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1 Introduction

The upstream oil and gas industry is committed to the health and safety of its workers and the public, and to the protection of the environment. Industry undertakes a number of initiatives to ensure worker and public health and safety.

This document has been developed to provide information and guidance to be considered by the oil and gas industry when using air monitoring equipment during an emergency situation. The information in this guide can also be considered by specialized air monitoring personnel. It provides information regarding air monitoring inside an operators site perimeter as well as outside the site perimeter where data can be used to track and predict plume travel.

Air monitoring conducted during an emergency assists industry and to do the following:

- Determine the presence, concentrations, location, and direction of travel of hazardous substances in the atmosphere and assess the threat level they pose;
- Communicate this information to industry response personnel, the public and others to allow them to take protective and planning measures; and
- Provide documentation of the event.

The intent of air monitoring during emergencies is to enhance safety of workers, specialized air monitoring response personnel, and the public during the event and also to provide a record that can assist in safety improvements after the event. Emergency air monitoring must itself be conducted in a manner that ensures the safety of the personnel who undertake this task and ensure that personal protective and safety equipment appropriate for the task is provided to these personnel. As such, the guidance provided by this document must be applied in a manner consistent with a company’s overall emergency response plan.

2 Document Scope

This document is intended for oil and gas personnel who would respond to a release event. Oil and gas personnel called upon for emergency response may not be formally trained in emergency air monitoring so this guide, to best management practices, is intended to build upon or supplement existing skills, recognizing that training standards in the upstream oil and gas industry are very high. Please note that this document is intended to supplement, not replace company or industry training.

The infrequency of emergencies requiring personnel to conduct air monitoring supports the need for a reference guide to best management practices. The use of one consistent set of air monitoring best management practices for all upstream oil and gas producers should lead to more harmonious response activities, particularly with the increasing prevalence of mutual aid groups and unified command situations.

While this document is not intended for professional third-party air monitoring companies, it can provide some guidance for oil and gas personnel engaging the services of these companies. Considerations relevant to the use of these companies in emergencies are referenced throughout the document.

This document is not intended for local authority emergency response personnel such as Police, Medical, and Fire Fighting services. Information in this document may be used to supplement the local authority safety protocol when assisting response activities to an oil and gas incident.

This guide to best management practices covers general considerations of emergency air monitoring such as the need for a communications process, the different types of air monitoring equipment, and the methodologies for their use.

The appendices cover specific substances that may require emergency air monitoring and include: a description of each substance; specific methodology for emergency air monitoring; and a description of challenges and risks air monitoring personnel may encounter.

- Appendix A: The release event contains hydrogen sulphide (H_2S) and release *is not* ignited, monitoring focuses on H_2S.
- Appendix B: The release event contains H_2S and release *is* ignited, monitoring focuses on sulphur dioxide (SO_2).
- Appendix C: The release event contains carbon dioxide (CO_2), monitoring focuses on CO_2.
- Appendix D: The release event contains sweet gas (non-H_2S), monitoring focuses on total hydrocarbon (THC) and flammability level monitoring. If sweet gas releases are ignited, carbon monoxide (CO) should be considered[1].

- Carbon monoxide monitoring has not been included in the scope of this document as it is most commonly observed in contained spaces rather than in situations where air monitoring is conducted in the area surrounding the release to ensure responder and public safety.

3 Communications

Communications are vital to achieving an effective response to an incident. Oil and gas companies prepare emergency response plans (ERPs) and outline their communication protocol to ensure emergencies are managed effectively.

Information and the flow of data are essential to an emergency response and may present challenges. Communication protocol must be established early in an event in order to support an effective response. Responders should be aware that their supervisor during day-to-day operations may not be their supervisor during an incident. Communication protocol should be established with the person designated in the company ERP as having a command role, commonly referred to as the incident commander, or their designate. It is important not to circumvent this protocol.

Key elements of effective communications include the following:

- Know the company's emergency response plan, particularly the roles and responsibilities of air monitoring personnel;
- Understand the company's communication protocol followed during an emergency;
- Maintain regular and accurate communications throughout the response; and,
- Provide third-party personnel with required information so they can follow the communication protocol.

4 Air Quality Monitoring Objectives

The overall goal of emergency air quality monitoring is to collect concentration data to meet one or more of the following objectives:

- **Responder and worker safety:** Document air quality downwind of the release point to determine safe or unsafe exposure levels for oil and gas workers and responders.
- **Public safety:** Document air quality to determine safe or unsafe exposure levels at public facilities (e.g., schools, community halls, campgrounds), nearby communities and residences, and access roads. This monitoring is critical to managing public safety.
- **Assessment:** Collect data that can be used to assess the potential for air quality impacts on surroundings. The intent is to determine if emission levels could result in adverse human health and environmental effects. Background ambient measurements downwind of the release point, near other sources, and upwind of the release point are required to determine overlapping effects. In some cases, additional background information can be obtained by continuing to monitor after the release has been controlled.
- **Communication of Data:** Provide air monitoring data on a regular basis throughout an emergency to internal response team members as necessary and to involved government agencies and public upon request.

  Air quality measurements to address responder and public safety objectives are needed in real time. Air quality measurements to address responder and public safety are needed during the event and well documented information may be required following the event as part of a post-incident review.

5 Air Quality Parameters

The air quality parameters that should be measured and documented include the following.

- **Concentration data:** Target concentrations monitored depend on the nature of the chemical or condition being evaluated, the focus of concern (i.e. safety, health and the environment), and the sensitivity of the monitor. Safety decisions require devices capable of measuring specific chemicals or chemical mixtures at peak concentrations or concentrations over a range of averaging periods (e.g. 15 minutes) for concentration levels referenced in published standards (i.e. regulatory requirements). Concentration levels reported by specific devices reflect the sensitivity of the device.

- **Location:** The location of the measurement and an understanding of surrounding topography enables the data to be interpreted in the appropriate context. Location data may be obtained and documented using Global Positioning Satellite (GPS) systems (as described in section 6.2.1) or through written descriptions relative to local features or coordinate information.

- **Meteorological conditions:** Wind direction, wind speed, temperature and atmospheric stability determine the transport and the dilution of the released substance. These conditions can be estimated by observation or determined by measurements.

- **Time:** The time the reading was taken and by whom.

- **Equipment**: The make, model, serial number, and calibration history of the instrument used.

Users should be familiar with the air quality parameters noted above and should be knowledgeable about:

- Concentration levels associated with adverse effects due to exposure to chemicals (i.e. safety, health and environmental impacts).
- The ability of individual devices to capture and report these values. Depending on the sensitivity of the monitor, the levels reported may represent nearly instantaneous concentrations (i.e., can be resolved in a few seconds to a few minutes) or longer averaging periods (i.e., resolved over longer periods such as 15-minute, 1-hour, or 14-hour averages). Users should review manufacturer specifications to become familiar with these details.

6 Air Monitoring and Related Equipment

A broad range of monitoring equipment is used to detect the presence of gases, vapours, and particulates and to describe the location and movement of these substances in the atmosphere. These equipment types, which are described in Section 6.1, are available from different manufacturers and apply a range of technologies and methods for detecting, reporting, storing and communicating various parameters and conditions of concern. The types of monitoring instruments available offer varying degrees of ease-of-use, accuracy, precision, sensitivity and responsiveness, ruggedness and reliability, and cost, as well as other options such as data storage, reporting, and geographic positioning capabilities.

The types of air quality instruments used in the oil and gas industry can be categorized by their method of deployment, intended application, and the time and aerial extent over which they are intended to be used. The types of equipment often fall into two groups.

- Equipment typically available and used by oil and gas industry emergency response personnel.
- Equipment available and used by air quality monitoring specialists.

As the intended users of this document are industry and specialized emergency response personnel, these individuals should be knowledgeable, trained, and proficient in the use and deployment of personal equipment such as hand-held portable devices. Industry and specialized emergency response personnel who may be requesting deployment of mobile air monitoring equipment should also have a basic understanding of the data this equipment will provide as part of the overall air monitoring data for event management.

Specialized service firms provide air quality monitoring services and, while their personnel will be familiar with more complex air quality measurement equipment and the related technologies, these firms may not be familiar with company-specific requirements and procedures. Prior to deployment of mobile air monitoring, safety and communication protocols must be established with the incident commander or designate.

Regardless of who is using it, all monitoring equipment must be:

- **Fit for purpose:** The technology, accuracy, precision, sensitivity and responsiveness, ruggedness and reliability, ease of use, and options selected must match the hazards present on-site and in the environment where the device will be used.
- **Calibrated on a regular schedule**: Calibration should be as per manufacturer's specifications and appropriate documentation must be available to verify testing and calibration requirements.
- **Familiar to the user**: Before using any air monitoring equipment, the user should be familiar with the specific equipment's purpose, limitations and operating practices.

6.1 Equipment Types

As previously noted, a broad range of equipment types used in the oil and gas industry apply different technologies and methods for determining the concentrations of gases, vapours and particulates in air and for establishing conditions such as flammability, toxicity, and oxygen depletion.

In addition to air monitoring requirements, other information such as location and weather data may be required during an incident to help manage personal and public safety and to support a post-event assessment. Meteorological data can be estimated by visual observations or can be determined from other sources such as portable or permanent regional meteorological stations. Location data may be referenced from maps or through global positioning satellite systems (GPS).

Brief descriptions of types of equipment are provided below.

6.1.1 Sample Tubes

Sample tubes are glass vials filled with a chemical reagent that reacts to a specific chemical or family of chemicals. A known volume of air is drawn through the tube with a manually operated pump. If the targeted chemical is present, the reagent in the tube changes colour and the length of the colour change typically indicates the measured concentration. These devices are portable and can provide real-time information.

6.1.2 Integrated Sampling Tubes

This method relies on drawing a known volume of air through an adsorption tube. The adsorption tube is analyzed in a laboratory to determine the associated ambient concentrations. The time average concentration depends on the pumping duration and can range from 1 to 24 hours. This method does not provide real-time information.

6.1.3 Electrochemical Sensor Monitors

These are commonly hand-held battery-operated devices that provide audible and visual warnings and alarms at predetermined concentration levels. In some cases, the devices include a data logger to store the measurements. Real-time information is available from this method. Most hand-held personal monitors fall into this category.

6.1.4 Passive or Diffusion Samplers

This method relies on chemical reactions on a reactive surface through a diffusion screen. The sampler is analyzed in a laboratory to determine the associated ambient concentration. The time average concentration is related to the exposure period that can range from a few days to a month. Real-time information is not available from this method.

6.1.5 Integrated Sampling Canisters

This method relies on drawing a volume of air into a container – commonly an evacuated stainless steel canister but also potentially a bag, integrated sampling filter or impactor. The sample is analyzed in a laboratory to determine the associated ambient concentrations. The time average concentration depends on a needle valve setting that controls the flow rate into the canister and can range from a few minutes to several hours. Real-time information is not available from this method.

6.2 Supplemental Equipment

6.2.1 Global Positioning Satellite Systems (GPS)

GPS devices provide location and time information in all weather conditions where there is an unobstructed line of sight to four or more GPS satellites. The locations can be provided in varying units (e.g., UTM, latitude/longitude). Mobile air monitoring systems typically include a GPS receiver and many hand-held GPS devices are available that provide location and time information in all weather conditions.

6.2.2 Meteorological Monitoring Stations

Meteorological stations include an array of sensors for real-time monitoring and recording wind speed, wind direction, and temperature, as well as, relative humidity, barometric pressure, solar radiation, and precipitation. At the minimum, wind speed and wind direction should be observed and recorded during an event. Meteorological data are available by using portable equipment, as well as, from nearby airports, ambient air quality stations, and mobile air monitors or can be obtained and documented in written form from visual observations by trained personnel.

6.2.3 Digital Camera

Digital, infrared, and video cameras can be used to document the monitoring location and conditions; some digital cameras have built-in GPS systems.

6.3 Deployment Strategies

Service firm personnel are familiar with more complex air quality measurement equipment technology and company personnel should similarly be familiar with deployment strategies for equipment they will be using. Brief descriptions of these categories are provided as follows.

6.3.1 Portable Devices

Portable monitors refer to devices, typically available to oil and gas industry personnel, that have been developed for personal monitoring related to workplace health and safety. This includes air monitors, portable weather stations and GPS units.

Air monitors can be specific to a single chemical or may be able to simultaneously measure several chemicals. These devices can be hand-held or worn on the wrist, clothing, belt, or harness of industry personnel and responders. Monitors are used primarily for personal protection and public safety on or near oil and gas operations over specific periods of time such as a few hours or a couple of days. These devices have limited-time use due to battery life, calibration and/or “bump test” requirements. Sample tubes and electrochemical sensor monitors fall into this category. Portable devices may also store monitored data to access at a later date. Note that real-time information must be communicated to the incident commander throughout the event. The use of equipment may be limited by operating conditions (e.g. temperature) and should be used in conditions that meet manufacturer’s specifications.

6.3.2 Mobile Air Monitors

Mobile air monitors refer to manned, vehicle-mounted analyzers and other environmental monitoring and communication equipment that can be rapidly dispatched to monitor air quality and meteorological conditions in the area of a release. Mobile air monitoring is focused on obtaining air quality data associated with the health and safety of the public and the protection of the environment beyond the lease boundaries of oil and gas operations.

Mobile air monitoring units are powered by onboard electrical generators and are capable of sampling, analyzing, displaying, recording, and reporting air quality information over longer time periods than hand-held monitors. As the units are mobile, monitoring equipment can be repositioned continuously in proximity and downwind of a release event. Measured air quality and weather data collected by mobile air monitors include zero and non-zero readings and, thus, can accurately reflect the situation on the ground.

These mobile units must be manned by trained, qualified personnel. During an incident involving a release, information collected from mobile air monitors may be communicated electronically to many stakeholders simultaneously, such as oil & gas industry emergency response personnel, government agencies, and the public in close proximity to the incident site.

6.3.3 Fixed Location Detectors and Monitors

Fixed location detectors and monitors refer to externally powered, permanently mounted or stand-alone devices often located inside oil and gas facility boundaries and near well drilling locations. Detectors simply detect the presence of one or more substances in the air, while monitors differentiate concentration levels of these substances.

These devices are typically located near critical infrastructure such as control rooms and near or surrounding potential release sources such as processing equipment and well locations.

While all detectors and monitors must be calibrated on a regular schedule, these devices can function continuously and over longer periods than hand-held devices.

Values obtained from these devices are transmitted to control systems to warn operators of the presence of a hazard and issue specific warnings. The devices alarm when reported levels exceed threshold limits. This may serve to trigger initial response actions, potentially including the activation of additional mobile air monitoring.

6.3.4 Ambient Air Quality Monitoring Stations

Ambient air quality monitoring stations refer to regional and/or compliance air quality stations that collect air quality data over longer periods of time and on a regional basis. Instrumentation typically includes the measurement of sulphur dioxide, ground level ozone, oxides of nitrogen, total reduced sulphur, carbon monoxide, total hydrocarbons, particulate matter, and meteorology. Incidents which occur at a local level may not have any significant impact on regional quality. Depending on the location of the release, there may be a fixed station near a release site that can provide important concentration data related to the release.

7 Monitoring Practices

An objective of air monitoring is to provide information to support decisions relating to responder and public safety. This section includes practices that are applicable to both air monitoring undertaken by oil and gas industry personnel and by specialty air monitoring firms. Personnel may receive additional air monitoring information from fixed location and ambient air quality monitoring stations through cooperation with government agencies, as noted in Section 6.3. This section includes general considerations for air monitoring. Subsections on safety practices relating to air monitoring personnel are addressed. Additionally, sampling location selection and sampling documentation considerations are provided.

Considerations for air monitoring conducted by oil and gas personnel

- In order to ensure satisfactory operation, hand-held monitors must be calibrated and bump tested on a regular basis according to manufacturer's specifications.[2]
- Due to meteorological variability, it may not be obvious where concentrations due to the release event could be occurring. Methods of establishing concentrations often involve travelling along access roads downwind of the release in a crosswind direction using a continuous movement device.
- Do not take readings by holding the hand-held device out the vehicle's window while the vehicle is in motion; this is an unsafe practice. From a technical standpoint, the vehicle's forward motion may cause "sensor-loading" by pushing too much air past the device and resulting in false readings.
- When monitoring, stop the vehicle in a safe location and shut off engine. If it is possible and safe to do so, take the reading at a location several paces away from the vehicle and toward the direction of the release source. This should serve to minimize sample interference from residual vehicle exhaust and trace hydrocarbons.
- Air monitoring personnel should not smoke while using hand-held devices as this may interfere with readings.
- Record the readings, location, and conditions immediately and report as per communications protocol.
- With electronic devices, note and report whether readings are trending down, are stable, or are trending up.
- If using a dry chemical pump device, take reading of colour-change tube immediately after finishing the recommended number of pump strokes. This will prevent erroneous readings resulting from "colour-creep" as the reaction may continue to cause colour changes further up the sample tube for some time after sampling has concluded.

[2] Alberta Energy Resources Conservation Board, 2008. *Directive 071*. Section 14.4, p. 54.

- Do not re-use chemical tubes that have shown no change after first use.

Considerations for personnel deploying third-party specialized air monitoring services

- Mobile monitors are expected to have pre-established field operation procedures. These may be supplemented by instructions from the incident commander or equivalent, government regulatory agency representative or other designated response personnel.
- A briefing of mobile monitoring personnel must be carried out prior to the commencement of field operations to review hazards and provide up-to-date situation reports.
- Calibration documentation and records must be available as a means of verifying acceptable instrument function.
- Monitoring can be undertaken while the vehicle is moving to identify the location of the plume, but stationary monitoring is required in the plume to obtain a stable fixed location measurement.
- Excessive vehicle speed may cause the operator to miss sudden "spikes" or isolated peak values, which may be significant to emergency response decisions.
- The area that a mobile unit can monitor is limited by road access and conditions and, therefore, may not give a full indication of the gas plume's extent.
- It is recommended that both downwind and upwind comparative monitoring scans of a source be carried out as time allows. This process can aid in eliminating confusion owing to background readings.
- Mobile operators must frequently report their monitoring data and ground position. This also provides an opportunity to maintain the communication protocol (as discussed in Section 3).
- As directed, a mobile air monitor will remain in the area to conduct repeated upwind and downwind monitoring as required. In the event of evacuation, return of evacuees and resumption of operations relies heavily upon assessment of normal conditions.

7.1 Safety Practices

Note that this discussion does not replace the safety practices associated with a company's health and safety management system or emergency response plan. This overview is presented to remind air quality monitoring personnel that safety issues must be addressed. Safety of personnel undertaking emergency air monitoring must be ensured.

- Responders must ensure they are aware of the potential exposures, affected areas, and the size of the emergency planning zones, if developed, as well as any pre-identified muster points in case of site evacuation.

- When responding to alarms, responders should consider whether their personal safety might be compromised. Appropriate actions should be taken to ensure responder safety.
- The location of a windsock and wind direction may form the initial risk assessment and also a consideration in initial response actions.
- Once a hazard has been identified and the oil and gas personnel have been alerted, industry and specialized air monitoring response personnel must don appropriate safety equipment prior to continuing monitoring. This may include the use of self-contained breathing apparatus (SCBA).
- Personnel undertaking emergency air monitoring must also have personal protective and safety equipment appropriate for the hazard identified in the hazard assessment and the risks associated with air monitoring.
- A vehicle will be the most likely base for collecting air quality samples or measurements. Driver attention is required when driving from site to site and when stopping the vehicle to conduct measurements.
- Whether walking or riding while air monitoring, considerations should be made to ensure the appropriate mode of transportation is selected.
- While increased mobility in the field can improve the effectiveness of monitoring activities, the mode of transportation selected should fit the terrain and ground cover in the area of the release and should be compatible with the nature of the hazardous substance of concern.
    - For example, while the use of all-terrain vehicles may allow monitoring personnel to access rough terrain, when flammable substances are involved, the use of motorized vehicles may represent a source of ignition and it may be necessary to conduct monitoring on foot using protective equipment and clothing.

The location of exposures can depend on several factors:

- The maximum exposure levels due to ground-level releases tend to occur near the release location.
- The maximum exposure levels due to an elevated or ignited release can occur at significant distance downwind from the release point.
- Wind direction at the release point may differ from wind direction measured away from the release point.
- During the night and early morning, the release will tend to be carried towards low-lying areas by cold drainage winds.
- For buoyant releases, the highest exposure levels may occur on nearby elevated terrain.
- Dense gas products such as ethane and other natural gas liquid (NGL) products may be heavier than air and may be prevalent in low-lying areas during a release event.
- Plume meander may affect exposure levels.

7.2 Sampling Location Considerations

This section provides guidance on where to sample or take measurements to meet monitoring objectives. These considerations are applicable to the monitoring conducted by both oil and gas industry personnel and specialized air monitoring firms.

- Review on a map the location of terrain features, nearby communities, nearby public facilities, nearby residences, other industrial facilities, and access roads in relation to the release location. This information is typically available from emergency response plan documents.
- Determine the wind direction from on-site or nearby instrumentation, visual observation of plumes and other visual clues. This will identify upwind and downwind areas to allow appropriate monitoring locations to be determined.
- Monitoring should also take place at several locations upwind of the release to determine baseline (background) readings if time and resources permit.
- In some cases, there may be other oil and gas facilities in the region that could be a source of the target chemicals associated with the release. Measurements should be conducted near these facilities to determine their contribution.
- For substance-specific sampling considerations, see “Methodology” in the appendices of this document.

7.3 Documentation

Virtually all uncontrolled release events will require a post-event evaluation to determine the causes, identify steps to prevent future similar occurrences, and determine potential human health and environmental effects. This post-event evaluation may take the form of a regulatory inquiry where the monitoring measurements may be reviewed. It is imperative that the monitoring methodology be thoroughly documented to support post-event evaluation.

When taking measurements, the following information may be documented as appropriate to the situation:

- sampling type and the equipment used
- person who took the sample
- details relative to the calibration of the associated equipment
- location of the measurement (use GPS, written description, and/or digital camera image) including distance from the ground
- time and date the measurement was taken
- duration of the sampling
- description of the weather conditions at the time of the measurement (this can be supplemented with actual meteorological measurements and or photographs)

If a sample is collected that requires laboratory analysis, the appropriate chain of custody procedures should be considered.

Scrutiny may be expected from corporate officials, local authorities and the public following an incident. Information and knowledge generated from post-incident review may be used to develop improved air monitoring processes. Documentation of data should be appropriate and carefully prepared. Be mindful not to record personal comments or speculations on official forms.

8 Training

All personnel who may be called upon to participate in emergency response actions in roles related to emergency air monitoring should be trained accordingly. This includes, but is not limited to, training on:

- the company’s emergency response plan including the specific responsibilities of his or her role,
- the equipment (i.e., hand-held air monitors) to be used for air monitoring,
- the specific hazards of the released contaminant, and
- the use of personal protective equipment including self-contained breathing apparatus (SCBA) where applicable.

This training is intended to promote responder safety and will also enhance interactions with air quality monitoring specialists and encourage the collection of relevant and valid air quality data.

Appendix A H_2S Air Quality Monitoring for Oil & Gas Response Personnel

A.1 Overview

Hydrogen sulphide (H_2S) is frequently encountered in the oil and gas industry. This appendix discusses air quality monitoring in an environment containing H_2S, also known as sour gas. It provides a brief explanation of typical challenges related to air monitoring, as well as challenges emergency air monitoring responders may encounter.

A.2 Hazard Information

H_2S

- is colourless and invisible at low concentrations (below 100-250 ppm)
- has an odour of rotten eggs at low concentrations
- is flammable and will convert to sulphur dioxide (SO_2) if combusted (see Appendix B for more information on SO_2)
- is heavier than air in its pure state; however H_2S in oil and gas is often found in mixture and therefore many be buoyant or neutrally buoyant.
- may cause irritation to the eyes, nose and throat at low concentrations (15 ppm for 15 minutes, 10 ppm for 8 hours)
- is immediately dangerous to life and health (IDLH) at levels of 100 ppm for exposures of 30 minutes or more
- may cause loss of consciousness and death within moments at high concentrations (1000 ppm)

For more information about the hazards of H_2S refer to the CAPP guide *Occupational Health and Safety of Hydrogen Sulphide*.

A.3 Methodology

Prior to working in an environment containing H_2S, personnel must perform the required risk assessments which should include information related to the following as applicable:

- H_2S concentrations
- potential H_2S release volume for pipelines and infrastructure
- potential H_2S release rates for wells (drilling, completion and work over operations)
- associated emergency planning zones for the sour gas operational area

Responders must ensure they are aware of the potential exposures, affected areas and the size of the emergency planning zones, as well as any pre-identified muster points in case of site evacuation. The location of a windsock and wind direction should be part of the initial risk assessment and also a consideration in initial response actions.

It is also possible that sweet (non-H_2S) operations may encounter an unexpected sour zone with the possibility of a gas release. Therefore, hand-held air monitors should be in use at these locations in addition to identified H_2S locations.

Roadblock Personnel: Initial roadblock positions are intended to isolate the pre-calculated emergency planning zone; however, air quality readings may require roadblock positions be located further away from original positions. Similarly, zero-value readings may indicate that the original roadblock positions, as indicated by the pre-calculated emergency planning zone, are satisfactory.

When securing a roadblock location, personnel must ensure they have H_2S air monitoring equipment and are well outside of the hazard area identified by the incident commander through the use of specialized air monitoring results.

Upon arrival, personnel will set up the appropriate equipment and take air monitoring readings.

Zero and non-zero value readings, along with the location, are to be documented continuously at intervals determined by the incident commander.

Public Protection/Air Monitoring Personnel (Rovers): Personnel will travel to the nearest un-evacuated downwind location. Never enter an area downwind or immediately surrounding the release location without H_2S air monitoring equipment or confirmation of safety from monitoring personnel who have access to the air monitoring readings from other sources in the area.

Personnel must be equipped with proper personal protective equipment. They must maintain communication and ensure the incident commander, is aware of their location at all times.

Air monitoring personnel may monitor and record all gas readings, including when results are zero. Teams will attempt to find the edge of the plume (plume tracking).

Initially, there may be zero value readings. Advance slowly toward the area, continually air monitoring. If at any point non-zero readings are observed then identify that location and back up; that may be the edge of the plume.

Document all communications, locations, and zero and non-zero value air monitored readings continuously. Maintain regular contact with the incident commander. Fifteen-minute intervals are generally acceptable.

If indicated by air quality readings, immediately shelter-in-place or evacuate potentially impacted people in the emergency planning zone according to instructions received from the incident commander.

For shelter-in-place instructions see the CAPP guide, *Emergency Response Planning: Shelter-in-Place Instructions*, or the Enform guide, *Emergency Response Planning Shelter-in-Place Instructions*.

Continue taking readings and acting under instructions from the incident commander.

Air monitoring personnel may assist police, fire, and other agencies with air monitoring and reoccupation plans to ensure there is no residual H_2S in exposed areas.

A.4 Challenges and Risks to Safety

Responders must be aware of the risks associated with air monitoring during an emergency situation. Ensure that appropriate training for response activities is provided. Responders need to ensure that breathing equipment may be safely used while operating a motor vehicle and that a briefing is carried out prior to commencement of field operations. Below are some of the air monitoring challenges specific to an H_2S release event:

- Determining downwind gas plume concentration, motion, extent of dispersion and current boundaries is challenging due to changing meteorological conditions, gas properties, and other factors. Monitoring personnel should be as thorough as possible in determining safe or unsafe conditions.
- The monitoring of safe levels at downwind locations may or may not indicate continued safe conditions extending further downwind. Wide-area monitoring coverage is superior to fixed or minimal-motion coverage as concentrations measured within a dispersing plume will vary in time due to factors such as changes in wind speed and direction , plume meander, plume height, fluctuations within the plume, etc.
- Mobile monitors may not be available immediately with dispatch response time potentially hours away. Therefore, in most gas release situations, initial air monitoring will be carried out by personnel using portable devices.
- Air monitoring effectiveness may be hampered by lack of access owing to poor or non-existent roads, natural obstacles such as rivers and lakes, or calm wind conditions where no discernible trend in wind direction is apparent.

Appendix B SO_2 Air Quality Monitoring for Oil and Gas Response Personnel

B.1 Overview

Sulphur Dioxide (SO_2) is produced when hydrogen sulphide (H_2S) is burned during flaring, incineration or during an emergency. The burning process carries the toxic gas upward into the atmosphere resulting in reduced ground-level concentrations; however, H_2S may still be present despite combustion. Because of increased plume heights and more opportunity for dispersion, SO_2 toxic ground-level concentrations are less common than H_2S ground-level concentrations. This appendix discusses air monitoring of an SO_2 plume travelling beyond the incident site. It provides a brief explanation of typical challenges related to air monitoring, as well as guidance for communications with response personnel and impacted members of the public.

B.2 Hazard Information

SO_2

- has a pungent odour
- colourless
- is not flammable
- is heavier than air in its pure state, however, in oil and gas operations it is most often a by-product of combustion, therefore, it is most often found aloft in the thermal column
- may cause irritation to nose and throat at low concentrations (6-12 ppm) and to eyes at slightly higher concentrations (20 ppm)
- is immediately dangerous to life and health (IDLH) at levels of 100 ppm.

B.3 Methodology

Prior to working in an environment where there is potential for exposure to SO_2, personnel must perform the required risk assessments and be familiar with the emergency response plan.

When an SO_2 release occurs, personnel may be called upon to monitor air quality off-site until a mobile air monitoring unit arrives; this is an acceptable temporary air monitoring measure. Personnel assigned for air monitoring duties must have appropriate training and must be equipped with personal protective equipment in good working order (See Sections 6 and 8).

Roadblock Personnel: Initial roadblock positions are intended to isolate the pre-calculated emergency planning zone; however, air quality readings may require roadblock positions be located further away from original positions. Similarly, zero value readings may indicate that the original roadblock positions, as indicated by the pre-calculated emergency planning zone, are satisfactory.

When securing a roadblock location, personnel must ensure they have the appropriate SO_2 air monitoring equipment and/or are well outside of the hazard area identified by the incident commander through the use of specialized air monitoring results.

Upon arrival, personnel will set up the appropriate equipment and take air monitoring samples.

Zero and non-zero value readings, along with locations, are to be documented continuously at intervals determined by the incident commander. Fifteen-minute intervals are generally acceptable.

Roadblock personnel should be in regular communication with the incident commander to confirm that ongoing mobile SO_2 air monitoring operations have determined that the roadblock location remains safe.

Public Protection/Air Monitoring Personnel (Rovers): Personnel will travel to the nearest un-evacuated downwind location. Never enter an area downwind or immediately surrounding the release location without SO_2 air monitoring equipment or confirmation of safety from monitoring personnel who have access to the air monitoring readings from other sources in the area.

Personnel must be equipped with proper personal protective equipment. They must maintain communication and ensure that the incident commander is aware of their location at all times.

Air monitoring personnel will monitor and record all gas readings, including when results are zero. Teams will attempt to find the edge of the plume (plume tracking).

Initially, there may be zero value readings. Advance slowly toward the area, continually air monitoring. If at any point non-zero readings are observed, identify that location and back up; that may be the edge of the plume.

Document all communications, locations, and zero and non-zero air monitored readings continuously. Maintain regular contact with the incident commander. Fifteen-minute intervals are generally acceptable.

If indicated by air quality readings, immediately shelter or evacuate all people in the emergency planning zone according to instructions received from the incident commander.

For shelter-in-place instructions, see the CAPP guide, *Emergency Response Planning: Shelter-in-Place Instructions*, or the Enform guide, *Emergency Response Planning Shelter-in-Place Instructions*.

Continue taking readings and acting under instructions from the incident commander.

Air monitoring personnel will assist police, fire and other agencies with air monitoring and reoccupation plans to ensure there is no residue SO_2 in exposed areas.

B.4 Challenges and Risks to Safety

Responders must be aware of the risks associated with air monitoring during an emergency situation. Ensure that appropriate training for response activities is provided. Responders need to ensure that breathing equipment may be safely used while operating a motor vehicle and that a briefing is carried out prior to commencement of field operations. Below are some of the air monitoring challenges specific to a SO_2 release event:

- Determining downwind gas plume concentration, motion, extent of dispersion and current boundaries is challenging due to changing meteorological conditions, gas properties, and other factors. Monitoring personnel should be as thorough as possible in determining safe or unsafe conditions.
- The monitoring of safe levels at downwind locations may or may not indicate continued safe conditions extending further downwind. Wide-area monitoring coverage is superior to fixed or minimal-motion coverage as concentrations measured within a dispersing plume will vary in time due to factors such as changes in wind speed and direction , plume meander, plume height, fluctuations within the plume, etc.
- Mobile monitors may not be available immediately with dispatch response time potentially hours away. Therefore, in most gas release situations, initial air monitoring will be carried out by personnel using hand-held devices. Hand-held monitors used for personal protection may not be outfitted to monitor for SO_2; however, when properly equipped, these monitors are effective to monitor air quality in the absence of a mobile air monitor or a stationary grid of monitors.
- Air monitoring effectiveness may be hampered by lack of access owing to poor or non-existent roads, natural obstacles such as rivers and lakes, or calm wind conditions where no discernible trend in wind direction is apparent.
- Responders should consider combustion efficiency. H_2S may still be present.

Appendix C CO_2 Air Quality Monitoring for Oil and Gas Personnel

C.1 Overview

Carbon dioxide (CO_2) is used in specific applications in the oil and gas industry and, as such, would be considered a hazard only on specific projects involving CO_2. This appendix discusses air monitoring of a CO_2 release. It provides a brief explanation of typical challenges related to air monitoring.

C.2 Hazard Information

CO_2

- is a normal constituent of air at concentrations typically ranging between 360 and 380 ppm (0.036% and 0.038%)
- is a stable, colourless, odourless gas typically shipped as a liquefied compressed gas
- has a sublimation point of -79^{o}C; as a result, contact with CO_2 gas or liquid may cause frostbite
- is approximately 1.5 times heavier than air and, therefore, may accumulate, displacing oxygen (O_2) and potentially causing O_2 deficiency
- is a mild nervous system depressant
- is not combustible or flammable on its own; however, decomposition products may include CO_2 and carbon monoxide (CO). Some studies indicate that CO_2 combined with CO may cause an increase in CO-binding to hemoglobin, increasing the rate of CO poisoning.

C.3 Methodology

Personal protection and air monitoring is the first concern if personnel are on location where released CO_2 is present. CO_2 gas not only has inhalation hazards relating to CO_2 toxicity (inhaling high concentrations of CO_2) and the displacement of O_2, but also has direct contact hazards such as irritation, frostbite or freezing of tissue.

All personnel need to be aware of the pre-identified muster points in case of site evacuation. They must also be aware of the location of a windsock and/or the direction the wind is coming from when an alarm occurs. Personnel should never approach or come into contact with CO_2 products whether in liquid, solid or gas form.

When a release occurs, emergency response protocols must be followed for communication with the incident commander. Personal hand-held monitors, typically used by oil and gas operations personnel, do not have CO_2 measurement capabilities, so operators and responders do not have the ability to monitor air quality until a mobile air quality monitor arrives.

While waiting for approved CO_2 air monitoring equipment to arrive on site, temporary short-term response actions include staying outside of the hazard area. The hazard area may be visible as a white-hued plume due to the expansion of the CO_2 gas and condensation of water vapour. Continually monitor O_2 levels with personal monitors, if available, to ensure displacement of O_2 is not a hazard.

<u>Roadblock Personnel</u>: Initial roadblock positions are intended to isolate the pre-calculated emergency planning zone; however, air quality readings may require roadblock positions be located further away from original positions. Similarly, zero value readings may indicate that the original roadblock positions, as indicated by the pre-calculated emergency planning zone, are satisfactory.

Hand-held monitors used for personal protection typically are **not** equipped to monitor for CO_2.

When securing a roadblock location, ensure you have the correct CO_2 air monitoring equipment and/or are outside of the hazard area identified by the incident commander, through the use of specialized air monitoring results.

If CO_2 air monitoring equipment is available to roadblock personnel, set up the appropriate equipment upon arrival, and take air monitoring samples.

Zero and non-zero value readings, along with locations, are to be documented continuously at intervals determined by the Incident commander. Fifteen-minute intervals are generally acceptable.

The Alberta Occupational Health and Safety eight-hour Occupational Exposure Limit for working in a CO_2 environment is 5000 ppm or 0.5%[3]. If readings approach 5000 ppm, then immediately re-locate to another acceptable location that indicates zero. Immediately report the concentrations received and the new location to the incident commander.

If CO_2 air monitoring equipment is not available to roadblock personnel, the location of the roadblock will be determined by emergency command using air monitoring readings that are continually being monitored in the area. The roadblock location should be outside of the hazard area.

Roadblock personnel should be in regular communication with the incident commander, to confirm that ongoing mobile CO_2 air monitoring operations have determined that roadblock locations remain safe. As an additional measure of protection, roadblock personnel should continually monitor O_2 levels on their personal monitors for any reduced O_2 levels that may indicate O_2 displacement by CO_2.

Public Protection/Air Monitoring Personnel (Rovers): Personnel will travel to the nearest un-evacuated downwind location. Never enter an area downwind or immediately surrounding the release location without CO_2 air monitoring equipment, or confirmation of safety from monitoring personnel who have access to the air monitoring readings from other sources in the area.

Personnel must be equipped with proper personal protective equipment. They must maintain communication and ensure the incident commander, is aware of their location at all times.

Personnel will take readings from specialized CO_2 monitors and/or stay well outside of the hazard area identified by the emergency response team. They will communicate the

[3] Alberta Occupational Health and Safety Eight-Hour Occupational Exposure Limit (OEL)

status of their readings regularly to the incident commander. Fifteen-minute intervals are generally acceptable.

Air monitoring personnel will monitor and record all gas readings, including when results are zero. Teams will attempt to find the edge of the plume (plume tracking). Due to the specialized nature of CO_2 air monitoring equipment, there may be less CO_2 air monitoring equipment available than there would be in an H_2S, SO_2 or natural gas release where hand-held personal monitors would supplement the information from mobile air monitoring equipment.

Field responders without personal CO_2 air monitoring equipment will be relying on the information collected and disseminated by air monitoring personnel to model their response actions and ensure safety. The air monitoring team must be appropriately staffed to take on this additional burden and personnel involved in air monitoring must have proper personal protective equipment.

Initially, there may be zero readings. Personnel with specialized CO_2 air monitoring equipment should proceed slowly toward the area, measuring concentrations continually. If non-zero readings are received at any point, identify that location and back up; that may be the edge of the plume. Document the information and communicate with the incident commander.

If indicated by air quality readings, immediately shelter-in-place or evacuate all people in the emergency planning zone according to instructions received from the incident commander. For shelter-in-place instructions see the CAPP guide, *Emergency Response Planning: Shelter-in-Place Instructions*, or the Enform guide, *Emergency Response Planning Shelter-in-Place Instructions*.

Continue taking readings and acting under instructions from the incident commander.

Air monitoring personnel will assist police, fire and other agencies with air monitoring and reoccupation plans to ensure there is no residue CO_2 in exposed areas.

C.4 Challenges and Risks to Safety

Responders must be aware of the risks associated with air monitoring during an emergency situation. Ensure that appropriate training for response activities is provided. Responders need to ensure that breathing equipment may be safely used while operating a motor vehicle and that a briefing is carried out prior to commencement of field operations. Below are some of the air monitoring challenges specific to a CO_2 release event:

- There is a misconception that because CO_2 is a naturally occurring gas in air and is part of normal respiration, that the hazard of the gas is diminished. This misconception may lead to complacency in a dangerous situation.
- Mobile monitors may not be available immediately with dispatch response time potentially hours away. Particularly for CO_2 air monitoring equipment that is not available from all air monitoring service companies and may have to be sourced from further away.
- Hand-held monitors used for personal protection typically are not equipped to monitor for CO_2, so this equipment, which is often relied upon for air monitoring in

the absence of mobile air monitoring equipment, cannot be used in a CO_2 release event.

- The absence of CO_2 measurement on typical hand-held monitors used for personal protection adds to the risk faced by emergency responders who are unable to measure the CO_2 content of the area where they are working with typical protective equipment.
- The absence of CO_2 measurement on typical hand-held monitors used for personal protection, and in some cases on mobile air monitoring equipment, may result in fewer air monitoring resources than are normally available during release events. Responder actions should be modified accordingly as response personnel without CO_2 air monitoring equipment need to rely on readings established by the available CO_2 air monitoring equipment.
- Readings from specialized hand-held CO_2 monitors are subject to meteorological drift. This means that the readings could be impacted by wind and other conditions, making the readings less accurate than mobile air monitoring units equipped with analyzers.
- CO_2 gas is approximately 1.5 times heavier than air and may accumulate in low areas. The measurements above and around these low areas may be measured as safe, but higher concentrations of CO_2 within these low points may pose a risk to responders. Responders to a CO_2 release event should be aware of this characteristic of CO_2 and should not enter low points where CO_2 may accumulate without proper measurement or protective equipment.
- CO_2 is not combustible; therefore, ignition is not an option for public protection.

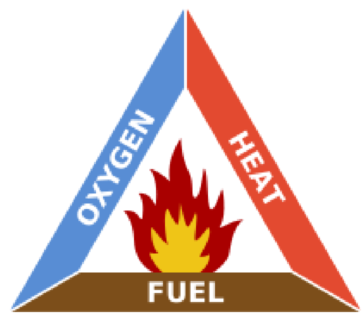
Appendix D Flammability Monitoring for Oil and Gas Response Personnel

D.1 Overview

A range of flammable products and materials are produced, stored and used at oil and gas facilities. Hydrocarbons represent the predominate source of flammable products at these facilities and is the greatest risk to industry personnel and the public. Hydrocarbons may be present in the air during normal operations or due to upset conditions such as accidents or equipment failure. This appendix provides a brief explanation of typical considerations and challenges faced when monitoring for flammable mixtures.

D.2 Hazard Information

The primary hazards linked with hydrocarbon emissions are associated with direct exposure to flame, exposure to excessive heat, and overpressure from an explosion following ignition of these emissions. Three conditions must be present to support combustion and they are represented graphically in the combustion triangle shown on the right.



These conditions include

- a fuel supply (for example, a hydrocarbon product),
- an oxidizing agent (usually oxygen present in the air), and
- the presence of heat (there must be an ignition source).

For combustion to occur, the ratio of hydrocarbons to air must fall between the upper flammability limit (UFL) and the lower flammability limit (LFL) for the gas mixture. For hydrocarbons concentrations above the UFL there is too much fuel to support combustion (i.e., the mixture is too rich). For concentrations below the LFL, there is not enough fuel to support combustion (i.e., the mixture is too lean). If the ratio of fuel to air forms a flammable mixture, and if an ignition source is encountered, fire can result and lead to the realization of the hazards noted.

Terminology used to describe flammability (i.e., UFL and LFL) is often used interchangeably with terminology used to describe the potential to propagate an explosion (i.e., the upper explosive level, or UEL, and the lower explosive level, or LEL). While gas mixtures that fall between the UFL and LFL will support combustion, additional specific conditions must exist to propagate an explosion and its associated overpressure. In other words, the gas must be confined (i.e., within a building) or must be dispersed through a congested region (i.e., pipe racks and vessels).

D.3 Methodology

Prior to working in an environment where combustible gas is present, personnel must perform the required risk assessments and have the appropriate personal protective equipment, including hand-held air monitors with LEL sensors and flame-resistant clothing (i.e., coveralls). Responders should ensure they are aware of any pre-identified muster points in case of site evacuation. The location of a windsock and wind direction should be part of the risk assessment, and also a consideration in initial response actions should an alarm occur.

Although the same principles apply, it is less likely that flammable gas levels will be detected off lease.

Roadblock Personnel: Initial roadblock positions are intended to isolate the pre-calculated emergency planning zone; however, air quality readings may require roadblock positions be located further away from original positions. Similarly, zero value readings may indicate that the original roadblock positions, as indicated by the pre-calculated emergency planning zone, are satisfactory.

When securing roadblock locations, personnel must ensure they have the appropriate LEL air monitoring equipment and/or are well outside of the hazard area identified by the incident commander, through the use of specialized air monitoring results.

Upon arrival, personnel should set up the appropriate equipment and take air monitoring samples.

Zero and non-zero value readings, along with locations, are to be documented continuously at intervals determined by the incident commander. Fifteen-minute intervals are generally acceptable.

Roadblock personnel should be in regular communication with the incident commander, to confirm that ongoing mobile LEL air monitoring operations have determined that roadblock locations remain safe.

Public Protection/Air Monitoring Personnel (Rovers): Personnel will travel to the nearest un-evacuated downwind location. Never enter an area downwind or immediately surrounding the release location without LEL air monitoring equipment or confirmation of safety from monitoring personnel who have access to the air monitoring readings from other sources in the area.

Personnel must be equipped with proper personal protective equipment. They must maintain communication and ensure the incident commander, is aware of their locations at all times.

Air monitoring personnel will monitor and record all gas readings, including when results are zero. Teams will attempt to find the edge of the plume (plume tracking).

Initially, there may be zero value readings. Advance slowly toward the area, continually air monitoring. If non-zero value readings are observed at any point, identify that location and back up; that may be the edge of the plume.

Document all communications, locations, and zero and non-zero value air monitored readings continuously. Maintain regular contact with the incident commander. Fifteen-minute intervals are generally acceptable.

If indicated by air quality readings, immediately shelter-in-place or evacuate all people in the emergency planning zone according to instructions received from the incident commander.

For shelter-in-place instructions see the CAPP guide, *Emergency Response Planning: Shelter in Place Instructions* or the Enform guide, *Emergency Response Planning Shelter-in-Place Instructions*.

Continue taking readings and acting under instructions from the incident commander.

Air monitoring personnel may assist police, fire and other agencies with air monitoring and reoccupation plans to ensure there is no residual combustible/explosive gases or vapours in exposed areas.

D.4 Challenges and Risks to Safety

Industry personnel accessing oil and gas facilities should have a general knowledge of the major hazardous products, volumes and storage conditions at specific facilities. They should also be provided with appropriate training and equipment.

Responders must be aware of the risks associated with air monitoring during an emergency situation. Ensure that appropriate training for response activities is provided. Responders need to ensure that breathing equipment may be safely used while operating a motor vehicle and that a briefing is carried out prior to commencement of field operations. Below are some of the challenges and considerations when monitoring for flammable mixtures:

- Industry personnel and responders who use monitors should be familiar with flammability levels referenced by the monitor and should have an understanding, in real terms, of what these concentration levels represent, as well as appropriate personal and public protection measures that correspond with these levels.
- Personnel should also be aware that the sensitivity/effectiveness of LEL sensors on monitoring equipment is impacted by the type of gas used to calibrate the sensor; manufacturer-provided charts to reference the measurement accuracy for different substances based on the calibration gas.
- When multiple hazards exist at a facility (e.g., at sour gas facilities there is a flammability hazard and an H_2S toxicity hazard), both hazards must be monitored and evaluated. When multiple hazards are involved, decisions and actions become more complex. Personal and public protection measures that may be effective when only one hazard is involved may be different in a situation where more than one product is involved.
- Monitors used to determine the flammability of gases released into the atmosphere measure total hydrocarbons and determine flammability limits (e.g., UFL, LFL, LFL/10) based on the total carbon atoms contained in the air being sampled. While flammability monitors typically are calibrated using propane, the flammability limits reported by a monitor *are not* compound specific: i.e., the flammability limits reported will vary based on the compound or mixture of compounds present in the atmosphere.

Table 1 below provides examples of flammability limits as reported by monitors and the typical safety criteria applied at these limits. For reference purposes, the table also provides examples of concentration levels associated with a number of specific compounds associated with the oil and gas industry activities.

Table 1 Examples of Flammability Limits and Flammability Criteria

Monitored Concentrations of Selected Compounds in Air (ppm)		**Percent of the Lower Flammability Limit** (% of LFL)	**Comments and Typical Actions**
methane	*50,000*	100% of the LFL (LFL) *see note 1*	A concentration level at which (in the presence of an ignition source) ignition and flame propagation through the dispersing plume is highly probable. Extreme caution should be exercised and emergency response personnel should withdraw from the area.
ethane	*29,000*		
propane	*21,000*		
butane	*18,000*		
methane	*25,000*	50% of the LFL (LFL/2)	A concentration level at which ignition and flame propagation through a dispersing plume may be possible due to the non-homogenous nature of dispersion in the atmosphere (i.e., concentration fluctuations). A meteorologically weighted distance to this criterion (as calculated using quantitative hazard analysis methods) is often used as the basis for establishing emergency planning zones for flammable substances. If measured by air monitoring, this concentration represents a level at which public protection measures such as removal of ignition sources, shelter-in-place or evacuation may be warranted.
ethane	*14,500*		
propane	*10,500*		
butane	*9,000*		
methane	*5,000*	10% of the LFL (LFL/10)	This concentration represents a level at which industry response personnel should leave the area or don fire protective clothing if continuing to work in this environment or approaching the source of a release.
ethane	*2,900*		
propane	*2,100*		
butane	*1,800*		

Note 1: Source – Engineering Data Book 11th Edition (Electronic) SI Volumes I and II, Physical Constants, Figure 23-2, p.23-4.

Note: Flammability limits reported will vary based on the compound or mixture of compounds present in the atmosphere.

While ignition and flame propagation cannot occur at concentration levels below the LFL, the release of product from high-pressure containment and its dispersion in the atmosphere is a non-homogeneous process. Envelopes of combustible products may exist independently of each other. This is to say that the peak to mean concentrations in the atmosphere and the measured concentrations derived from air monitoring can vary over time and space (i.e., flammability measurements may escalate or de-escalate quickly). Thus, industry personnel and responders entering a hazardous environment should apply training, experience, company procedures and knowledge.

APPENDIX E Glossary

Adsorption Tube: A glass tube filled with charcoal adsorbent material that can be used for atmospheric monitoring. Air is drawn through the tube by a pump and any contaminant present is adsorbed onto the charcoal. The charcoal is later removed and analyzed in a laboratory to determine contaminates.

Air Quality Monitoring: Measurement of atmospheric concentrations of a hazardous substance, such as H_2S or SO_2.

Ambient: Natural condition of the environment at any given time.

Best Practices: A technique or methodology that, through experience and research, has proven to reliably lead to a desired result. A commitment to using the best practices in any field is a commitment to using all the knowledge and technology at one's disposal to ensure success.

Bump Test: A function or bump test is a field test that is done at the start of each shift or before the meter is used. The test is usually done in a clean location at the site where the instrument is to be used. The test makes sure that the meter is working properly and has not been damaged during transport. During a function test, the meter is exposed to a known concentration of calibration gas. If the monitor responds within predetermined limits defined by the manufacturer, the instrument is ready for use. No attempt is made to re-calibrate the meter during a function test. A meter that fails the function test must immediately be taken out of service and returned to a qualified person or facility for a complete inspection and recalibration.

Calibrate: To determine the response or reading of an instrument relative to a series of known values over the range of the instrument; results are used to develop correction or calibration factors.

Carbon Dioxide (CO_2): Carbon dioxide is a colourless, odourless, non-toxic gas that is present in the atmosphere from both natural and man-made sources. Man-made sources of CO_2 include the burning of fossil fuels for heating, power generation and transportation.

Carbon Monoxide (CO): Carbon monoxide is a colourless, odourless gas resulting from the incomplete combustion of carbon-based fuels such as gasoline, natural gas and wood. Exposure to CO reduces the ability of blood to absorb and deliver oxygen to cells in the body.

Combustion: The chemical processes of burning a fuel in the presence of an oxidant releasing heat and which may release light.

Dispersion: Gas streams that are released to the atmosphere through a stack or from an accidental release (e.g., a pipeline leak) mix with the surrounding air due to atmospheric turbulence. This mixing process, referred to as atmospheric dispersion, or simply dispersion, dilutes the vented gas streams as they are being carried downwind from the release point.

Dispersion Model: A computerized set of mathematical equations that uses emissions and meteorological information to simulate the behavior and movement of air pollutants in the atmosphere. The results of a dispersion model are estimated outdoor concentrations of individual air pollutants at specified locations.

Emergency: A present or imminent event outside the scope of normal operations that requires prompt coordination of resources to protect the health, safety and welfare of people and to limit damage to property and the environment.

Emergency Management Program: A business framework that applies emergency management principles to mitigate the risks associated with activities, as well as prepare for, respond to, and recover from an emergency. It also includes details regarding:

- Management commitment and leadership
- Hazard identification and assessment
- Emergency response plan
- Responder competence and training
- Exercise and incident investigation programs
- Management review and continuous improvement

Emergency Response Plan (ERP): A comprehensive plan to protect the public that includes criteria for assessing an emergency and procedures to mobilize response personnel and agencies and for establishing communications and ensuring coordination among the emergency response.

Emission: Releases of pollutants into the air from a source.

Explosion: When a pressurized mixture of hydrocarbon liquid and vapour is released to the atmosphere, and the mixture is within its flammability limits and encounters an ignition source, the rapid combustion of the mixture is referred to as an explosion. Explosions produce pressure waves that can be damaging to people and nearby structures.

Fixed Location Detector and Monitor: A "fixed" or "*stand-alone*" detector or *monitor* is permanently installed in a chosen location to provide continuous monitoring of the plant and equipment. It is used to give early warning of leaks from the plant containing *toxic* or flammable gases or vapours, or for monitoring concentrations of such gases and vapours within the plant.

Flammable: Capable of burning with a flame.

Flammable Range: The concentration of flammable vapour in air falling between the upper and lower explosion limits.

Flaring: The controlled burning of gaseous hydrocarbon products using a vertical elevated burner. Products formed during the complete combustion of hydrocarbons products are heat, carbon dioxide and water vapour. The combustion efficiency of flaring can be reduced by environmental factors such as wind, the fuel supply, and burner design which can result in the formation of small quantities of other undesirable byproducts.

Hand-held Monitor: A hand-held or portable detector/monitor usually refers to a small, hand-held device that can be used for testing an atmosphere in a confined space before entry, for tracing leaks, or to give an early warning of the presence of toxic or flammable gas or vapour when hot work is being carried out in a hazardous area.

Hazard: A potential source of harm.

Hazardous Area: An area where flammable or explosive gas (or vapour-air mixtures) are present, or may be expected to be present, in quantities that require special precautions be taken against the risk of ignition.

Heat Radiation: Heat can be transmitted from a fire by thermal radiation, which is a form of energy transport consisting of electromagnetic waves travelling at the speed of light. Heat radiation can raise the surface temperature of exposed surfaces. High levels of thermal radiation can produce first, second or third degree burns on exposed skin. In addition, prolonged exposure to high thermal radiation levels can cause wood to spontaneously combust.

Hydrogen Sulphide (H_2S): A naturally occurring gas found in a variety of geological formations and also formed by the natural decomposition of organic matter in the absence of oxygen. H_2S is colourless, has a molecular weight that is heavier than air, and is extremely toxic. It is sometimes referred to as “sour gas”.

Depending on the nature of the source of a release (e.g., the gas composition, the change in pressure experienced as gas expands from storage conditions to atmospheric conditions, the size of the failure, etc.) the gas may initially behave in a manner which is:

- heavier than air (dense) and tend to fall towards the ground,,
- lighter than air (buoyant) and will tend to rise in the atmosphere, or
- about the same weight as air (neutrally buoyant) and will tend to travel with the flow of air.

H_2S Alive: Enform certified, or equivalent, training for oil and gas personnel who may be exposed to hydrogen sulphide.

Hydrocarbon: A large class of liquid, solid or gaseous organic compounds, containing only carbon and hydrogen, which are the basis of almost all petroleum products.

Ignition: A process by which combustion or burning is initiated. For example, a flammable gas mixture if coming into contact with a spark or open flame can initiate ignition and burning.

Immediately Dangerous to Life or Health Concentration Value (IDLH): As defined by the National Institute for Occupational Safety and Health (NIOSH), an immediately dangerous to life or health condition is a situation "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment." NIOSH also states that the purpose of establishing an IDLH is to "ensure that the worker can escape from a given contaminated environment in the event of failure of the respiratory protection equipment."

Incident: An unexpected occurrence or event that requires action by emergency personnel to prevent or minimize the impacts on people, property and the environment.

Incineration: The destruction of solid, liquid, or gaseous wastes by controlled burning at high temperatures.

Lower Explosion Limit (LEL): The lowest concentration of gas or vapour (per cent by volume in air) that explodes if an ignition source is present at ambient temperatures.

Lower Flammability Limit (LFL): Lower flammable limit is any hydrocarbon concentration below which there is insufficient hydrocarbon gas to support combustion.

Meteorological (weather) Monitoring Stations: Facility for observing atmospheric conditions.

Mobile Air Quality Monitoring: Mobile air monitors refer to manned, vehicle mounted analyzers and other environmental monitoring and communication equipment that can be rapidly dispatched to monitor air quality and meteorological conditions in the area of a release.

Muster Point: A location where responders must report to and gather immediately after an emergency occurs.

Off-site Air Monitoring: The area defined by emergency responders outside of the incident area. Off-site air monitoring is conducted to identify hazardous conditions to support emergency response decisions in the selection of public protection measures.

On-site Air Monitoring: The area defined by emergency responders usually in the immediate vicinity of an incident. On-site air monitoring is conducted to ensure worker safety.

Oxygen (O_2): Colorless, odorless and tasteless, oxygen has poor solubility in water. A specific gravity of 1.105 makes it slightly heavier than air. When cooled to its boiling point of -297^{o}F (-183^{o}C), oxygen becomes a transparent, pale blue liquid that is slightly heavier than water. Although oxygen itself is nonflammable, it enhances combustion and enables all materials that are flammable in air to burn much more vigorously.

Parts per Million (PPM)

Parts per Billion (PPB)

Personal Protective Equipment (PPE): Personal protective equipment is clothing or devices worn to help isolate a person from direct exposure to a hazardous material or situation. Recommended personal protective equipment is often listed on the Material Safety Data Sheets (MSDS). This can include protective clothing, respiratory protection and eye protection.

Plume: Plume is defined as a column of fluid moving through another fluid. From an air quality perspective, the plume is the gas stream released to the atmosphere (i.e., the column of fluid) and dispersing within the air (i.e., the other fluid). A plume initially has properties that are very different from that of the air, but as air continues to mix into the plume, the plume properties approach those associated with the air itself. The concentrations of chemicals in the plume will be the largest along the center of the plume and lower at the edges where air is being mixed into it.

Plume tracking: The tracking of a plume is the process of identifying the location of the plume as it is carried away from the emission source by the wind. For plumes that are visible, the location and the direction of the plume can be determined by visual observation. At very cold temperatures, the plumes from stacks tend to be become visible due to the condensation of water vapour in the plume cooling (which is not visible) to produce liquid water (which is visible). Plumes that are not visible can be tracked by using instrumentation that measure the concentration of a chemical that is specific to the plume. For example, a leak from a pipeline can be tracked using a total hydrocarbon analyzer that measures the high concentrations found along the centerline of the plume. A person tracking a plume would need to be aware of the wind direction at the release point to help determine the potential location of the plume.

Public Protection Methods: The use of sheltering, evacuation, ignition, and isolation procedures to mitigate the impact of a hazardous release on members of the public.

Risk: Risk is a measure of the potential to cause harm. It reflects both the likelihood that an event will happen and the magnitude of harm associated with the event.

Self-Contained Breathing Apparatus (SCBA): A respiratory mask that contains its own air supply. It is composed of a face piece connected by a hose to a wearable, compressed, clean-air supply pack much like a scuba tank.

Site assessment: Process to evaluate potential or confirmed releases of hazardous substances that may pose a threat to human health or the environment.

Sublimation: The transformation process from a solid substance directly to a vapor without first passing through an intermediate liquid state or phase.

Sulphur Dioxide (SO_2): A colourless, water-soluble, suffocating gas formed by burning sulphur in air; also used in the manufacture of sulphuric acid. SO_2 has a pungent smell similar to a burning match. SO_2 is extremely toxic at higher concentrations. The molecular weight of SO_2 is heavier than air; however, typical releases are related to combustion, which makes the gaseous mixture lighter than air (buoyant).

Sulphur Emissions: The release of sulphur-containing compounds, including SO_2, H_2S, and total reduced sulphur compounds.

Supplied Air Breathing Apparatus (SABA): SABA systems are equipped with a remote source of air which can supply continuous breathing air to several emergency responders. Air travels from a compressor, cylinder, air trailer, or a plant breathing air system through a regulator to a manifold which supplies air to a number of hoses.

Total Hydrocarbon (THC): Total hydrocarbon (THC) refers to a mixture of hydrocarbon gases. While a gas pipeline may be composed primarily of methane, it may also contain smaller amounts of ethane, propane, butane, pentane and hexane. Manufacturers produce analyzers that measure THC concentrations, and these can be used for plume tracking.

Total Volatile Hydrocarbon (TVHC): Volatile hydrocarbons are compounds that are either gases (such as butane) or liquids that can evaporate and act as a gas.

Toxic: Poisonous, injurious to health or dangerous to life.

Upper Explosion Limit (UEL): The maximum concentration of vapour in air above which the propagation of flame will not occur in the presence of an ignition source. Also referred to as the upper flammable limit or the upper explosive limit.

Upper Flammability Limit (UFL): Upper flammable limit is any hydrocarbon concentration above which air is insufficient to support combustion.

Vapour: The gaseous form of a material that is normally solid or liquid at room temperature and pressure.