Protecting Workers During Crude Oil Derailment Response

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Protecting hazardous material (HAZMAT) responders during the response and remediation of crude oil derailments challenges the normal conventions of worker protection and personal protective equipment (PPE). Hazards associated with crude oil derailment response such as chemical exposure, fire, water, and thermal stress require adaptation of worker protection and PPE to address worker safety. Traditional approaches to worker protection, in some cases, do not fully protect the HAZMAT responder with regard to the variety of hazards present at a crude oil derailment site. Those responsible for establishing worker protection and PPE must closely analyze all hazards present and alter process and/or PPE based on the most aggressive and predominant hazard for a specific task. Broad application of respiratory protection may protect only a small portion of workers from chemical exposure while adding additional hazards to other workers who are not at risk of exposure based on proximity or duration of their work task. In many cases, chemical protective suits are used to protect workers from skin contact and heavy soiling to clothes. With chemical suits, there is an increased risk of heat stress, loss of coordination and mobility, and other unintended hazards; therefore, a thorough risk assessment must be completed to determine if chemical suits are appropriate and if adaptations to chemical suits are required to reduce these additional hazards to cleanup workers. Furthermore, at derailment sites where large quantities of crude oil have been spilled, cleanup activities should be altered during hot work or during active fires to limit the presence of nearby workers

conducting oil cleanup operations. It is the responsibility of those directing safety and operations to work closely together and agree upon operational periods and PPE, while adapting where necessary to protect all workers during each day of the response.

INTRODUCTION

The phrase "…like a train wreck" is often used to describe a complete disaster or chaos or maybe a project with challenges too ominous to resolve. Actual train derailments can be intimidating and even overwhelming, but are often resolved in a safe and efficient manner. Railroads, contractors, municipalities, and state agencies experienced in train derailment response have refined their procedures and contingency plans to address the uncommon and often unpredictable environmental conditions that arise from a derailment. No two derailments are alike, and therefore, no two response plans are alike as well. Successful derailment responses are driven by a safety-first culture that seeks to mitigate the risk and manage the outcome such that community, worker, and environmental health is the driving force behind operational planning.

No single document can provide solutions for all train derailment scenarios, but thanks to the diligence and continuity among researchers and responders a wealth of information is available to provide responders with adequate information in most cases to handle the majority of response scenarios, especially those involving hazardous materials. Resources such as the Emergency Response Guidebook (ERG), Computer-Aided Management of Emergency Operations (CAMEO), American Association of Railroads (AAR), the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), Protective Action Criteria (PACs) to name a few are used often to provide responders with hazard assessment tools, protective distances and emergency response procedures, and chemical exposure limits (both public and occupational) that provide workers with the information necessary to work in an derailment environment under reasonably safe conditions.

This document addresses worker safety for crude oil derailments. The content discussed herein is based on actual boots-on-the-ground experience and observations. This document is not intended to replace any or all of the available resources, but attempts to address the most abundant safety and health concerns associated with a crude oil derailment response.

1.1 Crude Oil Derailments vs Marine Oil Discharge

In the past 10 years, the amount of crude oil shipped by rail has increased and with notable events such as the Lac-Mégantic, Canada derailment[1], health and safety issues that arise from such incidents are the subject of much concern. Information regarding worker health and safety for crude oil train derailment response is less developed than that of marine oil spills due to the lower number of train related oil spill incidents that have occurred in the past. Working conditions for train derailments are quite different than that of a marine-based oil spill. When seeking to better understand worker health and safety for crude oil train derailments it is important to analyze some major differences. The following observations highlight differences in working conditions and inherent differences in risk.

- *Spill sites may be more localized.* Inland derailments are influenced by topography and land features that affect the footprint of the oil spill and how oil may be concentrated in certain locations. In contrast, marine oils spills (disregarding confined spaces or containment vessels) seem to have common oil spill characteristics due to the uniformity

[1] The Lac Mégantic train derailment occurred in the center of Lac Mégantic, Quebec in the early morning hours of July 6, 2013. Almost all of the 63 derailed tank cars were damaged, and many had large breaches. About six million litres of petroleum crude oil was quickly released. The fire began almost immediately, and the ensuing blaze and explosions left 47 people dead. Another 2000 people were forced from their homes, and much of the downtown core was destroyed [1].

of the spill surface such as open ocean and rivers. Inhalation exposure risk is often affected by the nature of the oil spill footprint. For example, Bakken crude oil (BKN)[2] is known for its high American Petroleum Institute (API)gravity, which often generates more volatile hydrocarbons. When concentrated by land features such as in ponds, creeks, and diversion estuaries worker exposure is often greater than when spilled onto a large flat surface such as a continuous water body which allows for more surface area exposure which results in rapid weathering.

- *Simultaneous Operations (SIMOPS).* Worker health and safety can be influenced by hazards not limited to a specific task or operation, but also by hazards associated with nearby simultaneous operations or SIMOPS. It is often the case that wrecking operations and oil spill cleanup activity occurs in close proximity to each other. Traditional Oil Spill Removal Organizations (OSROs) may have little or no experience with train derailment operations and vice versa. Crude oil derailments often occur over land with a significant portion of the impact occurring to soil. Excavation activities generate a variety of conditions where worker exposure can be increased based on the liberation of hydrocarbon vapor from relatively undisturbed oil that lies in the soil of impacted areas.
- *Spill sites may be more congested.* For train derailments involving aggressive topography or unique land features, the work area can become congested due to the lack of available real estate and access to impacted areas. Heavy construction activity is often required to prepare the work area for safe train wrecking operations and clean up stations. For example, the frac tank staging area may be located near the spill site, influencing the

[2] Bakken crude is a light sweet crude oil with an API gravity generally between 40° and 43° and a sulfur content <0.2 wt.%. Common hydrocarbon constituents include lighter hydrocarbons such as butane and propane with trace quantities of ethyl benzene, toluene, xylene, n-hexane, and naphthalene [2].

health and safety for those responsible for off-loading recovered oil due to the close proximity to the derailment site.

1.2 Need for Task-Based Risk Assessment

Train derailment response, recovery, and remediation sites are complex working environments that include a variety of worker tasks conducted simultaneously and remain ever changing during the response. Operational change can occur rapidly with little or no advance planning allowed when circumstances require. The combination of a dynamic project scope, close proximity simultaneous operations, and within-operation task diversity will challenge the effectiveness of broad, area-based safety procedures and control measures. To truly assess the risk for workers in this environment, a task-based risk assessment is recommended to avoid underestimation of site hazards and their influence on each worker.

Train wrecking, excavation, and oil spill cleanup operations often result in higher worker population densities in smaller, sometimes egress-restricted work areas. These congested situations require that importance be placed on hazard communication of each operation to all potentially affected personnel and how those hazards may impact workers not assigned to, but adjacent to a specific operation. Operations planning and field supervisory personnel must remain aware of each operation's hazards and how those operations may adversely affect working conditions of adjacent work sites if workers are unaware and therefore unprotected. For example, these issues can occur when oil spill workers are skimming oil in a collection point near train derailment operations where fire hazards are a significant threat to not only the train wrecking personnel, but all workers in the fire hazard zone should ignition occur. On the other hand, workers involved in the train wrecking operations may not be at risk of inhalation hazards from crude oil based solely on their task but may be at greater risk of inhalation exposure due to their proximity to oil spill cleanup operations and the lack of available controls.

1.3 Hazard Ranking - What takes precedence?

Crude oil derailments present a variety of hazards ranging from severe hazards such as fire and flash or heavy equipment to more manageable hazards such as contact dermatitis from skin exposure to crude oil. As discussed in Section 1.2, adjacent SIMOPs may be prepared for less hazardous conditions while adjacent operations include hazards with a higher severity outcome. This dichotomy requires that a thorough operation-specific hazard assessment be performed for each operation, task, and operational period. Furthermore, adjacent SIMOPS should also be assessed not only for the hazards associated with their respective tasks but also those hazards that may be associated with adjacent activity.

The variety of hazards can confound safety professionals seeking to prescribe control measures that holistically address all hazards. To remedy this, a thorough task and operation-based hazard assessment must be conducted so that a hierarchy of risk can be established. Hazards with the highest severity, probability, and exposure must be given precedence. To do this, site safety and operations personnel must work together during planning to identify a comprehensive list of hazards and then rank those hazards so that the most significant threats receive the greatest amount of attention and controls.

An example of this is dermal protection in the presence of fire and flash hazards. Until recently, common oil spill chemical protective clothing fabrics were designed to prevent dermal exposure and reduce contamination to clothing, but were not designed to provide flash or fire protection. For workers at risk of dermal exposure to crude oil, but also at risk of flash fire injury a dilemma arises when deciding if impervious clothing should be worn. A fabric that is not resistant to heat can compromise the worker's fire retardant clothing (FRC) if a flash fire occurs. There are now fabrics designed to prevent dermal exposure to oil, but are also designed to complement the worker's primary FRC clothing, which is often required when dealing with a higher flammability crude oil such as Bakken. Operations and safety personnel must select PPE configurations based on exposure hazards from adjacent operations i.e., if the excavation of impacted soil generates vapor that may impact train-wrecking operations, does the wrecking manager know this so he can prepare to equip workers with respirators if needed? Alternatively, should one operation be conducted at a time based on safety issues associated with train wreckers wearing respirators?

CHEMICAL AND PHYSICAL PROPERTIES OF CRUDE OILS

The United States Environmental Protection Agency (EPA) has established four categories of crude oil types, not based on their geographical source, but relative to their chemical and physical properties as it pertains to oil spill remediation techniques and worker health. Briefly, the EPA ranks crude oils into four classifications (A-D) with Class A oils being the lightest, most mobile, least persistent in the environment, and most toxic to humans and the environment. Class D oils are non-fluid except at high temperatures, relatively non-toxic, and very persistent in the environment. These categories are described in detail on the EPA website (https://www.epa.gov/emergency-response/types-crude-oil).

The EPA has defined these categories as dynamic. Weather conditions and the ambient temperature greatly influence the behavior of oil and refined petroleum products in the environment. The classification may change daily and over the course of the response. For example, a Class C oil spilled at night may change into a Class B during daylight hours when sunlight warms the oil and causes the lighter hydrocarbons to volatilize more rapidly thus meeting the criteria of a Class B oil. Further, a Class C oil during the day time may behave like a Class D oil as temperatures drop and the oil becomes thicker.

It is important to understand the type of crude oil when assessing the risk of exposure. It is of equal importance to monitor the status of the oil as environmental conditions change. The precautions used to protect workers from inhalation or dermal exposures may require adaptations to address the influence of changing environmental conditions.

It is also notable that fresh crude oils may present a significant flammability hazard. Crude oil vapors are denser than air, and some crude oils, particularly lighter crudes, have sufficiently high flashpoints and low vapor pressures to present a significant flammability hazard at some distance away from the spilled oil. This is typically more of hazard when oil is spilled on land or in a confined location compared to open water spills where oil rapidly spreads and vapors rapidly disperse. Air monitoring for flammability is recommended at all oil spills to address this issue.

CHEMICAL EXPOSURE FROM CRUDE OIL

Chemical hazards from crude oil derailments are very similar to those encountered in water-based oil spill situations and a detailed description of each is beyond the scope of this paper; however, these hazards will be briefly discussed below. The most common pathways of chemical exposure occur via inhalation, dermal contact, and ingestion. Inhalation and dermal exposure are the most prevalent exposure pathways related to crude oil response work activity, particularly involving train derailments. Inhalation exposure risk may range from significant to non-existent, based largely on the chemical properties of the crude oil (e.g. hydrocarbon composition, flash point and vapor pressure). The volatile fraction of crude oil is the determinant of inhalation toxicity, with the exception of the production of oil mists. Under typical environmental conditions, when oil is exposed to weathering conditions such as elevated temperatures, wind, and solar energy, the majority of the volatile fraction of crude oil evaporates within 24-48 hours, and the remaining chemical hazards are primarily limited to dermal exposure and incidental ingestion. Whereas volatile constituents are typically quickly weathered from crude oil, especially in on-water oil slicks, in derailment situations, a safety professional must be aware of how the nature of confinement of spilled oil influences inhalation exposure risk and how this may vary significantly based on the task and situation. For example, a worker opening a frac tank containing recovered product may be at greater risk of hydrocarbon and hydrogen sulfide exposure than a worker assigned to maintain oil boom in an open environment.

Inhalation chemical hazards from crude oil spill can be divided into the following basic categories: 1) volatile organic compounds (VOCs); 2) hydrogen sulfide; and 3) combustion byproducts. VOCs represent the majority of compounds that will volatilize from a crude oil spill. VOCs released from crude oil include aromatic hydrocarbons such as benzene, toluene, ethylbenzene and xylenes (i.e. BTEX compounds) as well as alkane hydrocarbons containing three to ten carbons (C_3 - C_{10}) or less. Acutely, exposures to high concentrations (i.e. thousands of parts-per-million or ppm) of hydrocarbon VOCs can have general narcotic effects. These situations rarely occur in open-air spills, but can occur in confined spaces such as the headspaces of frac tanks. At lower concentrations, short-term exposures can cause transient irritant and annoyance effects such as eye irritation, nausea, and headaches. It is also important to note that chronic exposure to elevated benzene concentrations has been demonstrated to cause cancer in humans, and thus, benzene carries an OSHA substance-specific standard mandating a number or requirements for air monitoring, biological monitoring and worker protection. Airborne benzene concentrations are often the driver regarding respiratory protection and respirator use following oil spills. Details on the benzene standard (29 CFR part 1910.1028) are available on OSHA's website (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10042&p_table=standards).

Aside from flammability concerns, acute hydrogen sulfide (H_2S) exposure poses the greatest acute chemical hazard related to oil spills. It is notable that most light crudes, such as Bakken crude contain little H_2S, however, it is recommended to rule out this possibility with air monitoring at all crude oil releases. H_2S is well known for its "rotten egg" like odor, even at very low concentrations of a part per billion or less, which is many fold below applicable occupational exposure limits (OELs). The safety professional must also be aware of the fact that H_2S causes paralysis of the olfactory nerve (olfactory fatigue) at exposure concentrations greater than 100 ppm, and may not be smelled after the first inhalation at high exposure concentrations. Thus, H_2S has poor warning properties at high concentrations despite having a strong odor at low concentrations. Exposures to H_2S in the hundreds of ppm can result in rapid loss of consciousness, and higher acute exposures can result in death due to respiratory failure. H_2S concentrations typically do not reach acutely harmful levels in open-air oil spills, but harmful concentrations may accumulate in spaces with poor or no ventilation. It is also notable that H_2S is a flammable gas that is denser than air and will seek low-lying areas where concentrations can build up to flammable levels.

Combustion byproducts represent the final major category of chemical inhalation hazards related to crude oil derailments. The initial phase of a crude oil derailment may involve large fires which release intense heat and copious amounts of smoke as the oil is consumed. *In situ* burning of spilled crude oil is also a remediation strategy in some circumstances. Combustion products released from the burning crude oil include carbonaceous particulate matter, irritant gases such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) as well as asphyxiant gases such as carbon dioxide (CO_2) and carbon monoxide (CO).

Dermal exposure to crude oil constituents can result in skin irritation and dermatitis if the crude oil is not promptly removed from the skin. The timeframe over which this occurs depends on the nature of the crude oil, the presence or absence of sunlight, and the sensitivity of the individual, among other factors. Dermatitis-associated irritation is typically mild and transient in nature. It is unclear whether the aliphatic or polyaromatic hydrocarbon components of crude oil are responsible for producing the dermatitis. There is some evidence that simultaneous exposure to sunlight may exacerbate dermatitis produced by crude oil. Dermatitis in context of crude oil clean-up operations can be avoided through the proper use of PPE that prevents skin contact with crude oil.

Incidental ingestion of crude oil constituents is typically limited to incidental exposure via poor hygiene and workplace cleanliness. Ingestion of crude oil is more likely to occur as a result of workers eating, drinking, and smoking with contaminated gloves or unclean hands. Although ingestion exposure is likely negligible, any exposure that can be prevented with simple controls should be reduced. Administrative controls are often used to train workers regarding ingestion pathways and sources, as workplace hygiene provisions such as hand washing stations, effective decontamination practices, and through signage that reminds workers to avoid hand-to-mouth behaviors with contaminated gloves or unclean hands.

In conclusion, it is imperative for operations and safety planners to understand each task in detail and accept the philosophy that exposure risk can only be controlled when respect is given to the variance in exposure potential on a per-task basis. To do this, site planners and supervisors must also be familiar with the chemical exposure characteristics of the specific type of crude oil transported. Like all chemical mitigation or cleanup operations, the nature of the contaminant will dictate the level of risk that must be assessed. Understanding the exposure pathways for any chemical of interest is a good first step in prescribing effective and reasonable controls to limit exposure.

PPE COMMONLY RECOMMENDED FOR OIL SPILL CLEANUP

During the 2010 Deepwater Horizon oil spill response, the National Institute for Occupational Safety and Health (NIOSH) and the OSHA each provided PPE recommendations for oil spill cleanup workers during the 2010 Gulf Oil Spill. The NIOSH *Interim Guidance for Protecting Deepwater Horizon Response Workers and Volunteers* publication was treated as a living document capable of improving PPE selection for workers as information on exposures and injury/illness reports became available. OSHA partnered with the National Institute of Environmental Health Sciences and the U.S. Department of Health and Human Services to produce the *Safety and Health Awareness for Oil Spill Cleanup Workers – Worker Education & Training Program*[3] which was designed to provide Gulf Oil Spill clean-up workers with safety and health as well as PPE guidance. From this, OSHA published the *General Personal Protective Equipment Sampling Matrix*[4], which outlines the recommended PPE by task for oil spill cleanup.

Both organizations established PPE guidance based on in-field risk assessments, which included historic knowledge of PPE required for oil spill cleanup as well as a daily review of exposure, and injury/illness reports during clean up activity. The resultant recommendations provide thorough and well-researched PPE recommendations to protect workers from the hazards associated with oil spill cleanup in a variety of workplace settings relative to the coastal regions of the Gulf of Mexico. PPE selection considerations for railroad cleanup workers are discussed in Section 5 below.

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[3] Available at: https://www.osha.gov/Publications/Oil_Spill_Booklet_05.11_v4.pdf
[4] Available at: https://www.osha.gov/oilspills/oil_ppematrix.html

DERAILMENT HAZARDS THAT CHALLENGE CONVENTIONAL PPE USAGE

1.4 Heat Stress

The use of PPE has been linked to an increased risk in heat-related illnesses. Protecting workers from chemical inhalation or dermal exposure is difficult when respect is given to heat-related illness. In the *NIOSH Report of Deepwater Horizon Response/BP Illness and Injury Data (April 23 – July 27, 2010)*, 192 cases of heat illness were reported with 21 resulting in OSHA recordable injury. NIOSH discovered that for every 1 chemical-related first aid case (including both respiratory and dermal exposure) there were 64 cases of heat illness reported. In warm or hot environments, respiratory protection and chemical protective clothing are proven to increase the risk of heat stress in workers. Therefore, when chemical hazards are present, the risk imposed by chemical hazards must be equal to or greater than the risk posed by heat stress. The increase in thermal burden on workers must be evaluated when consideration is given to using respiratory protection and/or chemical protective clothing.

1.5 Fire

Undoubtedly, the risk of employee exposure to thermal burns through flash fire, combustion of clothing, or ignition of fuel soaked clothing is risk at the highest level of severity. Derailment sites involving crude oil may include active fires or the risk of fire based on the flammability of liquid crude oil or its vapor. FRC is required by all response personnel working in close proximity to the wreck site as well as near spilled crude oil. Since the majority of chemical protective fabrics are not flame resistant, workers are at risk of injury from burns as a result of melted or ignited Chemical Protective Clothing (CPC) when worn over FRC. If fire hazards are present, the use of CPC must be reviewed and the use may be limited or disregarded based on the most significant hazard. Short-term exposure to crude oil is likely to result in skin irritation, whereas exposure to flame or fire can result in serious bodily injury or death.

Prevention of worker exposure to fire hazards should be of the highest priority, even when the probability of occurrence is remote. The consequence of worker injury from fire or flash is often severe, leaving little room for flexibility when determining risk if based primarily on probability and exposure. The practice of elimination or substitution to control hazards is optimum but unfeasible for train derailments involving flammable liquids and combustible gases. Elimination and substitution are the first and second most desirable methods of hazard control listed in the CDC/NIOSH Hierarchy of Controls [5]. Elimination is simply the act of eliminating the hazard by removing the hazardous component, while substitution involves replacing the hazardous component with a material of equal utility that is less hazardous. Therefore, the options to control hazards are limited to engineering and administrative controls, and PPE.

A strong first step in preventing exposure to fire hazard is simply reducing the number of non-essential personnel where fire risk is present. Only trained workers essential to the operation and equipped with proper PPE should be permitted in the vicinity of operations where fire is present. Simply limiting the number of personnel reduces risk further decreasing the likelihood of injury. Site control methods such as barricades, authorized entrant status, and security can be helpful in managing non-essential personnel. All site personnel should be made aware of areas where fire hazards are present and the control measures enacted to further reduce exposure even though only a small number of personnel may be required to access higher risk work areas. Communication of fire safety procedures to all personnel will improve site control simply by establishing expectations that reduce the number of workers at risk.

Essential personnel required to enter fire risk zones are often required to don PPE that is designed to protect against chemical exposure from crude oil or other chemicals present. Level C PPE is a commonly used by oil spill cleanup and train wrecking technicians. Air purifying respirators, both half face and full-face are routinely used to reduce inhalation exposure to crude oil vapor and H_2S. Semi-impervious fabric suits and polycoat suits with gloves and boots are worn to reduce dermal exposure and contamination to clothing but provide little to no protection from fire or flash. The term “shrink-wrapped” is often used to describe the behavior of a non-fire resistant chemical suit when exposed to flash, flame, or extreme heat. On the contrary, common fire retardant materials such as FRC coveralls or fire-fighting bunker gear protect against fire and flash, but provide little protection from dermal exposure to hydrocarbon liquids. A common dilemma for safety professionals involves selecting the appropriate chemical suit, which prevents dermal exposure to crude oil, but also provides protection from fire, flash, or high temperatures.

Leading chemical suit manufacturers have developed fabrics that protect against hydrocarbon liquids, solvents, oxidizers and corrosives and are also in compliance with the National Fire Protection Association (NFPA) codes 1992, 2112, & 70E for fire and flash rating. These suits provide dual protection from dermal exposure to certain liquids while protecting the wearer from fire, flash and thermal burns. Unfortunately, these suits are difficult to implement as site-wide alternatives due to their cost and limited quantity. Recent advances in suit technologies have yielded fabrics that are designed to protect and preserve primary flame resistant garments, such as FRC coveralls. These suits can be used to prevent excessive soiling of the FRC, but are not proven to be impervious to hydrocarbon liquids. DuPont’s ProShield ® 6 SFR garment does just that but warns the user of the suits limitations with regard to low viscosity liquids. Wearers should avoid using these suits if they are at risk of direct contact with liquids where exposure occurs to liquids dripping or running, or is wet to the touch.

1.6 Train Wrecking Hazards

1.6.1 Hazards for Derailment Workers

Train wrecking personnel are tasked with stabilizing and removal of wreckage, removal of debris, and construction activity for access and safe removal of damaged train cars and equipment. Train wrecking technicians are typically working as heavy machinery operators or as ground crewmen responsible for assisting the machine operators in handling the wreckage and debris. Train wrecking machine operators work in close proximity to spilled crude oil or crude oil fires, increasing the risk of exposure to crude oil vapor and liquids, along with fire or smoke particulates. Ground crews are susceptible to trip/fall hazards, cuts and abrasions, thermal hazards, chemical exposure (respiratory and dermal), and mechanical crushing by equipment and rigging materials.

1.6.2 PPE Considerations for Train Wreckers

Derailment service companies work with heavy machinery in close proximity to one another often working simultaneously. The equipment is elevated above the ground and has a variety of line-of-sight obstructions. Further, with low-light conditions, the machine operator must have unobstructed views to safely operate his machine. Full-faced respiratory protection (and/or half-mask respirators with protective goggles) often limits operator visibility due to poor lighting or temperature changes causing the mask or goggles to fog. FRC is required for equipment operators and ground-men due to the abundance of ignition sources that exist among a wrecking operation. This creates a dilemma when using chemical suits, boots and gloves to protect workers against dermal exposure to crude oil. Train wreckage often has many cut/scratch/abrasion hazards. If CPC is worn in the train wrecking area, the suits will likely become compromised after a short period of use due to cuts or scrapes to the material or from excessive bending, stooping, and stretching.

1.6.3 Train Wrecking During Clean-up

Crude oil derailment sites include both train wrecking and oil spill cleanup operations each having their own unique set of hazards. When combined, the work area can become complex increasing the likelihood of underestimating or misidentification of hazards and therefore increasing risk of accident or injury.

If the spill area is located adjacent to the track and therefore in close proximity to wrecking operations, special consideration must be given to whether oil spill and train wrecking operations should occur simultaneously. It is possible for sparks or small fires to occur during the removal or repositioning of compromised crude oil tank cars with residual product. Further, if crude oil has impacted the rail track ballast in moderate quantities, ignition can occur from sparks generated by moving cars or through the use of cutting torches or shears to free entangled wreckage. It is reasonable to assume that a flash fire from wrecking operations could ignite crude oil in the spill area where workers are actively cleaning up spilled oil. Cleanup workers may be waist deep in oily water performing skimming and/or booming operations. Workers may also be performing these tasks from small vessels. An accidental fire could create a highly hazardous environment for all workers and may have serious consequences for the oil spill workers unable to egress from oiled areas.

If the spill areas contain moderate to significant quantities of oil, nearby train wrecking operators may be exposed to elevated concentrations of airborne contaminants such as benzene. In this case, respiratory protection may be required to prevent overexposure. The use of respiratory protection may inhibit the visual acuity of train wrecking operators making critical movements more hazardous for all workers in the area. To ensure that train-wrecking operations occur without increased risk of physical hazards from poor visibility, it may be necessary to remove the oil prior to commencing critical wrecking operations so that the need for respiratory protection is reduced if not eliminated.

RECOMMENDATIONS FOR WORKER PROTECTION ON CRUDE OIL DERAILMENTS

1.7 Begins with Risk Assessment

Risk assessment is a powerful aspect of safety planning but is often under-utilized in emergencies. Safety plans and Job Safety Analyses JSAs include aspects of risk assessment, such as hazard identification and controls, but often lack the specificity of a true task-based risk assessment.

1.7.1 Defining the Workplace and Tasks to be Evaluated

When defining the workplace hazards, response managers should attempt to segregate work areas based on the variety of tasks taking place along with the hazards associated with each task. In order to properly characterize the work area, efforts must be made to identify the various tasks underway in each work area. A thorough review of the operations being conducted should result in the identification of the tasks that may take place in each defined work area. The following items provide guidance on task identification:

1. Identify/characterize the task accurately and completely. Avoid generalizing the tasks and address upcoming changes in work tasks as operations progress.
2. Differentiate tasks based on standard versus non-standard tasks. It is important to determine which work tasks will be taking place regularly versus those tasks that will only happen for a short period of time and/or are infrequent in nature.
3. Summarize the type of operation with respect to the duration and location of the task.
4. Determine which tasks require chemical protective clothing.

5. Evaluate which tasks, if chemical protective equipment is worn, will create additional hazards and how those hazards will be addressed.

1.7.2 Identifying Chemical and Physical Hazards in the Work Area

The goal in hazard analysis is to discover what can go wrong, what are the consequences, and can contributing factors be identified to determine the likely hood of hazards creating negative consequences. Good hazards analyses describe where the task will occur, what are the present hazards and what may trigger an exposure followed by the consequence of exposure to identified hazards.

To properly assess the hazards present, the work area must be defined based on the list of potential chemical and physical hazards present. In some cases, chemical hazards may be the greatest threat, however, in most cases involving petroleum products the physical hazards can be greater based on the probability and severity of physical hazards when compared to that of chemical hazards.

Identify the specific chemical hazards involved in each task. This may not be limited to chemical hazards from the primary spilled species. Additional chemical hazards such as carbon monoxide, hydrogen sulfide, and smoke particulates may also be present and should be evaluated. Once the chemical hazards are identified, determine if a worker will perform various tasks in multiple work areas. The chemical hazards for each task in each area may change and this must be communicated to the worker so that adjustments to PPE are made to address newly emerging chemical hazards or to reduce chemical protective clothing in the event that certain chemical hazards are no longer present.

Understanding the physical and chemical properties of the chemicals of concern is essential when conducting a hazard assessment. The exact chemical composition for the crude oil in question is rarely available to site safety personnel. In fact, most crude oil composition is obtained by referencing generic Safety Data Sheets (SDSs) or antiquated Material Safety Data Sheets (MSDSs) of a similar crude oil type. Generic information can be problematic when classifying the crude oil in question regarding flammability and toxicity. Where feasible, product samples should be collected and expeditiously analyzed to provide the most accurate information when seeking to understand the hazards posed by crude oil. The chemical's physical state (whether liquid, solid, or gas) should be identified as well as any potential for the chemical hazard to change its state of matter based on environmental conditions or the influence of environment changing operations such as hot work or confined space. Recognizing the chemical's mobility (i.e. vapor pressure, boiling point, specific gravity, and solubility) as well as its flammability characteristics (i.e. flash point, auto ignition temperature, and flammable limits) will allow for proper hazard classification and will aid in selecting control measures based on the behavior of the material in the work environment. Since crude oil is a complex mixture, all chemical compounds should be addressed by order of importance based on flammability, toxicity, volume, and concentration.

The chemical contact period is also an important consideration in assessing the risk posed to workers potentially exposed. For inhalation hazards, understanding the duration of expected exposure will improve respiratory protection selection, especially when air purifying respirators are used. Chemical protective clothing fabrics are tested against the chemical of interest with a known concentration for various periods of time. Workers wearing chemical protective layers often assume that the presence of a protective barrier gives them the unlimited protection which may prove dangerous if the proper fabric is not selected. It is also important to determine if the exposure will be continuous emersion, direct contact with liquids, or intermittent splash, thus qualifying the fabric for use based on its documented permeation rate.

1.7.3 Non-chemical hazards

In addition to chemical hazards, there are a multitude of other hazards that often outweigh the potential chemical hazards. First and foremost, among these hazards is flammability. Assuming that any initial fires associated with the derailment have been extinguished, there may still be a very active fire hazard associated with the remaining product. The flammability hazard is depended on many variables, with the most prominent being the type of crude oil, and the degree of weathering (i.e. volatile fraction loss). Extreme caution and attention should be given to the topic of flammability, and all potential spark-producing activities such as rail car movement, cutting of rail, etc.… should be scrutinized and follow appropriate hot work procedures. Other physical hazards in addition to flammability include, but are not limited to, those listed below:

- Physical hazards (flying debris, slippery or uneven terrain, cuts/abrasions, fire/thermal etc.)
- Mechanical hazards (crushing, blunt force trauma, binding, heavy machinery, etc.)
- Environmental hazards (heat stress, cold stress, noise, lighting, wind etc.)
- Biological hazards (poison ivy, animals, mold, bacteria, insect bites)
- Thermal hazards (fire, contact with hot surfaces, radiant heat, sunburn)
- Electrical hazards

1.7.4 Estimate the Likelihood of Exposure

To determine the likelihood of exposure, it is recommended that a numerical scale be used to differentiate the potential of exposure based on variation in potential. Each work tasks will have variation in hazard exposure potential. To properly analyze the risk of hazards for each work area and task, the potential for exposure must be scalar and have variation in protective measures to ensure that adequate prevention is considered.

Rating	Likelihood of Exposure
0	Exposure cannot occur
1	Exposure very unlikely
2	Exposure possible, but unlikely
3	Exposure likely
4	Multiple exposures likely
5	Continuous exposure likely

Source: Chemical Protective Clothing, 2003 [3]

1.7.5 Determine the Possible Consequences of Exposure to Identified Hazards

In order to determine the rank order of worker protection measures, each hazard must be evaluated based on the consequence of exposure. For example, if fire hazards are present and the exposure risk (probability x severity x exposure) is high, one can determine that the consequence may in fact be more severe that dermal exposure to crude oil. Although protection should be provided for all hazards where feasible, there are some instances where certain worker protection measures must be reduced to accommodate the predominant risk based on exposure consequence.

This requires a thorough review of all hazards present as well as in-depth knowledge of the exposure potential and consequence. To determine which exposures may be acceptable in lieu of higher hazards, those responsible for determining the protective measures used may need to consult subject matter experts to obtain the information needed.

1.7.6 Evaluate the Unintended Consequences of PPE use (heat stress, visibility, overwater, limited mobility)

It is important to evaluate the hazards to determine if protecting workers against one hazard may create unintended, and more severe, consequences of additional hazards associated with the task. The following impediments may result from PPE usage:

- CPC increases the risk for heat stress.
- CPC and footwear may decrease mobility and safe traverse through obstructions. This becomes acutely hazardous when working near or over water and inside of confined spaces.
- Chemical protective gloves may reduce fine motor skill creating additional hazards based on the worker's task(s).
- Respiratory protection (specifically purifying respirators) increases demand on the respiration rate of the user. This may decrease oxygen supply and increase the risk of anoxia and cardiovascular function.
- Full-faced respiratory protection, goggles, and splash shields may reduce visibility or depth perception making traverse or fine motor skill problematic. This becomes acutely hazardous when working near or over water and inside confined spaces.
- The use of PPE, in general, can create a false sense of security for the wearer. In some cases, workers have submerged their whole body or extremities in liquid materials without regard to the protection capability of the fabric with respect to the permeation rate of a liquid compared to that of vapor.

1.8 Engineering Controls First

With respect to the Hierarchy of Controls and when the hazards cannot be eliminated or substituted, engineering controls should be considered first.

1.8.1 Ventilation (natural or mechanical)

For crude oil derailment sites, many traditional forms of engineering controls may not be feasible nor readily available. Dilution ventilation, however, does exist in portable capacities and may be useful in remote locations for small-scale work areas. COPPUS® fans are portable pneumatic fans that supply dilution ventilation to a small area of interest with relative ease. For workers in areas where contamination is present, but natural ventilation is reduced, copus fans may provide adequate dilution to reduce the potential for overexposure.

Natural ventilation is not considered an engineering control; however, it may be used when the wind direction and wind speed are sufficient to dilute or remove airborne contaminants. Where feasible, obstructions should be moved or repositioned to encourage the presence of natural ventilation through the work area. Sufficient natural ventilation can significantly reduce airborne contaminants, but attention should be placed on the potential for wind direction and speed to change therefore reducing its effect on airborne contaminants in the work area.

1.8.2 Long Handled Tools

Long-handled tools are an effective means of reducing the potential for splash hazards or immersion of extremities in liquid materials. For example, workers using sorbent boom, pads, or pom poms to remove crude oil from the soil or vegetation should avoid handling these materials directly by using long handled rakes or forks. Long-handled tools also improve worker posture (when used properly) thus avoiding ergonomic hazards associated with the limbs, shoulders, and lower back.

1.8.3 Machines vs. Manpower (i.e. do workers need to lug these soiled bags to trash can?)

Heavy machinery is present on most crude oil derailment sites. Although manual labor is required for oil-cleanup activities, heavy machinery can be used to minimize repetitive handling and transport of soiled materials. Once collected, soiled sorbent materials should be staged in a location where a backhoe or excavator could be used to migrate such materials into disposal bins. In many cases, workers are provided with CPC based on the potential for indirect soiling to occur from excessive handling of soiled materials.

Manual removal of impacted soil and vegetation should be used only when heavy machinery is unavailable or access is not feasible. When workers are required to shovel impacted materials the potential for splash hazards or gross contamination to the lower body increases significantly.

Additional types of engineering controls such as berms, levees, K-rail, or covers such as tarps and plastic may also be used to prevent splash hazards and contaminant migration further reducing the need for CPC.

1.9 Administrative Controls

1.9.1 Worker Rotations

Worker rotations are a reasonable means of decreasing the potential for overexposure based on the reduction of time exposed therefore, reducing the dose. For tasks where workers are required to be in close proximity to crude oil, where feasible, work rotations can be used to avoid excessive dermal or inhalation exposure to crude oil and crude oil vapor. Worker rotations are also beneficial when CPC is required in hot environments. Worker rotations reduce the time spent in CPC therefore reducing the thermal burden placed on the worker. NIOSH has published Recommended Exposure Limits (RELs) for heat stress, which provide work/rest rotation guidelines [4]. These guidelines may be helpful when determining the maximum allotted time for workers using chemical protective PPE.

For work rotations to be effective, all workers available for rotation must be equally trained and fit for duty using chemical protective PPE.

CONCLUSIONS

Crude oil derailments present a unique set of hazards and considerations for the safety professional compared to on-water oil spills. The often-present fires combined with the restricted work areas and physical hazards associated with train wrecking and remediation activities produce hazards not often observed in other oil spill situations. Safety and health professionals in these settings need to be hyper-vigilant to the complex and changing work environment and the tasks being conducted. Hazard assessment is critical, as not all solutions are as straight forward as they appear. Through following sound principals of risk assessment and hazard control, the response to crude oil train derailments can be managed in a safe and effective manner.

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