Irrespirable atmosphere in a mine or quarry

Incident learnings and recommendations

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Queensland Government

Summary

An atmosphere is considered to be irrespirable under conditions where there is an immediate threat to life or the potential for adverse health effects. The potential for the atmosphere in a mine or quarry to become irrespirable due to airborne contaminants, the loss of a fresh air supply, or other causes is well recognised in industry.

Irrespirable atmospheres can occur as a result of oxygen depletion or the presence of hazardous gases such as methane (CH_4) or carbon dioxide (CO_2) displacing oxygen (O_2).

Low oxygen levels pose a great risk to workers and can be fatal. Symptoms of oxygen deprivation include increased heart rate and breathing, impaired judgement or awareness, fainting and loss of consciousness. Exposure to an atmosphere containing less than 6% oxygen can lead to death by asphyxiation within minutes.

Queensland legislation[1] requires mines and quarries to have effective control measures in place to ensure that workers in every part of the mine or quarry are supplied with air of sufficient quality, volume and velocity to ensure a healthy work environment.

This report summarises several incidents that have occurred in recent years in Queensland mines and quarries where a worker was exposed to an irrespirable atmosphere. It states the contributing factors and makes recommendations to industry with the aim of highlighting risk controls which must be implemented and verified to prevent the unwanted outcomes of worker injury and death.

[1] *Mining and Quarrying Safety and Health Act 1999*, Mining and Quarrying Safety and Health Regulation 2017

[1] *Coal Mining Safety and Health Act 1999*, Coal Mining Safety and Health Regulation 2017

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Purpose of the report

The Queensland Government believes that providing information relating to incidents on mine sites is an important part of continuous improvement in mine safety and health[2].

In the past 15 years there have been 24 incidents related to irrespirable atmosphere in the Queensland mining and quarrying industry including three serious accidents (requiring hospital admission) and one workplace fatality.

This report provides learnings from these incidents in order to raise industry awareness and makes a number of recommendations related to risk management.

Irrespirable atmosphere

Irrespirable atmospheres can occur in mines and quarries as a result of oxygen depletion or the presence of hazardous gases such as methane (CH_4) or carbon dioxide (CO_2) displacing oxygen (O_2). Low oxygen levels pose a great risk to workers and can lead to serious injury or death.

Symptoms of oxygen deprivation include increase heart rate and breathing, impaired judgement or awareness, fainting and loss of consciousness. Exposure to atmosphere containing less than 6% oxygen can lead to death by asphyxiation in minutes.

The table below shows the effects of being exposed to low oxygen levels.

Table 1: Effects of exposure to low oxygen level[3]

Physiological effects	**Concentration of oxygen (%)**
None – normal concentration in air	20.9
None – acceptable concentration range in confined space[4]	19.5 - 23.5
Slight increase in breathing effort, some loss of night vision	18.0
Slight increase in pulse and breathing rate, night and colour vision affected and judgement affected	16.0
Abnormal fatigue upon exertion, emotional upset, impaired judgement and fault co-ordination	14.0
Poor judgement; rapid fatigue, risk or cardiac damage	12.0
Nausea, vomiting, inability to move or cry out, loss of consciousness may occur	< 10.0
Convulsions, respiration ceases, heart function ceases	< 6.0

[2] Resources Safety and Health Compliance Policy, MIN/2018/4325

[3] Bird et al., 1999, *Emergency Preparedness and Mines Rescue,* Mines Rescue Board, NSW, p 139.

[4] Section 144 of the *Mining and Quarrying Safety and Health Regulation 2017*.

The incidents summarised in this document describe events where a worker was exposed to an irrespirable atmosphere including:

- entering an unventilated area
- working in a confined space
- working in an area where oxygen was displaced as a result of carbon dioxide release from water
- working in an area where argon – an inert gas used in industrial processes including welding - was released during the removal of sealing bungs
- driving through a barricaded area.

The document identifies contributing factors for these incidents and explores one of them in detail. It also highlights physical and chemical properties of carbon dioxide that must be considered when entering an area where gases may be present:

- Carbon dioxide is denser than air; a layering effect can lead to reduced oxygen nearer the floor
- Carbon dioxide is water soluble; a pressure change (e.g. static head from a diamond drill hole into old workings/open pit above) can release it to the atmosphere.

List of incidents (2004 to 2018)

Table 1: List of incidents, mines and quarries, 2004 to 2018, irrespirable atmosphere

Date	Mine type	Summary	Contributing factors
27/09/2018	Underground mineral mine	A pump fitter, driving a light vehicle, entered an unventilated area of the mine. Approximately 100m off the decline his vehicle stalled without warning. On exiting the vehicle, he immediately had difficulty breathing, so re-entered the vehicle, donned his self-rescuer and made an emergency call over radio. Upon confirmation from his supervisor, he walked up the decline and waited for assistance. He was then brought to the surface and taken to the site medical technician. First aid was administered and he was able to continue his shift. The emergency response team attended the scene to test the air quality and found low levels of oxygen (<10.0%) and excessive levels of carbon dioxide (>6.8%).	• No risk assessment was completed to inform the decision to re-enter the old workings of the mine. • A failure to identify the risk of a potentially contaminated atmosphere. • An area of the mine with inadequate ventilation was not barricaded. • The lack of ventilation also meant the area was subjected to a build-up of vehicle exhaust fumes. • Underground pump fitters were not required to carry gas detection devices. • Risk had become normalised as workers had been accessing the area without ventilation for a considerable time, even though this was in conflict with the mine's procedures.

Date	Mine type	Summary	Contributing factors
6/07/2017	Underground mineral mine	During a 6-monthly calibration test, it was discovered that photo ionisation detectors (PID), which measure the concentration of specified gases, had been turned off on three of five portable gas detector units used in a processing area. This had the potential to expose workers to harmful levels of carbon disulphide and methyl isobutyl carbinol gas. Carbon disulphide and methyl isobutyl carbinol are flammable and toxic. Methyl isobutyl carbinol vapour irritates eyes and nose and may cause anaesthesia. Carbon disulphide can cause permanent injury; affecting the central nervous system, cardiovascular system, eyes, kidneys, liver and skin[5].	• The PID is a critical control (its absence or failure significantly increases the risk of serious harm to a worker). • No verification of PID operation had been performed outside of the 6-monthly planned maintenance schedule. • Gas detectors were not made tamper-proof. The PID could be turned off without raising an alarm or notification. • Pre-start checks for the portable gas detector units were found to be inadequate. Even though the PIDs had been turned off, the units passed a function test which involved connecting them to a gas cylinder containing known concentrations of specified gases.
16/04/2015	Surface mineral mine	While performing maintenance on an Apron Feeder, which the mine had designated a confined space, a worker (spotter) entered the feeder to retrieve a rescue line which had been accidentally dropped inside. This resulted in the both workers being inside a confined space without the required risk controls in place (e.g. no spotter).	• The rescue line length was too short for the work being undertaken. • The spotter breached the mine's confined space entry procedures.

[5] CAMEO Chemicals, https://cameochemicals.noaa.gov/chemical/3942, viewed on 3 April 2019.

Date	Mine type	Summary	Contributing factors
28/07/2014	Surface mineral mine	An electrician entered a pontoon, which the mine had designated a confined space, to perform maintenance on a sensor. As work commenced he realised he lacked the correct tools to perform the job. The electrician asked his co-worker (spotter) to leave the work area and obtain the required tools. Upon returning, the spotter assumed the electrician was no longer inside the pontoon and replaced the sealing hatch. Unable to exit the pontoon, the electrician made an emergency call by radio and was rescued by co-workers; he did not sustain physical injury.	• Procedures for confined space entry were not adhered to. • Work should have ceased while the correct tools and equipment were obtained to complete the job. • A lack of communication between the spotter and electrician resulted in the latter being trapped inside a confined space.
6/05/2014	Underground coal mine	While calibrating gas detectors, an electrician opened a hatch which released a flow of an irrespirable atmosphere, asphyxiating him almost immediately. The worker was provided with a Job Card that directed him to perform electrical maintenance work at a location that was within a goaf and caused him to open the hatch.	• The Mines Inspectorate Investigation Report identified several contributing factors, spanning supervision, planning, and training.
7/03/2011	Underground mineral mine	Two underground workers were performing maintenance work on a dewatering pump which had developed a fault. On completion of the work, while turning their vehicle around at the sump, both experienced breathlessness and promptly drove back up the decline. They barricaded the area to prevent entry and reported the incident. Atmospheric testing conducted during the investigation found the oxygen level to be 19%; below the mine standard of 20%.	• Oxygen levels in the low-lying area of the pump had been displaced by carbon dioxide, released from the water. • A build-up of carbon dioxide may have occurred when the mine's primary ventilation system was shut down for testing earlier in the day. • A barricade preventing access to the area was absent as it had been removed by workers some time prior to the incident.

Date	Mine type	Summary	Contributing factors
2/10/2010	Underground mineral mine	A shift supervisor driving a light vehicle entered an unventilated drive. The vehicle engine stalled and the supervisor exited the vehicle and returned to surface. Subsequent gas readings taken in the vicinity of the vehicle recorded oxygen levels of 14-15%. The supervisor was monitored by medics and sustained no illness or injury.	• Ventilation to the area had been removed some days prior to the incident, allowing the depletion of oxygen below a safe level. • The irrespirable atmosphere hazard was not identified. • A personal gas monitoring device was not worn.
18/06/2006	Surface mineral mine	A worker entered a confined space to remove bungs and inspect recently completed welds. After entering the space, argon gas (used in the welding process) was released, displacing oxygen and activating the worker's personal gas monitor alarm. The worker immediately exited the confined space and did not suffer any ill effects.	• The irrespirable atmosphere hazard was not identified. • The removal of bungs caused argon gas to release into the unventilated confined space.
30/06/2004	Underground mineral mine	An operator was tramming up a decline in the vehicle he was operating. His vehicle stopped suddenly and would not restart. The operator exited the vehicle and walked downhill approximately 500 metres to report his location to the control room. He complained of being short of breath and believed his vehicle had stopped due to lack of oxygen. Subsequent atmospheric testing by mine rescue personnel confirmed that oxygen levels were below 19%. The worker did not suffer any ill effects.	• The irrespirable atmosphere hazard was identified but inadequately risk assessed. • Signs and barricades in the area did not clearly identify the area as having limited ventilation. • The operator drove through an infrequently traversed area of the mine which was not adequately ventilated. • Risk controls largely administrative and inadequate.

Incident in detail

27 September 2018 – Minjar Gold, Worker exposed to irrespirable atmosphere

Incident summary

An underground mine heading was being progressively de-watered to enable re-entry to old workings and establish a ventilation circuit.

A pump fitter entered the unventilated heading in a light vehicle to check a sump pump. Approximately 100m off the decline, the vehicle's engine stopped (see Figure 1).

While the fitter was investigating why the engine had stopped, he experienced a rapid heartbeat and shortness of breath. He re-entered the vehicle, made an emergency call over the radio, and then donned his self-rescuer. Upon hearing that his supervisor was responding, he walked from his vehicle back to the decline.

The worker was brought to the surface and taken to the site emergency medical technician for monitoring. First aid was administered and he was able to continue his shift. Subsequently, emergency response team personnel attended the scene to test the air quality and found low levels of oxygen (<10.0%) and excessive levels of carbon dioxide (>6.8%).

The action of the pump fitter donning his oxygen-generating self-rescuer prevented this incident from escalating.

Contributing factors

Organisational:

- A decision was made to re-enter old workings for remnant mining and access a new ore block. No prior risk assessment was completed and there was no requirement to routinely undertake a design assessment before re-entry into remnant mining areas.
- The plan to de-water the drive failed to identify the risk of work being completed with no ventilation installed and the lower levels were found to be flooded.
- No formal appointment of a ventilation officer.
- Failure to implement the site's ventilation management plan requirement where unventilated areas are to be barricaded to prevent access.

Individual/team actions:

- Supervisor failed to ensure workers were working in a ventilated area.
- Pump fitter (and others) failed to identify the risk of a potentially contaminated and oxygen depleted atmosphere in a non-ventilated drive prior to commencing work.

Absent or failed defences:

- No ventilation was installed in the drive.

- A ventilation survey identified the area as ‘foggy’, however this, and other inadequately ventilated areas, were not barricaded to prevent/warn personnel from accessing them.
- Underground pump fitters were not required to carry gas detection devices.

Task/environmental conditions:

- A change in the environment such as the receding water level exposing old workings, drying mud and drilling lubricants, and potentially the opening of a nearby air rise may have initiated a release of carbon dioxide. The lack of ventilation also enabled a build-up of vehicle exhaust fumes.
- There was a normalisation of risk; workers had been accessing this area without ventilation for a considerable time, even though this was in conflict with the mine’s procedures.

An investigation conducted by the mine concluded that three possible scenarios either acting singly or together could have resulted in the irrespirable atmosphere:

Scenario 1 – As the water retreated along the drive it exposed mud and drilling residues that had been submerged. Once exposed to the atmosphere a chemical reaction took releasing carbon dioxide to the atmosphere.

Scenario 2 – The bottom of the air rise to the Janet B workings (see Figure 1) had been submerged for a sufficient period of time to allow a build-up of carbon dioxide, which may have entered from adjoining workings. As the water slowly exposed the base of this rise there may have been a slight positive pressure releasing carbon dioxide and displacing oxygen.

Scenario 3 – A combination of scenario 1 and 2.

Corrective actions by mine site

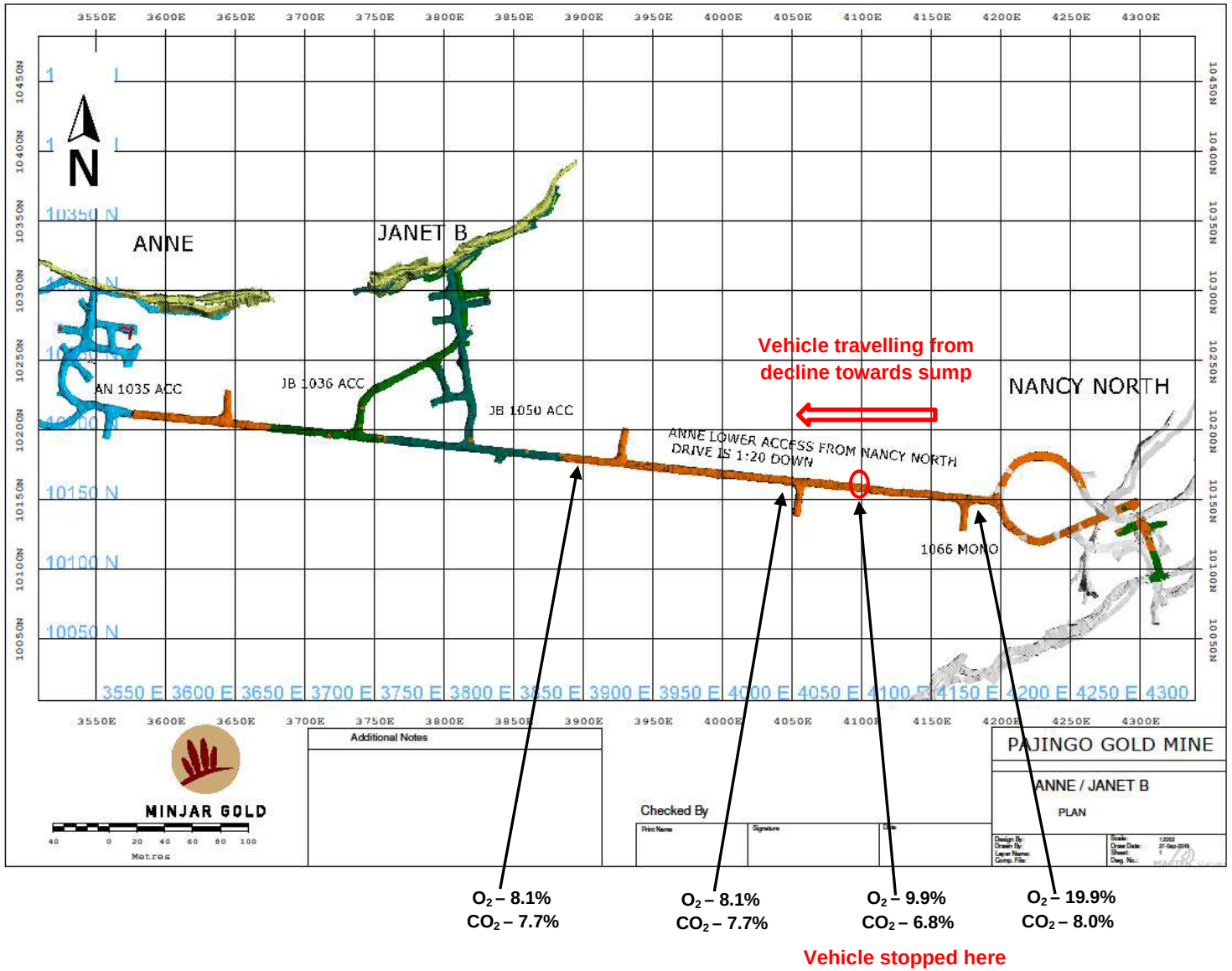
- Conduct an over-arching risk assessment on remnant mining risk.
- Develop a process to ensure effective supervision of fitters, electricians and itinerant workers.
- Develop an incident summary slide and include it in the underground worker induction, to increase awareness of the irrespirable atmosphere hazard.
- Amend relevant documents to ensure that when required to go into an unventilated area:
  - two personnel must travel together, unless approved otherwise by a supervisor;
  - oxygen monitors and/or gas detectors must be worn; and
  - the underground supervisor must be notified before entering and after exiting the area.

Actions taken by the Mines Inspectorate after the incident

- Mines safety alert no. 360, issued on 4 December 2018, highlights the hazard of working in areas of insufficient ventilation and made recommendations to ensure workers in every part of a mine are supplied with air of sufficient quality, volume and velocity to ensure a healthy atmosphere.
- Two compliance directives and one substandard corrective practice (SCP) were issued in relation to technical design of new areas and remnant mining and ventilation of operating areas of a mine. Compliance directives require immediate action by the mine and are verified by a mines inspector:

- Directive 1, review the change management process to ensure risk in future mining activities is adequately controlled.
- Directive 2, cease work in any area which does not have sufficient quality, quantity and velocity of air to enable a healthy atmosphere. These areas must be barricaded and signed.
- SCP, review investigation to ensure adequate identification of technical and organisational factors which contributed to the incident.

Figure 1: O_2 and CO_2 readings taken by ERT following the incident



Recommendations

Mines and quarries in Queensland must ensure that systems and controls are implemented to prevent worker exposure to irrespirable atmospheres. The Mines Inspectorate recommends, as a minimum:

1. Prior to work commencing in a new area or remnant mining areas, ensure appropriate design considerations and procedures minimise the risk to persons, including but not limited to:
    - excavations
    - ventilation and air quality
    - ground control.
2. All mines should complete an audit of all unventilated headings to ensure they are:
    - barricaded/secured to prevent inadvertent access
    - signposted as to the nature of the hazard and accurately depicted on plans and other relevant documentation.
    - A risk assessment must be completed prior to work commencing in a new area or accessing old workings, particularly if they have been flooded.
3. In relation to maintaining a healthy atmosphere:
    - Active mine workings should be routinely monitored to confirm whether any changes in the environment or otherwise require control measures to be reviewed/updated.
    - Ventilation surveys must be completed to identify areas of poor air quality, and workers made aware of hazardous areas. Consideration should be given to a CO_2 audit of the mine, particularly where water storage occurs.
    - Any change to a ventilation control device should be assessed and modelled to determine the impact on all areas of the mine. Changes should be documented and communicated.
    - Install ventilation as close as reasonably practical to where personnel are working.
    - No work is to occur in an area which does not have sufficient quality, volume and velocity of air to ensure a healthy atmosphere. These areas must be barricaded and signed. Any removal of ventilation from an area should trigger it to be barricaded and signed.
4. In relation to roles and responsibilities:
    - The SSE and Operator must ensure that workers in every part of the mine are supplied with air of sufficient quality, volume and velocity to ensure a healthy atmosphere.
    - Underground mines must have a competent ventilation officer to establish and implement effective ventilation standards.
    - Supervisors should monitor work areas and activities to ensure adherence to procedures. Location and welfare of persons working alone requires constant monitoring by supervisors.
5. Persons should only enter an unventilated area, areas of water storage and old workings with an operational gas monitor. They must be trained in the use of the monitor and be accompanied, with one person remaining in fresh air as a spotter, and a supervisor notified of entry and exit.
6. In relation to training:
    - Hazard identification training should be conducted.
    - Workers entering non-ventilated headings should be trained in confined space procedures.
    - Training of ERZ controllers in basic ventilation practices.
    - Workers must be trained in mine ventilation standards and the requirements for gas monitoring.