Sampling for Oil Mist and Hydrocarbons on Drilling Rigs in Northeast British Columbia

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Table of Contents

Executive Summary

Problem under Investigation

During drilling, a large volume of drilling fluids are circulated through the well and into open, partially enclosed or completely enclosed systems at elevated temperatures. When these fluids are agitated (as they are during part of the recirculation process), there is a potential for significant worker exposure and subsequent health effects.

Several preliminary studies, completed by drilling contractors in British Columbia, showed worker overexposure to hydrocarbons (as diesel) and oil mist. Oil mist exposures were as high as 1.4 mg/m^3 over a potential 12 hour work shift – compared to the WorkSafeBC exposure limit (EL) of 0.1 mg/m^3 (for Mildly Refined Oil Mist).

Results

WorkSafeBC collected occupational and area samples for oil mist from two drilling rigs on August 11 (Rig No. 1) and 12 (Rig No. 2), 2009. Both rigs were located southeast of Fort St. John, British Columbia.

Oil mist measurements on Rig No. 1 (both occupational and area) were less than the WorkSafeBC 12 hour occupational Exposure Limits (EL) for both Mildly Refined and Severely Refined Oil Mist.

On Rig No. 2, the results from the Derrickhand (0.8 mg/m^3) and the area sample collected near the Shaker (0.29 mg/m^3) were significantly higher than the 12 hour EL for Mildly Refined Oil Mist (0.1 mg/m^3). The "Mildly Refined" EL was selected as the exposure criteria, because there was no evidence from the Material Safety Data Sheet (MSDS) that the oil-based drilling fluid was free of aromatic hydrocarbons (which are much reduced in severely refined oils).

Total hydrocarbon concentrations ranged between 60 parts per million (ppm) and 160 ppm around the Shakers and reached 25 ppm above the Mud Tanks. Background concentrations were between 0 ppm and 6 ppm, on both Rigs.

Conclusions

The results of this investigation confirm previous sampling, conducted by a number of Drilling Companies, that workers on the Drill Rigs are potentially overexposed to hydrocarbons and oil mist likely generated from agitated drilling fluids. A number of options to control worker exposure, including substitution of more hazardous drilling fluids with less hazardous products, various engineering and administrative controls and personal protective equipment options, are discussed in this report.

Introduction

What are Drilling Fluids?

Drilling fluids, also known as “drilling mud” and “invert mud”, are used in the Oil and Gas industry as a part of the well drilling process. They serve a number of functions, including:

- Lubricating and cooling of the drill bit and drill string (pipes)
- Cleaning rock cuttings from the hole
- Stabilizing the drill hole to prevent cave-in and collapse
- Preventing the flow of reservoir fluids (e.g., oil) into the drill hole
- Transmitting hydraulic power to the drill bit (during lateral drilling).

There are several types of drilling fluids used for different drilling applications, depending on the formations that are drilled, including:

- Water-based fluids (fresh or seawater; used in off-shore platforms or in environmentally sensitive areas)
- Oil-based fluids (diesel oil, mineral oil or synthetic oil; used when drilling through shales, etc.)
- Gas-based “fluids” (air, air and water foam, or natural gas; used in very stable formations – speeds drilling).

The most common types of drilling fluids used in B.C. are mineral and synthetic oil-based fluids. Diesel-based fluids are not generally used in B.C., however, diesel oil has been used as a mud additive, depending on the drilling application.

Problem under Investigation

During the drilling process, a large volume of drilling fluids are circulated through the well and return into open, partially enclosed or completely enclosed well circulation systems at elevated temperatures. When these fluids are agitated (as they are during recycling and filtration), there is a potential for significant worker exposure to hydrocarbons and other contaminants, with subsequent health effects.

These health effects include dizziness, headaches, drowsiness and nausea (typically associated with exposure to hydrocarbons), as well as dermatitis and sensitization from repeated skin contact with the drilling fluids. In addition, exposure to oil mists can cause irritation and inflammation of the respiratory system. Some of the mildly refined base oils have also been associated with cancer, due to the aromatic compounds in the oil mists.

Several preliminary studies have already been conducted by drilling contractors in British Columbia that showed worker overexposure to hydrocarbons (as diesel) and oil mist. The workers most affected included the:

- Derrickhand – who mixes and adds chemicals to drilling mud, collects mud samples, monitors pumps and handles pipe during tripping activities (the removal or addition of pipe to the drill string).
- Motor Man – who is responsible for all of the motors and generators and general equipment maintenance and housekeeping.
- Roughneck – who makes pipe connections during tripping activities from the drill deck, collects core and cutting samples and performs general housekeeping.

For some of these workers, oil mist exposures were as high as 1.4 mg/m^3 over a potential 12 hour work shift – compared to the WorkSafeBC exposure limit (EL) of 0.1 mg/m3 (for mildly refined oil mist).

These workers may also spend a significant portion of their shifts in areas where there is an elevated concentration of airborne contaminants, including the:

- Drilling Floor
- Chemical Mixing Station/Room
- Mud Pits/Tanks (where treated drilling fluids are retained prior to pumping to the drill hole)
- Shale Shakers (where drill cuttings are "shaken" from the drilling fluids that return from the drill hole)

Hydrocarbon and oil mist measurements were as high as 240 mg/m^3 and 3.2 mg/m^3, respectively, in the vicinity of both the Mud Tanks and Shakers. The WorkSafeBC EL for hydrocarbons (as diesel) is 50 mg/m^3 over a 12 hour shift. These exposures exceeded the regulated limits by a significant margin.

Materials and Methods

Sampling Locations

WorkSafeBC collected occupational and area samples for oil mist from two drilling rigs on August 11 (Rig No. 1) and 12 (Rig No. 2), 2009. Both rigs were located southeast of Fort St. John, British Columbia.

Rig No.1 was a relatively new (about 3 years old) "triple" rig (the derrick was tall enough to handle 3 stands of pipe), with semi-enclosed mud tanks and shale shakers (both had a roof on top). The drilling fluid in use was a synthetic oil (Amodril 1500 Synthetic Olefin). The weather at the time of sampling was sunny and warm with a stiff breeze.

Rig No. 2 was an older rig, also a “triple”, however the mud tanks and shakers (Figure 1) were open (no roof). The drilling fluid in use was the oil-based Drillsol (60-100% straight-run middle distillate). The weather was rainy and cool with wind in the afternoon.

Samples were collected from similar workers and areas on both rigs and included occupational samples, from two Roughnecks and one Derrickhand, and area samples located at the Drill Floor and near the Shakers (Figure 2).

Figure 1: Open Shale Shakers on a Drill Rig – Note the Visible Mist

Sample Analysis Methods

The analytical method used was NIOSH 5524 Metalworking Fluids (MWF) All Categories.

Samples were collected on standard 2 micron 37 mm PTFE cassettes connected to SKC PCXR4 personal sampling pumps set at a flow rate of 2 L/min. The cassettes were set up as “closed-face” in order to minimize interference from rainfall and oil splashed during the drilling operations. The sampling times were between 6 and 6.75 hours.

Flow rate was to be measured and recorded before and at the end of sampling using a calibrated Bios Drycal DC-Lite flow calibrator. Five blank samples were collected on each day.

Total hydrocarbons were measured in spot areas around the Mud Tanks and Shakers, on both rigs, using a RAE Systems MiniRAE 3000 Photoionization Detector (PID).

Figure 2: Typical Sampling setups (pump and cassette) on the Drill Rig (left – occupational sample on a Roughneck; right – area sample over Shakers)

Results

Oil Mist

On Rig No. 1, all of the oil mist measurements (both occupational and area) were less than the WorkSafeBC 12 hour occupational Exposure Limits (EL) for both Mildly Refined and Severely Refined Oil Mist (and were below the Limit of Detection for the analytical method used – Table 1).

On Rig No. 2, the results for the Derrickhand (0.8 mg/m^3) and the area sample collected near the Shaker (0.29 mg/m^3) were significantly above the 12 hour EL for Mildly Refined Oil Mist (0.1 mg/m^3). The "Mildly Refined" EL was selected as the exposure criteria, because there was no evidence from the Material Safety Data Sheet (MSDS) that the oil-based drilling fluid was free of aromatic hydrocarbons (which are much reduced in severely refined oils).

Table 1 – Summary of WorkSafeBC Oil Mist Sampling on the Two Oil Rigs

Rig	Sample Type	Worker or Location	Oil Mist (mg/m^3)	WCB 12hr EL Mildly Refined (mg/m^3)	WCB 12hr EL Severely Refined (mg/m^3)
Rig 1	Occupational	Derrickhand	< 0.05	0.1	0.5
	Occupational	Roughneck	< 0.05		
	Occupational	Roughneck	< 0.05		
	Area	Shaker	< 0.08		
	Area	Drill Floor	< 0.05		
Rig 2	Occupational	Roughneck	< 0.07		
	Occupational	Roughneck	< 0.08		
	Occupational	**Derrickhand**	**0.80**		
	Area	**Shaker**	**0.29**		
	Area	Drill Floor	< 0.05		

The American Conference of Governmental Industrial Hygienists (ACGIH) has published exposure limits for many contaminants, including oil mists. For example, the ACGIH 8 hour TLV for oil mist (both mildly and severely refined) is 5 mg/m^3 – the 12 hour equivalent would be 2.5 mg/m^3. WorkSafeBC has separate ELs for both mildly and severely refined oil mist and both values are much lower than the ACGIH TLVs.

Total Hydrocarbons

Total hydrocarbon concentrations (as sampled using the PID) ranged between 60 parts per million (ppm) and 160 ppm around the Shakers and reached 25 ppm above the Mud Tanks. Background concentrations (away from Mud Tanks and Shakers) were between 0 ppm and 6 ppm, on both Rigs.

Discussion

The results of this investigation confirmed some of the previous sampling, conducted by Drilling Companies, that workers on the Drill Rigs are potentially overexposed to hydrocarbons and oil mist likely generated from agitated drilling fluids.

Controlling Exposure

The Occupational Health & Safety Regulation requires that employers select controls for contaminants (including hydrocarbons and oil mist) based on the following hierarchy:

- Substitution – replace more harmful drilling fluids with less hazardous substitutes
- Engineering Controls
- Administrative Controls
- Personal Protective Equipment.

Due to the nature of the work and potential worker exposures on Drill Rigs, a combination of these controls should be utilized.

Substitution Considerations

Substitution is the first issue to be considered when developing an Exposure Control Plan (ECP) for workers. Some drilling fluids are inherently less hazardous to workers than others (e.g., synthetics that contain fewer or no aromatic compounds such as benzene).

The use of synthetics may reduce exposure to certain hydrocarbons (e.g., oil mist), however, all fluids including synthetics may still release other hydrocarbons especially when agitated and heated.

The following should also be considered as part of an ECP for drilling fluids:

- Do not use diesel-based drilling fluids (these can cause fires and explosions as well as worker health issues).
- Oil in oil-based fluids should be “severely” refined (to remove aromatic hydrocarbons).
- Additives to drilling fluids may also affect worker health (and may have their own Regulatory exposure limits).
- All fluids may become contaminated while in the drill hole.

Engineering Control Considerations

Engineering controls are mechanical solutions that can move contaminants away from a worker or isolate the worker from contaminants. To the best of our knowledge, the following are controls that already exist or are in various stages of development with Industry for control of worker exposure to drilling fluids:

- Exhaust ventilation (e.g., canopies) for Shakers and other equipment which can agitate drilling fluid. Ventilation systems should be equipped with condensers to remove the contaminants from the exhausted air. More ventilation may be required in "enclosed" areas (e.g., on partially covered or completely enclosed rigs).
- Enclosed Mud Tanks that use remote sensors for inspection.
- Automatic mud sampling devices.
- Remote handling for solid and liquid "additives" (e.g., pump liquids into the mixing system; handle solids in bulk form from pre-loaded containers).
- Barriers between travel pathways (decking and stairwells) and Shakers.

Administrative Control Considerations

Administrative controls are work procedures (rather than mechanical controls) that can assist in reducing worker exposure. Based upon our observations on the Oil Rigs, the following controls should be considered:

- Hygiene (wash) facilities should be set up in the Doghouse (workers were observed eating food with dirty hands).
- Diesel and other oils should not be used by workers to wash their hands.
- Workers should only work for short durations in high exposure areas (e.g., around the shakers).
- Workers should not wash parts and equipment with diesel spray/wash guns – they should use covered parts washers.
- Workers should be trained in basic chemical awareness as well as good hygiene.
- Material Safety Data Sheets should be reviewed and updated/corrected for content – many of the MSDS sheets for chemicals in the drilling fluids, that we reviewed, were missing information.

Personal Protective Equipment Considerations

Personal protective equipment (PPE) is the "last line of defense" for worker protection and should only be considered where engineering and administrative controls are not sufficient. However, if these controls are not practicable, workers may need to wear PPE.

Workers on the Drill Rigs are already required to use the following PPE for general protection:

- Eye protection (safety glasses with side shields).
- Safety footwear (chemically resistant).
- Protective clothing (fire & chemical resistant coveralls – e.g., Nomex).
- Skin protection using barrier creams and gloves (e.g., Viton; not leather or fabric).

In addition to the PPE listed above, we would recommend (based on our results) that workers in the vicinity of equipment where drilling fluids are agitated (e.g., near the Shale Shakers) wear respirators and a higher level of eye protection. For example, chemical splash goggles and a half-face respirator equipped with combination organic vapour and HEPA cartridges, or a full-face respirator with combination organic vapour and HEPA cartridges.

Additional Considerations

Absorption through the skin is a concern and long-term exposure may lead to dermatitis. Although workers generally protect their hands (e.g., with barrier creams and gloves), other portions of their bodies may still be exposed to drilling fluids. For example, if coveralls become soaked in drilling mud, the material may remain in contact with the workers' skin for many hours and cause skin irritation.

Workers should be encouraged to frequently launder coveralls to avoid long-term contact with spilled drilling fluids. Consideration should also be given to providing workers with disposable coveralls to wear over their fire-retardant coveralls when working in situations where contact with drilling mud is a certainty (e.g., when tripping pipe). These coveralls can be discarded (as contaminated waste) when the operation is finished.

The results of the WorkSafeBC sampling confirmed previous findings about the chemical hazards arising from drill rig operations. This report highlights the need for vigilance in recognizing and eliminating or controlling potential worker exposures.

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