of death (10). Most (51.5%) victims were driving a pickup truck at the time of the fatal accident, with the majority (55.9%) involving non-collision incidents such as jack-knifing or overturning (38.6%). Among the fatalities, equal numbers were not wearing a seat belt or their belt status was unknown (38.1% each) and 11.9% of occupants were ejected (unknown belt status, but assumed unrestrained). Only 11.9% were wearing a safety belt. Workers employed by well servicing companies and drilling contractors were significantly more likely to die as a result of a highway crash than those employed by oil and gas operators. Workers from small and medium sized establishments were also significantly more likely to die in a highway crash while at work than were workers from large establishments (10).

Given the high fatality rate in the oil and gas industry associated with motor vehicle accidents, OSHA and National Institute for Occupational Safety and Health (NIOSH) have created safety training specific to the industry. Some companies have developed in-vehicle monitoring programs that record date, time of day, speed, acceleration, deceleration, and safety belt use, with an estimated 50% to 93% reduction in motor vehicle crash rate (11).

Risk for explosive injury



Methane is a flammable and explosive hydrocarbon gas, which may leak from the oil and gas infrastructure or is vented by extractors who don't flare the natural gas they opt not to capture or sell (12, 13). Typically, concentrations of 10% to 20% of the lower explosive limit (LEL) are considered a risk for fires or explosions. Direct reading instruments in one recent study identified instances of short-term concentrations of total hydrocarbon vapor as high as 40% of the LEL adjacent to separators and flowback tanks. Calibrated personal flammable gas monitors with alarms are recommended for use in areas near flowback tanks and tank batteries during well control activities, drilling plugs, and snubbing, only after ensuring that workers understand how to use and respond to monitors (7). It is critical to remember that many flammable gas sensors are oxygen dependent and will not provide reliable readings in an oxygen deficient atmosphere, such as those potentially present in a confined space (14). A multigas monitor containing sensors for oxygen, LEL, and relevant toxic gases is appropriate for this reason. Employee training on the proper response to alarms is important.

Risk for toxic exposures

Most research to date regarding the toxicological risks in oil and gas extraction pertain to workers in downstream processes such as refining, manufacturing, and processing of petroleum products, rather than exploration and drilling, servicing, or workover operations.

However, there is a developing body of literature around potential occupational exposures and associated health effects related to upstream unconventional gas development. While some exposures currently under study are unique to this population (i.e. hydraulic fracturing fluid mixtures), there are also exposures that have been studied extensively with known negative health effects (i.e. benzene, silica, and diesel exhaust).

"Workplace concentrations of airborne respirable silica exceeded occupational exposure limits by factors of 10, 20, or more, with Sand Movers and Transfer Belt Operators having the highest relative exposures" (2)

Respirable crystalline silica (2)

- Inhalation of respirable crystalline silica is associated with the development of silicosis, lung cancer, autoimmune diseases, and chronic kidney disease. Workers with silicosis also have a greater risk of developing tuberculosis (11).
- Silica is contained in the sand used as a proppant in oil and gas extraction. Research shows that occupational exposure to respirable crystalline silica is a hazard for workers at hydraulic fracturing sites. Observed levels exceeded occupational exposure limits for workers performing certain high-exposure tasks such as sand loading and blending operations, sand truck refilling and sand mover operations. All produce freshly fractured quartz, which has greater toxicity than aged quartz. Specifically, sand mover operators and T-belt operators had personal breathing zone exposures exceeding the recommended and permissible exposure limits (REL and PEL, respectively) by a factor of ten or more. Workers outside areas of primary sources of dust generation and those working in both closed and open cabs on their machinery also sometimes exceeded the occupational exposure limits. Engineering controls to reduce silica exposure include passive enclosures, staging curtains, skirting, and shrouding, minimizing the distance that sand falls, use of water for dust control, and placing end caps on fill nozzles. Administrative controls might include limiting worker time at dusty sites. The lowest level of control consists of a respiratory protection program, signage, hazard communication, periodic training and medical monitoring (9, 11).

Benzene and other hydrocarbons

- Benzene is carcinogenic to humans, causing acute myeloid leukemia and acute non-lymphocytic leukemia in humans (Group 1) (15).

- A recent NIOSH air sampling study at oil and gas extraction sites demonstrated airborne concentrations of benzene that exceeded occupational exposure limits. The primary risk factor for inhalational exposure was working around flowback and production tanks, particularly for flowback technicians who manually open thief hatches and gauge tanks. Flowback technicians in the vicinity of exposure sources like flowback tanks, but not actively gauging, also had full-shift personal breathing zone benzene exposures that met or exceeded the NIOSH REL. Control measures might include developing alternative tank gauging procedures to limit exposure to hydrocarbon vapors and adapting sampling ports and vents to exhaust away from workers; providing training on the risks of hydrocarbon exposure; limiting time around hydrocarbon sources and using personal monitoring during activities involving exposure to flowback fluids; and using appropriate respiratory and dermal protection in the interim until engineering controls are in place (7). In addition to benzene, this study revealed that airborne concentrations of other volatile organic compounds, including naphthalene, toluene, ethylbenzene, and xylene, were variable but similarly spiked with tank gauging activities.

Hydrogen sulfide

- “Sour gas” is a component of natural gas, but can also occur as a result of anaerobic bacterial digestion of organic matter during the extraction process. Exposure to high concentrations may cause loss of consciousness and death. Exposure to hydrogen sulfide can cause temporary loss of the sense of smell, and irritation of the eyes, nose, or throat (16). Exposures may occur during well servicing, tank gauging, and swabbing operations. Many companies in the industry routinely require the use of personal monitors and offer hydrogen sulfide training programs (1).

Lead

- “Pipe dope” typically contains about 30% of lead by weight, and can contain up to 60% or more. A study from 2011 identified elevated blood lead levels in children of workers who used leaded pipe dope on the job. High lead levels were also found on clothing, washing machines, furniture, and in the blood of two of three exposed workers (one not tested) (17).

Naturally occurring radioactive materials

- Rock formations that contain hydrocarbons also typically contain naturally occurring radioactive material (NORM), particularly uranium and thorium. These elements and their decay products, including radium-226 and radium-228, can be brought to the surface in drill cuttings and produced water (12). NORM is a waste product of oil production and its presence in pipelines, plants, and machinery may cause radiological health hazards, particularly for workers who come into contact with or are in close proximity to contaminated materials. Proposed strategies for NORM management in the oil and gas industry include: baseline surveys of NORM accumulation in facilities; pre-test and inspection surveys whereby proper procedures are implemented to protect workers; routine NORM assessments using portable instruments to identify sources of contamination; and legacy contamination surveys to ensure the identification and remediation of these areas prior to decommissioning or releasing these sites (i.e. evaporation ponds or disposal pits) (18).

Diesel particulate

- Diesel engine exhaust is a health exposure of concern, as it is carcinogenic to humans (15). NIOSH air sampling assessments suggest that exposures are episodic, with increases in ultrafine particulates during periods of heavy pumping (i.e. during hydraulic fracturing operations) (19, 20). Wind direction and location of the worker relative to the source of diesel exhaust are determinants of exposure. Transition to use of natural gas and electric vehicles and equipment can reduce or eliminate diesel exposure.

Noise

- Diesel engines, generators, heavy equipment, mechanical brakes, hoisting machinery, radiator fans, pipe handling, and drilling equipment generate noise at oil and gas extraction sites. Baseline noise exposure data and systematic studies for this industry are lacking. From October 2010 to September 2011, national OSHA inspections of oil and gas industry have resulted in two citations for noise-related issues, however inspections and citations are limited because companies involved in oil and gas well drilling and servicing are exempt from several sections of the OSHA noise standard, as described below (1). In general, when employees are exposed to noise levels of 90 decibels for eight or more hours per day, administrative or engineering controls must be utilized to reduce exposure. If controls fail to reduce noise to appropriate levels as outlined in the OSHA standard, employers must provide personal protective equipment consisting of hearing protectors.

Temperature extremes

- Outdoor workers are susceptible to the health effects of exposure to temperature extremes. Workers in hot environments may develop a spectrum of heat-related illness ranging from heat rash to heat stroke, particularly if they are 65 years or older, are overweight, or have heart disease or high blood pressure (21). Exposure to low temperatures may result in development of cold stress ranging from chilblains to hypothermia, particularly in those in settings where temperatures drop below those expected for that particular geographic region and wind speed increases (22). Outdoor workers are also exposed to ultraviolet radiation, placing them at increased risk for skin cancer (23).

Is the oil and gas industry subject to Occupational Safety and Health Administration (OSHA) regulations?

Exposures to hazards present in the oil and gas well drilling, servicing, and storage industry are addressed in specific standards for general industry (29 CFR 1910), with the exception of site preparation (leveling the site, trenching, and excavation), which is the only aspect of oil and gas well drilling operations covered by construction standard (29 CFR 1926) (24).

There are limited OSHA standard exceptions for oil and gas well drilling and servicing, which are described in more detail below.

The oil and gas industry is covered by OSHA standard 1910.95 (a) and (b), which require employers to protect workers against the effects of excessive sound levels and to implement feasible administrative and engineering controls if excessive levels are present. If those controls are not available, then personal protective equipment must be provided to employees. The industry is exempt from standards involving “hearing conservation program”, “monitoring”, “employee notification”, “audiometric testing program”, and related standards.

Oil and gas well drilling and servicing is also exempt from OSHA lockout/tagout standard as per 1910.147(a)(1)(ii)(E). Oil and gas drilling, production, and servicing operations are exempt from the benzene standard as per 1910.1028 (a)(2)(vi). Benzene exposure limits for this industry are included in *Limits for Air Contaminants* (1910.1000 Table Z-2). The 8-hour time weighted average (TWA) is 10 parts per million (ppm), acceptable ceiling concentration of 25 ppm, and the acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift is 50 ppm for a maximum duration of 10 minutes.

Oil and gas well drilling or servicing operations are exempt from the process safety management of highly hazardous chemicals as per 1910.119(a)(2)(ii) (25).

Exemptions from OSHA regulatory standards do not preclude the oil and gas industry from taking a protective and proactive approach to preserving the health and safety of their workers.

What questions remain?
A demographic description of workers in the oil and gas industry would help focus future research examining injury and illness in this field. Further, occupational injury and illness data should be readily available so public health researchers can better understand fatal and nonfatal risks by occupation. This information is invaluable for directing future prevention-based efforts in the fields of occupational safety and health and addressing the causes of underreporting. When possible, including industry and occupation descriptors in datasets containing health information will facilitate ongoing research.

Of particular interest are the intermediate- and long-term health effects for workers, including respiratory effects of silica exposure and hematologic effects of benzene exposure. Longitudinal studies are especially important in examining diseases of latency such as silicosis, leukemia, and lung cancer. Other areas of concern that warrant further research attention include exposure to naturally occurring radioactive materials, diesel exhaust, noise, and chemical mixtures. The cooperation of industry is essential in addressing these research needs. Additional research and more focused surveillance are needed.

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