Table of Contents

22.0 Abandoned Surface and Old Underground Workings

Introduction

Mineral exploration may take place in regions where there are abandoned mines that can provide valuable geologic information when re-evaluated or re-explored. However, abandoned surface and old underground mine workings (including old exploratory drifts) are among the most hazardous places where exploration geoscientists may work. Primary risks include the potential collapse of ground and confined space, which is defined as any enclosed space having a single point of entry and exit. Confined spaces may have a potential to concentrate toxic gases such as carbon dioxide, methane, or hydrogen sulphide, or they may contain insufficient oxygen to support life.

It is tempting for geologists and prospectors to enter old mine workings, especially where they are horizontal adits and light is penetrating from outside some distance into the entrance. Often the best outcrops of mineralization are in old adits. However the dangers are considerable.

An exploration company should have written safe operating procedures (SOPs) in place before permitting exploration work at abandoned surface or old underground mine sites. Careful assessment, planning and preparations are necessary. Employees should be familiar with the general and site specific risks and hazards, the company SOPs and emergency response plan (ERP), and have appropriate training to carry out the exploration work safely. They should not venture into abandoned surface or old underground workings without specific company and jurisdictional permission to engage in such activities.

Some hazardous sites may not be easily recognized. For instance, there is evidence that numerous sites, particularly in Eastern Europe and the former USSR, may be contaminated with hazardous chemicals or radioactivity. Exploration programs undertaken in such areas require special preparations to determine whether these potential hazards are present.

It should be borne in mind that hazards similar to those of abandoned or old mine sites may also exist under other circumstances. For example, there are documented fatalities caused by accumulations of toxic gases that were encounter while monitoring a closed mine site where tailings or waste rock piles were generating hazardous gases that migrated and concentrated in buildings constructed at the toe of the tailings or waste pile. See section 22.4.3 below.

Some information in this chapter is based on text from Berkman, D. A., 2001. *Field Geologists' Manual, 4th edition,* Section 11.2 pp 364-366, (The Australasian Institute of Mining and Metallurgy: Melbourne). The information is adapted with the permission from The Australasian Institute of Mining and Metallurgy.

Acronyms

ACGIH – American Conference of Government Industrial Hygienists

AHJ – Authority Having Jurisdiction

ERP – Emergency Response Plan

HEPA – High Efficiency Particulate Air

OHS – Occupational Health and Safety

PFD – Personal Flotation Device

PPE – Personal Protective Equipment

ppm – Parts Per Million

SCBA – Self Contained Breathing Apparatus

SOP – Safe Operating Procedure

22.1 Risks and Hazards

Death and injuries may result from numerous risks and hazards at old or abandoned sites. They include but are not limited to:

- Asphyxiation, suffocation or illness from oxygen deficient atmospheres due to:
    - Insufficient underground ventilation
    - Oxidation of carbonate and sulphide waste rock in underground passages or in tailings piles
    - Carbon monoxide in exhaust caused by incomplete combustion of fuel used in motors or engines in trenches, underground, or in other confined spaces
    - Breathing toxic fumes, dusts or mists that originate from toxic waters or waste rock
- Slips, trips and falls due to rough, slippery or collapsing ground; collapse of structures covering old adits, winzes or ore passes; failure of old infrastructure; wearing inadequate footwear, not wearing fall arrest PPE
- Injuries or death sustained from:
    - Falls of rock, collapse of ground
    - Failure of old infrastructure (e.g., ladders, manway covers, timbers)
    - Water covering hazards, inflow from surface waters, unexpected underground flooding
- Burns or death from fire or explosions due to the presence of methane, old blasting materials
- Exposure to diseases (e.g., tetanus, leptospirosis); potentially from inhaling guano residues: histoplasmosis (bird and bat guano) and rabies (bat guano)
- Wildlife encounters with snakes, bats, rodents or larger mammals
- Confined spaces: See section 22.11 below for specific risks and hazards.

Figure 22.1 Contents: Residues in drums of unknown, unidentifiable chemicals © Courtney Mitchell

22.2 Responsibilities (Due Diligence) with Regard to Old or Abandoned Sites

As presented in section 1.2 Due Diligence with Respect to Safety, companies should be able to demonstrate due diligence with respect to safety any place their employees work.

Exploration Company Responsibilities

- Make sure the health and safety of each employee is protected, including during the investigation of abandoned surface or old underground workings.
- Comply with occupational health and safety (OHS) legislation, Mines Safety Acts and Regulations and those of any other authority having jurisdiction (AHJ), including permissions.
- Perform risk assessments to identify the risks and hazards that must be addressed before exploring old or abandoned sites.
- Prior to developing work plans within old or abandoned sites, safe operating procedures (SOPs) guidelines or a manual should be in place that addresses the findings of the risk assessments.
- Develop written emergency response plans (ERPs) and training procedures that cover the risks, hazards and potential accidents that could occur.
- Make sure employees and contractors doing exploration of old and abandoned sites are trained and qualified for the job.
- Provide all necessary safety equipment and personal protection equipment (PPE).

Supervisor Responsibilities

- Make sure employees are trained in the SOPs and ERPs and that they are implemented by everyone participating in the exploration of old or abandoned sites work programs.
- Carry out a job hazard analysis of both surface and underground tasks (e.g., sampling, ventilation).
- Provide appropriate supervision of employees who explore old or abandoned sites.
- Make sure the employees who explore or work in old workings follow their predetermined exploration or work plan and do not deviate from it without notifying and confirming the changes with support people on the surface.

Exploration Employee's Responsibilities

- Be aware of the risks and hazards at old or abandoned mine sites.
- Follow company policies and SOPs developed for the safe exploration of old or abandoned sites.
- Be familiar with and participate in training programs to acquire skills to follow the ERPs, especially mine rescue procedures.
- Wear all required PPE. Carry and know how to use the safety equipment supplied by the company.
- Follow and do not deviate from the predetermined exploration plan without notifying and confirming any changes with support people on the surface; "plan the plan and follow the plan".
- Report any unsafe conditions you observe to co-workers.

22.3 Guidelines and Preparations for Exploring Old or Abandoned Sites

Each company, their employees and contractors should maintain an extraordinarily cautious attitude toward personal safety and that of their co-workers when entering or exploring old mine workings. Always adhere to safe practices. No one should proceed with work at old surface or underground workings if conditions are judged to be so hazardous that they cannot be mitigated or avoided through safe work techniques. In general, experts in safety in mine workings should be involved.

Company plans: Management, as they are ultimately responsible, should have an overall plan in place before any surface or underground exploration occurs at old or abandoned sites. Plans should include but not be limited to the following measures:

1. Compliance: See comments under company responsibilities above.

    - Information: Gather all available mine plans, sections and mine records. Obtain local knowledge and information that will make the exploration safer. In some regions it is important to check for the possible presence of hazardous chemicals or radioactive wastes at the site.
    - Risk assessments: Complete risk assessments and use the observations and conclusions to mitigate the hazards by developing a site specific exploration plan and SOPs for the proposed investigation.
    - Requirements: Set requirements for the use of PPE and training (e.g., mine rescue, use of gas detection equipment, first aid, SOPs, ERPs).

2. Complete a risk assessment of the potential work area:
    - Surface hazards include but are not limited to:
        - Pits and highwalls
        - Openings to underground workings including shafts, raises, stope workings that might be hidden by vegetation or old, deteriorated covers
        - Deteriorated buildings and machinery
        - Scrap metal, scrap wood with exposed nails
        - Undetonated explosives and blasting caps
        - Hazardous chemicals
        - Unstable rock
        - Water hazards include filled or partially filled raises of unknown depth, flooded pits
        - Wildlife
    - Underground hazards include but are not limited to:
        - Oxygen deficient atmosphere, toxic atmosphere
        - Deteriorated metal and wooden support materials
        - Unstable rock
        - Water hazards include water-covered timber or steel plates on floors of tunnels that hide winzes or ore chutes and flooded passages at depth. Raises may be water-filled and in very cold climates they may be frozen at the bottom due to partial thawing.
        - Unseen holes and/or ore passes
3. Procedures: An exploration company should develop safe operating procedures and emergency response plans.
    - Safe operating procedures should be based on the results of risk assessments. They should also address required equipment, training and safe behaviour. General SOPs should be part of a company plan that addresses safe exploration at old and/or abandoned surface and underground sites. Site specific SOPs should be developed as required before any exploration occurs at a chosen site.
    - Emergency response plans should address potential accidents, potential injuries, potential rescues and communication breakdowns etc. Plans must include a list with required contact information and numbers in case a rescue is necessary.
4. Training: Sufficient and appropriate training is essential. Anyone exploring surface or underground sites should be trained to recognize and evaluate the potential hazards. Training should include:
    - Education of employees that they may refuse work considered unsafe
    - Hazard recognition: Both surface and underground hazards may impact jobs. A job hazard analysis should be carried out (e.g., sampling, ventilation, dewatering).
    - Confined space recognition and safe procedures
    - First aid, mine rescue training

- Operation of: gas detection equipment, self rescue breathing apparatus, and/or self contained breathing apparatus (SCBA)
- Fall protection requirements for surface or underground, as required
- Evacuation procedures if going underground to work

5. Safety equipment: Determine the requirements for safe operation in the hazardous area. Provide and require employees to wear or use all PPE, gas monitors and have available all necessary mine rescue equipment.
6. Communications: Have a system in place to communicate between crews exploring on the surface or underground and people in charge of potential rescues.
7. Develop contingency plans to follow while exploring old or abandoned sites. Employees should submit a detailed written plan with proposed exploration procedures for management approval before commencing work. They should "*plan the exploration and follow the plan*".
8. It should be a requirement that employees are always accompanied underground by a person who has experience working underground on the property under investigation.

22.4 Surface Hazards at Old Workings

22.4.1 Abandoned Surface, Pit or Strip Mines

- Be vigilant when working at the base or top of a highwall or rock face. Make a habit of shouting "Rock!" to alert co-workers to any falling rock. Do not stand below someone who might dislodge loose rock.
- Highwalls that remain following mining operations are more dangerous than natural cliffs because of potential collapse. Minor movement, water saturation or vibration may initiate a slide of loose or unconsolidated material.
- Rock slopes formed by blasting are prone to rock falls, especially after freezing and thawing.
- Beware of climbing on broken rock piles. It is easy to dislodge large masses of rock that may be resting in a precarious position.
- Try to avoid collecting samples on unstable or precipitous slopes. Look for the safest exposed areas to collect samples.
- Wear PPE, including a hard hat, proper footwear and eye protection.

Figure 22.1: Unstable loose rock above a pit wall, dangerous footing, and a risky place to sample. © Courtney Mitchell

22.4.2 Surface Structures and Machinery

- Never enter old buildings unless it is absolutely necessary. Unmaintained structures at old mine and mill sites can be extremely dangerous as they may easily collapse. Be aware of potential encounters with wildlife (e.g., snakes, skunks). Old buildings may trap gases under certain circumstances.
- If you *must* enter, examine and look for the following:
  - Foundations – signs of structural failure
  - Stability of walls and strength of the floor or stairs. Check for rotten wood by testing the floor with a large object before placing your weight on it. While it may support rodents and snakes, it may not support you.
  - Slope movement from above and below
- Never go on the cover over a shaft or other vertical opening. It is difficult to determine whether it is safe or not.
- Watch out for explosives and blasting caps left in old buildings. Do not touch, step on or try to detonate them. Deteriorating dynamite is very unstable. Because dynamite contains nitro-glycerine, touching explosives may affect the heart rhythm and breathing in some people.
- Watch out for subsidence around headframes and shafts.
- Avoid walking on or around machinery. A tangle of sharp and rusted machinery parts can cause severe injury if they whip back or one falls on them. Tetanus may be contracted from cuts received from old dirty metal.

- Stay far away from headframes and tramlines during a lightning storm. The charge from a lightning strike may travel along metal cables for more than a kilometre.

22.4.3 Tailings and Water-Filled Areas

- Tailings that are incompletely dewatered may not support your weight. Dry tailings may release harmful dust (including heavy metals or chemicals) when you climb or sample them. Wear an appropriate dust mask to sample dry, dusty tailings to avoid inhaling airborne particles.
- Tailings or waste rock piles may be steep and unstable.
- Be careful and observant when exploring near tailings and waste rock dumps. Sulphide and/or carbonate minerals may react to produce an oxygen deficient atmosphere and toxic gases within or in the immediate area of the oxidizing rock piles. Factors such as soil cover and air temperature may limit the mixing of escaping gases so they concentrate within the piles. If air and water circulation patterns cause the gases to be forced out of the rock piles at the toe of the dump, they may accumulate in monitoring stations or natural depressions, which may in effect become "confined spaces" that contain toxic atmospheres with potentially deadly consequences. Please visit the following link: http://www.pdac.ca/pdac/advocacy/health-safety/health-safety-aac-confined-spaces-dumps.pdf
- Water may fill old surface workings and conceal various hazards. While water may appear shallow, it may conceal shafts, trenches, pits, machinery, illegally dumped material or sharp rocks etc. Do not wade across surface waters to collect samples. Be especially careful if it is necessary to sample the walls of a water-filled pit or depression. Wear a personal flotation device (PFD) and/or a full-body harness with shock-absorbing lanyard if there is any doubt about your safety.
- In very cold climates, abandoned raises or shafts may be filled with water in summer and yet have an ice plug remaining at the base. Should the ice melt, it might suddenly flood the lower levels while exploration is underway.
- In winter, the ice formed on tailings ponds may not freeze sufficiently to support your weight. Waters may contain chemicals that interfere with ice formation; there may be drainage or undetectable currents that cause ice to be thinner than normal despite very cold air temperatures. Gases liberated from organic sediments covered by tailings may also cause localized zones of weakness in tailing pond ice. Always measure the ice thickness before an initial crossing and on a regular basis. Work with a partner and follow recommendations in section 15.10 Working on Ice.

22.4.4 Surface Subsidence

- Watch for subtle signs of subsidence that indicate instability around shafts, raises and stopes that approach the surface. Weathered rock may collapse easily and vegetation may obscure holes, and depressions. A depression may indicate the presence of a shaft, a raise, a pit or excavation that has been backfilled, or subsidence over a stope. If the stope was worked upward to just below the surface, sometimes only a minimal crown pillar or sill may remain.
- Near shafts, watch for loose material that slumps into the shaft. Material may form a funnel-shaped crater surrounding the shaft. Look for cracks in the ground surface some

distance from the shaft that indicate slumping is in progress. It is very dangerous to approach a slumped shaft.

- Do not enter slump craters to obtain samples unless you are absolutely certain that the bottoms are solid. They may overlie a shaft, ventilation raise, or other underground working. Use a full-body harness with shock-absorbing lanyard if there is any doubt about safety and stability.
- To determine if a crater overlies a shaft or a pit, look for evidence that indicates whether the area was used as a shaft. Usually a shaft can be recognized by the presence of dump material, machinery, old timbers, and foundations of a headframe.

Figure 22.3: Slumping ground on the surface above underground mine workings © Courtney Mitchell

22.4.5 Explosives and Chemical Hazards

- Always assume that any explosives are dangerous; deteriorated explosives become unstable and they may detonate with only a slight disturbance. Leave them alone and report them to local authorities or a certified explosives expert.
- Explosives sometimes remain in holes and muck piles where the mine was last worked. There may be blasting caps in unexpected places. Watch out for blasting caps in old buildings and underground passageways. Do not step on them.
- Old nitro-glycerine based explosives should not be handled, but if it is absolutely necessary, wear rubber gloves. Explosives leak and/or sweat over time; these escaping volatiles may cause headaches and affect the heart rhythm and respiratory rate of some people if they are handled or if dust containing the compounds is inhaled.
- Hazardous chemicals may be present and may include reagents used for milling, separation processes or fuelling or lubricating old equipment. Beware of equipment such as mercury retorts, old transformers containing PCBs, decomposing bags of chemicals and leaking drums or boxes etc. Beware and keep away from anything that smells strongly of chemicals.

- Abandoned mines may have been used for illegal dumping of hazardous wastes. Be wary of all deteriorating containers whether labelled with toxic contents, or unlabelled.
- Seek immediate medical attention if you suddenly feel ill or develop respiratory or skin reactions after visiting old workings.
- In the southwestern USA, tracts of land on which old mines occur may have been used for military target practice. You risk encountering undetonated military explosives in these areas. Never touch anything that might be a military explosive device.

Figure 22.4: Old chemicals. The contents may not be identifiable. © Lisa Dyer

22.4.6 Wildlife

- Watch out for snakes, spiders, and scorpions that may live around and in old mine workings. Snakes favour protected ledges and holes. Bees and wasps favour building nests near old mine entrances and cliff faces.
- Dens: Coyotes and other wildlife (even bears) may use mine portals or culverts for dens.
- Diseases: Some animal-borne diseases are directly associated with old mine workings.
    - Histoplasmosis, a respiratory disease that may be difficult to diagnose, is caused when fungus spores associated with bat droppings enter the lungs. If you *must* enter an area with a large quantity of bat droppings, it is essential to wear the proper PPE. This includes disposable clothing, gloves and a respirator equipped with a high efficiency particulate air (HEPA) filter capable of filtering particles down to two microns in size. The respirator needs to be fit tested and the wearer needs to check frequently that it functions properly. For additional information, refer to section 12.8.5.5 Histoplasmosis and the following website: http://www.ccohs.ca/oshanswers/diseases/histopla.html
    - Leptospirosis is a bacterial infection spread to humans by contact with water or soil contaminated with infected animal urine. Leptospirosis may potentially be

contracted by people working at mine sites, especially when rats or other rodents are present. Refer to section 12.8.5.8 Leptospirosis.

- Hantaviral diseases may be contracted if humans come in contact with or inhale dust containing saliva, urine or droppings of some species of rodents. Refer to section 18.6.5.3 Hantaviral Disease.
- Rabies may be contracted from the bite of a bat and perhaps very rarely by breathing air contaminated with the rabies virus. Foxes, raccoons, and skunks are well known for carrying rabies. Refer to section 12.8.5.12 Rabies.

Figure 22.5: Coyotes den in these abandoned pipes. Other animals may also be present. © Courtney Mitchell

22.5 Preparation Requirements to Enter Old Workings

No one should explore old workings unless they have sufficient safety training plus the experience and knowledge to accurately judge the risks and hazardous conditions at the site.

22.5.1 Exploration Team Requirements

Make sure the party is large enough and each member has all the required training and equipment to do their job safely. Exploration of old underground workings should involve a team of at least three and preferably five members. The number should depend on the condition of the mine and how far the exploration proceeds. For safety, always have enough people in the party even if the country where you work does not have mine safety legislation of this nature.

- There must be at least two persons per underground team. Each team going underground should be under the supervision of at least one person who is trained to determine (1) ground conditions – scaling (barring) and sounding, (2) ground support mechanisms and (3) ventilation quality and how to use gas detection equipment. This person should be an experienced underground miner, a mine geologist or a mine engineer, preferably one familiar with the site.

- Members of the team going underground should be required to stay together. No individual should ever work alone underground. Every team member going underground should have training in mine safety techniques. The more training – the safer the investigation should be.
- One person must always remain on the surface and not enter the old workings. This person acts as liaison for those underground and any mine rescue or authorities who might require notification should problems develop. This person should have continuous access to any communication equipment necessary for this job, which may require a satellite phone.
- The team going underground should bring a mine plan with them and they should leave a plan or good sketch map showing the parts of the mine to be explored with the person remaining on surface. The team members who remain at the surface are required to know where the underground team is going and the expected time of return. Those going underground should follow the saying *“plan the exploration and follow the plan”*. Do not change the plan while underground. If changes to the plan are necessary, return to the surface and make changes to the plan with the full understanding of the person(s) at the surface. Then, return underground and follow the revised plan.
- Make sure each individual (underground or surface) has all necessary equipment (see the next section). Do not share equipment between teams.
- During exploration, rope off unsafe areas and place flagging tape across the entrances of drifts etc., that your team is NOT taking. This mine rescue practice makes it easy to follow the route in case emergency evacuation is necessary. A lost individual will be found sooner.

22.5.2 Equipment

Each person going underground should be trained and equipped with the following safety equipment:

- Hard hat
- Safety boots
- Eye protection
- Gloves
- Cap lamp (with fully charged batteries)
- Alternative light source (e.g., halogen or LED flashlights)
- Spare fully charged batteries and light bulbs
- Safety belt and line (for horizontal work)
- Full-body harness and shock-absorbing lanyard (for work in or around vertical openings), as required
- Hammer
- Spray paint or flagging tape
- Self-rescuer (oxygen producing type). It is recommended that all initial exploration be done with self contained breathing apparatus (SCBA).

- Communication devices (e.g., two-way radio approved for underground use, satellite phone at the surface, as required)
- Wrist or pocket watch – to keep track of time underground and progress of the exploration plan
- Pocket knife

Each team should carry:

- Two (2) scaling bars
- Shovel
- Airflow testing device, as required
- Gas measuring equipment:
  - Oxygen detector
  - Toxic gas detector
  - Flammable gas detector
- Wire rope-type ladders
- First aid kit
- Safety line or rope (20 metres)

Those remaining at the surface should be equipped with all necessary rescue equipment:

- Rope
- Winch
- Stretcher
- Self contained breathing apparatus (SCBA)
- Communication equipment
- First aid kit

22.5.3 Tests and Procedures Prior to Entry

- Assess the ground stress conditions – both before entering and continuously while you are in the workings.
- Assess the ventilation requirements. Carefully follow government regulations and company guidelines.
- Always test the mine atmosphere before entering, as there may be insufficient oxygen and/or dangerous levels of harmful gases present (see sections 22.6 Ventilation and 22.7 Gases). Do not enter until the workings have been flushed with fresh air if there is *any* doubt about the safety of the mine atmosphere.
- Devise an evacuation plan. Ideally, all members of the team should be familiar with and capable of executing the rescue plan. Take into consideration the equipment and personnel available for rescue. People who remain on the surface should be trained in mine rescue techniques or have a plan to promptly obtain the help of trained mine rescue personnel. Rescue personnel should be capable of retrieving a person from the mine who may be overcome by deadly gases. This may require a winch and stretcher in addition to emergency SCBA. Rescuers will need lengths of rope and the ability to tie appropriate knots for rescue work.

22.5.4 Underground Lighting

Use the best quality approved lighting equipment available. You will need to see well to avoid hazardous conditions underfoot and around you. Maintain your equipment in good condition; a life may depend on it. When in coal mines, use only equipment approved for use in coal mines.

- Only use approved equipment for the type of mine being explored.
- Use belt-mounted, rechargeable battery packs with focussing headlamps.
- If only a brief underground examination is planned, halogen flashlights may be acceptable. Always carry this type of flashlight for emergency backup lighting.
- Always carry spare, fully charged batteries and bulbs.

22.6 Ventilation

Carefully follow all government regulations and company guidelines for testing ventilation before entering any old workings or confined spaces. Improve the ventilation system wherever necessary.

- Check underground workings for any natural ventilation. Test all exhaust airways for harmful gases.
- Forced ventilation will be necessary whenever the mine atmosphere contains insufficient oxygen or unacceptable concentrations of hazardous gases. Forced auxiliary ventilation may be necessary if an extensive exploration program is planned. This type of system should have sufficient capacity (correct sized fans) to deliver fresh air to all planned work areas. Complete any necessary inspections of a forced ventilation system before venturing into work areas.
- It is always advisable to use self contained breathing apparatus (SCBA) during the first tour of exploration in an old or abandoned underground site, even when the ventilation has been inspected and found to be acceptable.
- Anticipate dangerous levels of radon in unventilated mine workings in granites, granodiorites or similar felsic volcanic rocks. If there is insufficient natural ventilation, flush out old workings with fresh air before entry, use SCBA and wear dosimeters (see section 22.7.8 Radon).
- If the mine ventilation system is questionable, each and every team that goes underground must be fully equipped with an oxygen meter and gas detection equipment to detect toxic and explosive gases *in addition* to their self rescue breathing apparatus. Do not share equipment between crews.

22.7 Gases

Many abandoned and old mine workings contain toxic, flammable or asphyxiating gases or an oxygen deficient atmosphere. Toxic gases may accumulate when ventilation ceases in old workings. This allows gases to concentrate and settle, especially in dead end drives, raises, or winzes. Follow the guidelines above in section 22.6 Ventilation.

- It should be mandatory to carry and be trained in the use of gas detection equipment (e.g., Drager Multigas tubes, single or multiple gas monitors, explosion meters) whenever an employee enters any area with no perceptible air movement. If your equipment detects dangerous gases or oxygen deficient atmosphere, abandon all exploration activities and plans and EVACUATE THE WORKINGS AT ONCE.
- Choose gas detection equipment that is suitable for the type of gas that may be encountered. Gas monitors should have an audible alarm that sounds at certain gas levels and the equipment should have an “ON” switch that cannot be turned off accidentally.
    - Follow the manufacturer’s instructions for the model of gas monitor that is used.
    - Calibration: Calibrate all monitors frequently and calibrate them on-site, whenever possible. An external authority should calibrate some monitors at prescribed intervals. Take into account the effects of relative humidity and altitude when reading the monitors.
- Never smoke, light a fire or use a gasoline engine underground. Fires consume existing oxygen and may ignite explosive gases. Gasoline engines emit deadly carbon monoxide. Even the use of a diesel engine underground requires the approval of a qualified mines inspector and will require a system of forced ventilation.
- Exposure limits: The recommended exposure limits in this chapter are taken from the current *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* published by the American Conference of Government Industrial Hygienists (ACGIH). Some jurisdictions enforce more stringent limits.

22.7.1 Oxygen O_2

Normal O_2 concentration is 20.9% in the atmosphere. To function properly, the human body needs oxygen in concentrations close to this percentage. Any concentration below 19.5% is considered oxygen deficient. Use an oxygen monitor that sounds an alarm when O_2 concentrations fall to 19.5%, and leave it turned on whenever you pass through or work in an area with no fresh air flow. In a confined area, it is possible to consume enough oxygen in 10 minutes to diminish the O_2 concentration by 2%. If more than one monitor is carried and one monitor sounds an alarm, heed that alarm and leave the area immediately. Recalibrate the monitors to determine which one produced an erroneous reading.

Symptoms of exposure to an oxygen deficient atmosphere: A person will breathe more rapidly at 17% O_2 concentration. At 15% O_2 concentration, a person will experience dizziness and headaches and unconsciousness will soon follow.

The following causes contribute to oxygen depletion in mines:

- Oxygen may be diluted by the build-up of nitrogen, methane and/or carbon dioxide.
- Old workings sometimes contain piles of broken sulphide-rich rock within the mine. Gradual oxidation of these wastes may consume the available oxygen or produce sulphur dioxide (SO_2).
- Ground water depleted in O_2 will absorb oxygen from the atmosphere.
- Dry rot etc., which causes timber to decay, requires atmospheric oxygen. Oxygen depletion will be more rapid if the air is hot and humid and if timbers are crushed.

- Rusting iron pipes, rails, rock bolts etc., and other iron materials abandoned in mines will utilize atmospheric oxygen.
- Lack of air flow contributes to an oxygen deficient atmosphere.
- The atmosphere in confined spaces may become "layered" if there is no air movement.

Tests for oxygen depletion

- Use an oxygen monitor to test for oxygen depletion. Always use an oxygen monitor and keep it turned on when (1) there is any question about the oxygen content of the atmosphere at the work area, and (2) if the work area or transit route has limited or no air flow.
- If symptoms of oxygen deficiency develop and an oxygen monitor in not available, leave the area and do not return until you secure proper oxygen testing equipment and ventilate the area.
- An oxygen test using a candle or a match is not a good test. Disposable cigarette lighters and carbide lamps will continue to burn in low oxygen atmospheres. Never depend on them as indicators of oxygen depletion.

22.7.2 Carbon Dioxide CO_2

Carbon dioxide is a colourless and odourless gas. CO_2 is classified as an asphyxiant because it may dilute or replace the oxygen required to breathe. CO_2 is heavier than O_2 so it sinks, displaces oxygen and accumulates in low areas.

Exposure to CO_2

- Exposure to CO_2 should not exceed 5000 ppm. This level of concentration can build up in old mine workings especially in low areas with no air flow.
- Symptoms of carbon dioxide exposure: You will breathe more heavily and deeply when you breathe CO_2 concentrations at a low level. This effect is accentuated by exertion. An acid taste develops in your mouth when you breathe CO_2 concentrations at a moderate level.

Sources of CO_2

- Mine fires and the slow combustion of timber release CO_2.
- The breakdown of carbonate ores and some sulphide ores releases carbon dioxide, which may displace oxygen in the atmosphere; this may cause death in confined spaces, see section 22.11 Confined Spaces below.
- Standing water in old mines and biochemical action in moist confined spaces liberate CO_2.
- Blasting releases CO_2.

Tests for CO_2

- The only reliable test of CO_2 content is to use a CO_2 detection instrument or detection tubes.

22.7.3 Carbon Monoxide CO

Carbon monoxide is a colourless, odourless and tasteless gas. It is very toxic in very low concentrations because it actively replaces oxygen in red blood cells and starves the brain of oxygen. Humans will die of asphyxiation no matter what the atmospheric oxygen concentration when enough oxygen in the blood is replaced by CO (carbon monoxide poisoning.) Mechanical ventilation systems are necessary when diesel engines are used in any mine situation and gasoline engines are prohibited due to the CO produced and carried in the exhaust. Exhaust from engines operating at the surface must not be allowed to enter mine ventilation systems.

Exposure to CO

- Exposure to CO should not exceed 25 ppm.
- Exposure to 1200 ppm or higher is immediately dangerous to life and health.
- Symptoms of carbon monoxide poisoning begin with a headache. Confusion, staggering, nausea and death will quickly follow. If you suddenly encounter high concentrations of CO, you may collapse with no prior symptoms. Employees should be trained to recognize the symptoms of carbon monoxide poisoning and understand how rapidly it can kill.

Sources of CO

- Incomplete combustion produces CO (e.g., smoldering or slow burning mine fires)
- Blasting operations
- Combustion by-products from fuel burning engines, motors, heating sources
- CO is commonly present in coal mine atmospheres.

Tests for CO

- The only reliable test for CO is to use instruments designed to detect the presence of CO (e.g., Drager Multigas Detector or a gas monitor).

22.7.4 Hydrogen Sulphide H_2S

Hydrogen sulphide is colourless, extremely flammable and smells initially of rotten eggs. You cannot smell high H_2S concentrations because the gas overwhelms the olfactory (smell) nerves. Like carbon monoxide (CO), H_2S can cause asphyxiation by replacing oxygen in the red blood cells when inhaled. Although this poisonous gas is rarely found in active mines, it is often present in stagnant waters in old workings.

Exposure to H_2S

- Exposure to H_2S should not exceed 15 ppm. More stringent limits may apply depending on local regulations. Exposure to 20 ppm may require breathing apparatus depending on the local regulations.
- Exposure to 100 ppm or higher is immediately dangerous to life and health.
- Exposure to 500 ppm can cause immediate collapse and death.

Sources of H_2S

- The reaction of acidic water with sulphide minerals produces H_2S.
- The reducing action of bacteria in acidic water produces H_2S.
- H_2S is associated with oil and gas operations or may accumulate in petroliferous rocks.
- H_2S may be released in dangerous quantities by disturbing waters in old mine workings because it is very soluble in water.

Tests for H_2S

- Use an appropriate detection instrument to check the concentration of H_2S.
- If you encounter the slightest smell of hydrogen sulphide, DO NOT PROCEED. Evacuate the area immediately and stay out.

22.7.5 Methane CH_4

Methane (natural gas) is colourless, odourless and tasteless. It is highly explosive in air in the presence of an open flame if the concentration is between 5% and 15%. Methane may dilute the O_2 concentration in air and cause asphyxiation. In a pure state it is lighter than air and it usually concentrates near the roof in a mine. If CH_4 mixes with carbon dioxide, the mixture sinks to the floor.

Exposure to CH_4

- Ambient air in a mine should have levels of methane below 1 to 1.5%. Use gas monitoring equipment to verify that the CH_4 concentration is below this level.

Sources of CH_4

- Methane is derived from coal seams, decaying timbers and organic matter in rock.
- Methane is most commonly found in coal mines, but it can also be present in metalliferous mines in sedimentary wallrocks.

Tests for CH_4

- Use instruments such as a Drager tube or an explosion meter calibrated for methane.

22.7.6 Nitrogen Oxides NO and NO_2

These gases are very toxic and small concentrations can cause death. NO_2 (nitrogen dioxide) combines with body fluids to produce nitric acid in the lungs and it will replace the oxygen in red blood cells. Enough NO_2 to produce irritation in your nose and respiratory tract may be lethal. While one may not feel the effect for several hours after contact, it may be enough to be fatal.

Exposure to NO and NO_2

- Exposure to NO should not exceed 25 ppm.
- Exposure to 100 ppm or higher of NO is immediately dangerous to life and health.
- Exposure to NO_2 must not exceed 5 ppm.
- Even with an appropriate respirator, exposure to NO_2 must not exceed 20 ppm as that concentration is immediately dangerous to life and health.

Sources of NO and NO_2

- NO and NO_2 form during the detonation of explosives. Water down any dry muck pile where there has been recent blasting. This will convert any NO_2 to nitric acid and prevent people being overcome by NO_2.
- NO and NO_2 form during combustion in diesel engines.

Tests for NO and NO_2

- Use gas monitoring equipment to detect the presence of NO and NO_2.
- The odour of NO_2 is similar to burnt blasting powder. It is unlikely that a person would be able to smell NO_2 as the odour is usually masked by that of diesel or other blasting by-products. If you smell NO_2, DO NOT PROCEED. Evacuate the area immediately and stay out.
- Nitrogen dioxide has a reddish-brown colour. Nitric oxide gas converts to nitrogen dioxide on contact with oxygen.

22.7.7 Sulphur Dioxide SO_2

Sulphur dioxide is a very poisonous, colourless, irritating gas that smells strongly of sulphur. SO_2 irritates your eyes and respiratory passages as it combines with body fluids to produce sulphuric acid in your upper respiratory tract. SO_2 is a more common problem in active mines rather than in old mine workings, as diesel engines produce the gas during combustion.

Exposure to SO_2

- Exposure to SO_2 should not exceed 2 ppm.
- Exposure to SO_2 of 100 ppm or higher is immediately dangerous to life and health.

Sources of SO_2

- SO_2 may result from spontaneous combustion (fires) in sulphide ore bodies.
- SO_2 may be produced during the oxidation of sulphide ores.
- SO_2 is a product of combustion from diesel engines.

Tests for SO_2

- Use a monitor to detect the presence of SO_2.
- SO_2 produces a suffocating, pungent sulphurous odour. If you smell it, DO NOT PROCEED. Evacuate the area immediately and stay out.

22.7.8 Radon Rn

Radon and its decay products are a serious hazard to lungs because they are radioactive. Once inhaled, the radioactive atoms tend to remain in the lungs and emit alpha radiation, which destroys lung tissue. Flush old workings with fresh air before entering and always carry and use detection equipment (using this equipment may be a complex procedure). For extended work, consider the use of dosimeters. Respirators are needed when the concentration of radon gas and radon daughter products exceed recommended levels.

Sources of radon

- Expect dangerous levels of radon and decay products in the stagnant air in old uranium mines and any mine within granitic, granodioritic or felsic volcanic rocks. These rock types frequently contain radioactive minerals that decay and produce radon as daughter products.
- Radon levels can be high even though a mine has never produced uranium.
- Radon may be present in water in old mine workings in higher concentration than in the mine atmosphere. If you disturb the water you may release radon that was not initially detected.
- Avoid dust and smoke (cigarettes) as radon and decay products attach to smoke particles.

Tests for radon

- Use detection equipment to test the exhaust air of the mine. Continue monitoring the atmosphere while working in the mine unless the atmosphere is well flushed and the work is only for a short time.

Information about ionizing radiation risks can be found in 15.0 Guidelines for Radiation Protection during Exploration for Uranium on the Environmental Stewardship toolkit at www.pdac.ca/e3plus and on the following website: http://www.ccohs.ca/oshanswers/phys_agents/ionizing.html

22.8 Shafts, Adits, Tunnels and Declines

Shafts

Exploration personnel should never enter old or abandoned vertical shafts without the project having first been examined and safety determined by appropriate mine engineers and safety personnel. It is beyond the mandate of these guidelines to cover safe entry or descent of mine shafts. Thus the PDAC recommends that no one enter such workings without professional mining staff involved (e.g., professional miners, mining engineers or specialists trained in mine remediation).

Adits, Tunnels and Declines

To investigate adits, tunnels and declines, there should be at least three (preferably five) fully trained and fully equipped members on the team. No less than two team members may enter the workings. The leader should be an experienced underground miner, a mine geologist or a mine engineer, preferably one who is familiar with the underground workings. At least one team member must remain at the surface to act as liaison for the underground team members and for any mine rescue or government authorities who might require notification should problems develop or if the underground team does not return by a pre-set time. Team members should follow the required preparation procedures as described in section 22.5 Preparation Requirements to Enter Old Workings.

- Check for air movement. Do not enter abandoned workings unless there is a perceptible air current or you have flushed the workings with fresh air. If there is any doubt whatsoever, carry and use gas detection equipment, an oxygen monitor and SCBA.

- Portal: Carefully clear away loose rock and debris in front of the portal. Inspect the wall rock, back (roof) and any support material before entering. Rock falls commonly occur at the portal because it is commonly a zone of weakness. Before entering, check carefully for snakes, rodents and larger animals. Use the portable lighting equipment to inspect the interior before entering. Do not touch the back (roof) or ribs (sides), especially if entering a decline.
- Declines: Use extra caution. Some declines are steep and may require ropes and belays to enter safely. Bar down or scale as required before entry but do not touch the back (roof) or ribs (sides) unnecessarily, as this may dislodge material.

As you proceed:

- Scaling (barring): Check the condition of the back (roof) with a scaling bar. Check for the hollow sound of loose rock in the back. Never pass under "drumming" (hollow sounding) ground without scaling down. Never ignore this job. The experienced person present should scale and follow strict safety procedures while scaling. The entire roof may cave in if scaling is not done correctly.
- Watch out for slabs or rock that may break off the walls.
- Continuously watch for signs of loose ground. These may occur in areas of geologic weakness or where blasting has taken place. They include cracks, fractures, rock falls etc.
- Evacuate the area immediately if you hear a trickle of ground falling – however gently – from the back (roof).
- Evacuate the area immediately if you hear any loud snapping sounds. These sounds indicate a potential rock burst.
- Be wary of water that runs or trickles down passes or chutes as it may trigger a run of material.
- Never disturb hang-ups in chutes and ore passes under any circumstance. You may trigger a rock fall or cave-in.
- Watch out for open holes, winzes, chutes and passes. Secure yourself with proper fall protection equipment (including a full-body harness and shock-absorbing lanyard) whenever working near winzes, ore passes or other vertical openings.
- Mark the route clearly at each junction with spray paint or flagging tape. Place flagging tape across the drifts and openings that are not entered or explored. This mine rescue practice indicates to any followers the route that was *not* taken. Rope off any sections of the mine that are considered unsafe. Do not rely on old maps as they are often inaccurate or incomplete.
- Beware of abandoned equipment or objects that may stick out from walls (e.g., nails, wires and pipes, boards with nails or sharp rails).
- Do not unnecessarily touch any equipment, service ducting or valves that may be encountered.

22.9 Common Hazards in Old Underground Workings

22.9.1 Timbers

- The presence of underground support materials may give a false sense of security; these may be very weak even though they appear strong and well maintained.
- Stay out of old timbered areas and stoped areas, as it is impossible to determine the support strength of old timbers. Dampness will rot timber quickly, but dry rot can occur even when a mine is very dry.
- When you find the remains of timber, this may indicate a zone of weakness that required support at the time of mining. Anticipate that ground conditions will have further deteriorated.
- The condition of timbers may reflect the stability of the ground in the mine. Watch out for rocks sitting on timbers, crumpled or compressed tops of timber supports, and broken or compressed cribs and stulls.
- You could be injured or killed by falling timbers. Do not bump them or do anything to add to their load. Because it is impossible to determine how much weight timbers can support, it is only safe to assume that they are at their limit. One should be particularly suspicious of the strength of old timbers on the floors of tunnels and those found in shaft collars and adit portals. Dry rot may have weakened them; they may collapse when stepped on or jarred.

22.9.2 Ladders

- Unmaintained ladders are extremely hazardous due to rust, which weakens the ladder and fasteners to rock. Wooden ladders may be rotted and unsafe to use. Use rope and belay techniques when using an unmaintained ladder the first time – and any time you are unsure of its safety. Use ladders only when there is no other choice.
- Before use, inspect the ladders to make sure they are properly affixed to the rock or to timber that is in good condition. Old ladders may show signs of deterioration (e.g., rusted metal nails, rotten timber, missing rungs).
- Never step off a ladder without checking that the landing is safe. Ladders sometimes end where staging has fallen away. Check that your footing is secure as loose rocks on landings may cause falls.
- As you descend, go slowly and carefully – one person at a time on the ladder. Hold on to the rungs rather than the sides of the ladder. Take care when placing your feet because there may not be much space between the rungs and the wall. Take care not to kick material onto someone below you. The first person down the ladder may be able to safely remove loose debris, but never knock anything down if there are people below.
- While descending, note the condition of the ladder and timber. If it deteriorates, do not descend further. Do not count on another exit route.
- Do not look upwards when ascending a ladder. Do so only if wearing safety glasses.

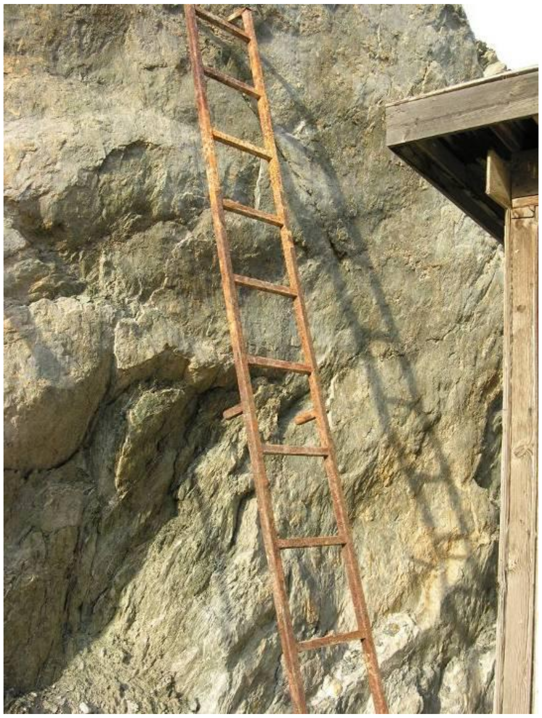

Figure 22.5: This ladder was removed due to its deteriorated condition. © Courtney Mitchell

22.9.3 Water

- Do not proceed through old workings when the floor is under water until the floor is well tested with a probe. Water may conceal slippery, slimy surfaces. It may hide winzes, holes or pits, old machinery, sumps, rail lines, broken rocks etc. If you must proceed and there is any question of safety, wear a safety rope.
- Before walking on them, carefully test all boards, steel plates or timbers on the floor that cover pools of water. They may cover passes or winzes and may no longer have sufficient strength to support any weight.
- Disturb standing water as little as possible. Pools of water may contain dissolved H_2S or radon that may be liberated when people splash through them.
- Water may enter an old working and flood it or it may be an intermittent problem. It is never safe to enter unfamiliar old mine workings (or caves) in rainy weather, as nearby streams may overflow and enter shafts or other openings.
- Water may be alkaline or acidic and cause skin irritations.

22.9.4 Muck Piles and Mine Fill

- Do not follow anyone up a muck pile. Wait for them to reach the top before ascending. Take care when descending not to dislodge material onto people below.
- Watch out for fine muck piles (particularly massive sulphide muck), as these may begin to avalanche if you step on them.

- Beware of wet slime that has accumulated as fill; it may retain its moisture content and not support your weight – you may sink into it. Coarse-sized mine fill is usually very sound and should support a person's weight.

22.10 Sampling on Abandoned Mine Sites – Surface and Underground

- Before taking samples, complete a tour of the workings to determine if it is safe to do so. Use common sense. Never take samples from workings with unstable ground, collapsed timbers or where rock has fallen from backs (roofs), raises or chutes.
- Before taking samples, a trained person must carefully sound and scale (bar) down loose material with a scaling bar to test the back and sidewalls. Scaling is very dangerous and should only be done by an experienced underground miner.
- Do not take samples from shatter points caused by explosives or around old drill holes. The impact of your hammer may detonate any remaining explosives.
- Do not sample from underground equipment (e.g., scoop trams).
- Wear eye protection while sampling. Watch out for nearby effects – loosening of pieces of rock overhead and slabs on walls.
- Use caution when searching for core samples in old core storage areas. The supporting framework may have deteriorated and core boxes may be very unstable. Watch out for snakes or scorpions etc., that may inhabit old core boxes.
- Do not wade across surface waters to collect samples. Be especially careful if it is necessary to sample the walls of a water-filled pit or depression. Wear a personal flotation device (PFD) and/or a full-body harness with shock-absorbing lanyard if there is any doubt about your safety.
- Sampling on the surface near old abandoned shafts is very unsafe. Wear a safely anchored full-body harness with shock-absorbing lanyard.

22.11 Confined Spaces

Confined spaces present special hazards to workers that include oxygen deficiency and/or toxic or asphyxiant gas accumulations, fires, flooding, falls and entrapment. The exact definition of "confined space" varies according to the type of industry and the jurisdiction, but the basic criteria for a confined space commonly include the following:

1. There is a limited opening for entry and exit.
2. There is limited natural ventilation with the potential for containing hazardous atmosphere.
3. The space is not designed or intended for continuous occupancy, but is large enough for an employee to perform work.

All Canadian and US jurisdictions have regulations that address confined space entry although different jurisdictions use additional criteria to define a permit-required entry into confined space. It is extremely important for a company to identify any confined spaces and permit-requiring confined spaces that their employees or contractors may be required to enter.

Confined space fatalities: Almost 70% of confined space fatalities involve compromised atmosphere – victims die from lack of oxygen or are overwhelmed by toxic gases. Some studies indicate that about half of these deaths are would-be rescuers. Studies also indicate that the deadly conditions were pre-existing, which indicates that no testing and no ventilation of the space were carried out before the accident. The earth's normal atmosphere contains 20.9% oxygen and the oxygen level must be between 19% and 23% for safe entry into a confined space.

Risks and hazards of confined spaces that may be encountered by exploration employees

- Death or injury caused by atmospheric hazards:
  - Suffocation: The lack of ventilation, the presence of some oxidizing processes, the presence of some gases and/or water may all contribute to an oxygen deficient atmosphere causing death.
  - Asphyxiation: Some gases create a toxic atmosphere and poison the body (e.g., carbon monoxide, hydrogen sulphide). Carbon monoxide poisoning is frequently the cause of death when fuel powered equipment is used in an enclosed space (e.g., power washer, heating device, generator).
  - Agitation of stagnant waters, sludges and/or residues can liberate dissolved or trapped toxic gases.
  - Mineral decomposition processes may release toxic or asphyxiant gases that replace oxygen in the atmosphere.
- Difficult or dangerous rescue conditions:
  - Rescuers may be at risk due to oxygen depletion.
  - Restricted access may make a rescue very difficult.
- Slips, trips, falls caused by walking on uneven or slippery ground, stepping on material that collapses, wearing inadequate footwear
- Getting lost caused by poor visibility
- Thermal or chemical burns caused by fire and/or explosion:
  - Flammable gases may be present in dangerous concentrations (e.g., methane).
  - Too much O_2 in the atmosphere (over 23%) creates a fire/explosion hazard.
  - Restricted access makes escape very difficult if there is a fire.

Responsibilities Regarding Confined Spaces

Exploration Companies

- Develop written safe operating procedures for entry to and working in all confined spaces. Comply with requirements of the AHJs for entry into confined spaces. Develop a confined space safety program, as required. See the prevention and preparation section below.
- Make sure a risk assessment of any confined space is completed by a qualified person and the risk information is fully documented. The results should be communicated to supervisors and workers so they know what hazards to expect.
- Make sure supervisors and employees are adequately trained to safely perform their duties, use their PPE, and carry out potential emergency procedures related to the specific type of confined space.

- Supply all required PPE, such as gas monitoring and testing equipment, and make sure it is properly calibrated.
- Make sure that people are aware of confined spaces by posting signage and restricting access. Make sure employees conform to confined space entry requirements including the issuing of an entry permit, as required. Make sure safety measures remain in place.

Supervisors

- Develop site specific SOPs regarding confined spaces that conform to the elements of the confined space safety program, as required. Make sure employees are trained and that they understand and implement the SOPs.
- Make sure hazards are identified and evaluated each time before any employee enters a confined space.
- Make sure workers are aware of the risks and hazards associated with confined spaces and the requirements to enter a confined space if they are required to do so as part of their job.
- Develop a site specific ERP that addresses situations where there is potential for oxygen depletion and rescue when an employee collapses.
- Prevent access to confined spaces by unauthorized, unprepared people (workers, public, site visitors etc.).
- Make sure the correct PPE and equipment are used by any employee who enters confined spaces.
- Document all testing and/or entry permits and keep them for the required length of time.

Employees

- Follow all SOPs, training, and use all required PPE regarding confined spaces.
- Always test the atmosphere and document the test results. Continue testing while working in any confined space, as required.
- Follow all ERPs, especially regarding potential oxygen depletion situations if a co-worker collapses.

Although true “confined space” work is rare in the mineral exploration industry, there are circumstances when confined spaces may be encountered.

- Old or abandoned underground mine workings: These fit some of the general criteria and the most obvious hazards stem from potentially low oxygen atmospheres or toxic atmospheres due to the higher than normal presence of carbon dioxide and hydrogen sulphide etc. If diesel motors are used, there is the additional risk of carbon monoxide build up. Some old mine workings contain methane, which is a potential explosive hazard. Hazardous amounts of radon and hydrogen sulphide may be dissolved in underground water, which can be disturbed and liberated when workers splash through it. Any long narrow opening such as a tunnel may develop features of a “confined space” when air flow is limited.
- Unexpected confined spaces: Monitoring stations – a small enclosed building may, through its design, be an enclosed space. Be careful and observant when exploring near tailings and waste rock dumps. If the site contains a combination of sulphide and carbonate minerals in the waste rock dumps, tailings piles, tailings dams, ore stockpiles etc., the minerals may react to produce carbon dioxide and potentially produce a severely

oxygen deficient atmosphere. Factors such as soil cover and air temperature may limit the mixing of escaping gases and cause the gases to concentrate within the piles. In addition, if temperature conditions combined with air and water circulation force the gases out of the rock piles at the toe of the dump, they may accumulate at a low point in a closed monitoring station. This can in effect become a "confined space" that contains toxic atmospheres – with potentially deadly consequences. This is a documented cause of death in the mining industry. At old mine sites it is also possible for heavy gases to accumulate in open spaces such as low lying depressions or sheltered ravines below dump toes etc.

- Trenches or pits: Their configuration and the use of gasoline or diesel powered equipment (even nearby on the surface) may cause exhaust fumes to drift and sink into the excavation and asphyxiate workers. This is a documented cause of death in the mineral exploration industry. Refer to the Anglo American SHE Bulletin 149/2006 *Dangers of Gas Emissions From Solid Waste Dumps,* available here: http://www.pdac.ca/pdac/advocacy/health-safety/health-safety-aac-confined-spaces-dumps.pdf
- Adits or shallow mine shafts: Any long narrow space may develop an oxygen deficient atmosphere if the space lacks ventilation.
- Tanks, sumps: Enclosed storage tanks for fuel etc., are typically considered to be confined spaces. Maintenance work on the inside of any tank would require a confined space entry permit (see the prevention and preparation section below). The presence of rust on the inside of a structure is an indication that oxygen has been absorbed from the atmosphere. This may result in an oxygen deficient atmosphere, which may not be obvious to people who are not trained in confined space safe work procedures.
- Anglo American has granted permission for the PDAC to post on its website the following Anglo American Safety, Health & Environment Bulletin and supporting documents:

  SHE Bulletin No 148/2007 *Gas in Confined Spaces: A Silent, Deadly Killer*
  http://www.pdac.ca/pdac/advocacy/health-safety/health-safety-aac-confined-spaces.pdf

  SHE Fact Sheet supporting Bulletin No 148/2007 *Gas in Confined Spaces: The Facts*
  http://www.pdac.ca/pdac/advocacy/health-safety/health-safety-aac-confined-spaces-facts.pdf

  SHE Example Sheet supporting Bulletin No 148/2007 Examples: *Gas in Confined Spaces: Illustrating the Dangers*
  http://www.pdac.ca/pdac/advocacy/health-safety/health-safety-aac-confined-spaces-examples.pdf

Prevention and Preparations

- Identify any confined spaces that may be accessed by employees. Identification should include any possible confined spaces at old mine sites in the area that employees might be inclined to visit. Companies are advised to develop a policy regarding the entry to such confined spaces including possible access to those spaces when employees have recreation time.
- Training: Employees should receive training regarding (1) the recognition and identification of confined spaces and potential specific hazards, (2) the elements of the site confined space safety program, (3) the proper use of PPE, (4) the emergency response procedures should a co-worker collapse, and (5) confined space and/or mine rescue training, as appropriate.
- Carry out the following before each and every entry into a confined space:

  - Testing is essential to determine if the atmosphere in the confined space is safe for workers to enter.
  - Check and calibrate (if necessary) all gas testing equipment according to manufacturer's instructions. Before use, make sure the correct sensor is in the air monitoring equipment. Keep maintenance records.
  - Rescue plans: Employees should be familiar with the requirements of the AHJs regarding rescue equipment that must be immediately available. They should be able to rescue co-workers and have all necessary means of communication and transportation to a medical centre in place.
- Carry out the following while working in a confined space
  - Continue testing while working in a confined space. Take measurements at high and low levels. Gases that are lighter rise and those that are dense sink. In an old drift, it is possible for one person can consume enough oxygen to deplete the atmosphere in about 10 minutes.
  - PPE: Employees should wear or have available all required PPE, which may include safety glasses, hard hat, appropriate safety footwear, gas monitoring and testing equipment, SCBA, a self-rescue breathing apparatus, and other items required by the company or AHJs. Only trained employees should be permitted to use SCBA.
- Confined space safety program: A confined space safety program should be developed as required by AHJs. The safety program should include the following elements as a minimum:
  - Confined space policy that clearly defines responsibilities
  - Confined space identification, warning signage
  - Written SOPs that apply before and during work, which may include a required entry permit system.
  - Personal protective equipment
  - Atmospheric testing and ventilation
  - Fire safety
  - How to control all hazards before and during work
  - Emergency response plans and procedures
  - Training program
- Confined space entry permit: The use of a confined space entry permit verifies that proper safety procedures are followed each time a worker enters a specific confined space. The permit identifies the location and type of confined space, the permissible duration of the work, details of the work performed, and the safety tests performed (e.g., atmospheric tests, precautions taken before entry, PPE requirements). The permit is filled out and signed by a person in authority and the entry workers; it should be kept as a record of compliance with AHJs.
- Additional information regarding confined spaces is available on the following websites:

  http://www.ccohs.ca/oshanswers/hsprograms/confinedspace_intro.html
  http://www.ccohs.ca/oshanswers/hsprograms/confinedspace_program.html
  http://www.mediaroom.gov.bc.ca/sullivan_mine/ACMER-Phillip-et-al-Sullivan-Mine-Fatalities-Investigation.pdf
  http://www.hrsdc.gc.ca/eng/labour/publications/health_safety/confined/page00.shtml

22.12 Resources

The Prospectors & Developers Association of Canada (PDAC) thanks the following for granting permission to include material from their publications.

Association for Mineral Exploration British Columbia (AME BC)

The Australasian Institute of Mining and Metallurgy

Their permission does not imply that they endorse the PDAC Health and Safety Guidelines. The PDAC is solely responsible for the content of these Health and Safety Guidelines.

Books

American Conference of Industrial Hygienists, (annually updated) *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.*

Berkman, D. A. (2001) *Field Geologists' Manual, 4th edition,* Section 11.2 pp 364-366, The Australasian Institute of Mining and Metallurgy: Melbourne.

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