# Queensland Guidance Note

QGN 20 v 3.5

09 February 2017

Management of oxides of nitrogen in open cut blasting

***Mining and Quarrying Safety and Health Act 1999***
***Coal Mining Safety and Health Act 1999***
***Explosives Act 1999***

# Guidance Note – QGN 20
# Management of oxides of nitrogen in open cut blasting

This Guidance Note, has been issued by the Mines Inspectorate and the Explosives Inspectorate of the Department of Natural Resources and Mines (DNRM). It is not a Guideline as defined in the *Mining and Quarrying Safety and Health Act 1999* (MQSHA) or a Recognised Standard as defined in the *Coal Mining Safety and Health Act 1999* (CMSHA). This Guidance Note is not called up in the *Explosives Act 1999*. In some circumstances, compliance with this Guidance Note may not be sufficient to ensure compliance with the requirements in the legislation.

Guidance Notes may be updated from time to time. To ensure you have the latest version, visit Mining Safety and Health, the Explosives Inspectorate or contact your local Mines or Explosives Inspector.

A fume management webpage is also available on the DNRM website:

https://www.business.qld.gov.au/industry/explosives-fireworks/licensing-other-requirements/blasting-shotfiring/managing-blast-fumes

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This publication has been compiled by the Mines Inspectorate and the Explosives Inspectorate of the Department of Natural Resources and Mines.



Suggestions for amendment, corrections and improvements to this guidance note can be made by sending an email to: **explosives@dnrm.qld.gov.au** Please identify the section, page number, paragraph or appendix that relates to your submission.

# Acknowledgements

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- JKTech Pty Ltd

# Contents

# Section 1 – Introduction and background

## Introduction

1.1. A meeting was called by the Chief Inspector of Coal Mines and Chief Inspector of Explosives on 18 March 2011 to address issues associated with fumes[1], in particular, oxides of nitrogen (NOx) associated with blasting activities. This followed a number of fume events at open cut coal mines in central Queensland that resulted in persons being taken to hospital as a precautionary measure. The workshop was used to identify the key factors in the production of fumes and possible mitigations. The meeting included representatives from coal mining companies, explosives companies, as well as the Mines and Explosives Inspectorates. At the end of the meeting, a steering group was formed to create methods to prevent the generation of fumes, manage a fume event and manage exposure to fumes.

1.2. This guidance note does not prevent persons with safety obligations using other methods to achieve an acceptable level of risk in the prevention of fume, fume event management and the management of fume exposure. Prevention of fumes is the best approach.

1.3. This guidance note is focussed on the management of oxides of nitrogen. The major issues are involved with the quantity of nitrogen dioxide produced, its toxicity and the potential exposure.

1.4. The department has provided the following other guidance on the management of fumes:

- ***Mining and Quarrying Safety Bulletin 61*** - Flammable and toxic gases in open cut coal mines
- ***Explosives Safety Alert 44*** - Prevention and management of blast fumes
- ***Explosives Safety Alert 28*** - Post blast gases

**Disclaimer**

1.5. It should be noted that not all matters in the guidance note were always agreed upon by all members of the steering group. The prevailing view has been taken by the Fume Steering Group. Any matters where there has been disagreement have been reviewed from a regulatory point of view and that view will prevail in this document.

## Purpose

1.6. The purpose of this guidance note is to:

- Understand the known causes of fume by identifying the contributing causes, then mitigating those causes and identifying persons responsible in the different roles.
- Manage a fume event, whether predicted or not, in the context of a prepared blast and the existing meteorological conditions.
- Manage exposure to fumes.

## Scope

1.7. This guidance note is applicable to blasting activities in open cut blasting. This may be in coal or metalliferous mines.

## Definitions

1.8. Annex A lists definitions and abbreviations used in this guidance note.

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[1] In this guidance note, fumes refer to the gases belonging to oxides of nitrogen, particularly $NO_2$, the most prevalent and harmful.

# Legislation

1.9. The three key Acts, covering operations on a mine site in Queensland with explosives, are the:

- *Coal Mining Safety and Health Act 1999*
- *Mining and Quarrying Safety and Health Act 1999*
- *Explosives Act 1999*

All explosives used in Queensland are required to be authorised[2] in accordance with section 8 of the *Explosives Act 1999*. The process for obtaining authorisation for an explosive is outlined in Explosives Information Bulletin 10.

# Background

1.10. Mine blasting is performed to liberate and comminute a rock mass, enabling the downstream mine processes to occur efficiently and safely. The safe delivery of effective blasting practices, within acceptable environmental and community standards, necessitates the understanding and management of post blast fume.[3]

1.11. The mining industry operates in a variety of ground types under varying conditions, which means that operating conditions are not ideal and this can affect the efficiency of the explosives product.

1.12. The variables that affect explosives performance are:

- Under or over fuelled ammonium nitrate (AN).
- Poorly mixed fuel AN mixture.
- Density of loaded explosives.
- Degree of confinement of explosives.
- Water damage to explosives
- Ground conditions e.g. fissures and voids can result in explosives forming without the critical diameter for an ideal explosives reaction causing fume.
- Manufacture and specification of explosive ingredients including AN and EP.

1.13. The Fume Steering Group (FSG) identified two areas that required further examination in order to tackle the prevention of fume. These areas over the full life cycle are:

- Activities associated with blasting.
- Persons/organisations associated with blasting.

# Definition of post blast fume

1.14. The definition of a fume event is an event that generates the visible gas nitrogen dioxide that moves outside the standard blast exclusion zone. The standard blast exclusion zone is designed to provide protection from projections and blast overpressure.

1.15. Fume is a combination of post blast gases, which are predominantly nitrogen dioxide, but may also include small amounts of nitrous oxide, nitric oxide, carbon monoxide, carbon dioxide and

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[2] An authorised explosive has been accepted to be safe and suitable for service during its life cycle. The technical data sheet includes information on the performance and use of the product and any limitations. The manufacturer has obligations to ensure the product specification and performance remains within its design and authorisation. The user has obligations to use within the advised parameters.

[3] JKTech Pty Ltd 2015 Understanding the physical and detonation characteristics of bulk explosives to minimise post blast fume generation in deep hole, soft ground and wet conditions.

sulphur dioxide. Nitrogen dioxide is the only post blast gas that is visible. The two main gases are nitric oxide (NO) and nitrogen dioxide ($NO_2$).

1.16. Nitrogen dioxide is heavier than air and may accumulate in low-lying areas where it may displace oxygen and/or reach toxic concentrations.

1.17. Nitric oxide in air is unstable and gains an extra oxygen atom from the atmosphere, to become nitrogen dioxide. Two of the most toxicologically significant compounds are nitric oxide (NO) and nitrogen dioxide ($NO_2$). Other gases belonging to this group are nitrous oxide, $N_2O$, and nitrogen pentoxide ($NO_5$). Annex B details the properties of nitrogen dioxide.

1.18. While oxides of nitrogen are created in varying amounts when blasting, they are mainly generated from high temperature combustion such as vehicles. The largest contributor to NOx fumes in the atmosphere is the automotive industry. Some cities have a haze that is often coloured brown – this includes NOx pollution, predominantly from motor vehicles.

# Toxicology of nitrogen dioxide

1.19. Nitrogen dioxide is a yellow, orange or brown coloured, acrid smelling gas that is heavier then air. Details of the toxicology of nitrogen dioxide are contained in Annex C. This appendix covers the occupational exposure standards and health effects.

1.20. The toxicology of blast fume is important to consider as the occupational health and safety of mineworkers must be at the forefront of mine operations. The exposure limits for nitrogen dioxide are listed in Table C-1 (in Annex C).

1.21. Throughout this guidance note, the objective of the management of fume is to ensure that persons are not exposed to levels of nitrogen dioxide above the Short Term Exposure Limit (STEL) of 5 parts per million (ppm). A technical data sheet for nitrogen dioxide is at Annex D.

1.22. Fatal contact with post blast fumes was reported as early as 1916 in the mines of Rand, South Africa. A report by Louis G. Irvine in a 1916 British Medical Journal described gas poisoning as responsible for a "good number of deaths" annually, and the presence of post blast nitrous oxides resulted in lost working time in pit.[4]

# Blasting explosives that produce fume

1.23. Explosives that contain nitrogen, normally in the form of ammonium nitrate, can produce oxides of nitrogen, commonly called fume. All blasting explosives produce large volumes of gas in very short time spans (fractions of a millisecond) which is the basis of the energetic work, for which they are used. Typically, the volume of gases released is about 1000 times the original volume.

1.24. In the mining context, the explosives that produce fume are a combination of ammonium nitrate and fuel oil with other additives. These may be in the form of ammonium nitrate fuel oil (ANFO) prills, or emulsions and water gel containing ammonium nitrate or combinations of these.

1.25. The ammonium nitrate prill used is a Class 5.1 Dangerous Good, with UN number 1942 and the emulsions or water gels are also Class 5.1 Dangerous Goods, with UN Number 3375. The emulsions and water gels are generically referred to as matrices.

1.26. Ammonium Nitrate is water soluble and therefore is damaged by water. The emulsions and water gels have more resistance to water damage than ANFO mixtures.

1.27. Where ammonium nitrate is supplied as prills to the explosives industry, the prill size, density and porosity can affect the adsorption of fuel oil and subsequently the detonation performance of the ANFO. Ammonium nitrate prills for blasting, have different physical characteristics to ammonium nitrate fertilizer, in order to enable the adsorption of fuel oil. Imagery of fertiliser and

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[4] Section 1.27 – JKTech Pty Ltd Report

explosive grade ammonium nitrate, using an electron microscope, was conducted by Zygmut and Buczkowski (2007); the difference in the crystal structure is apparent in Figure 1 below.[5]

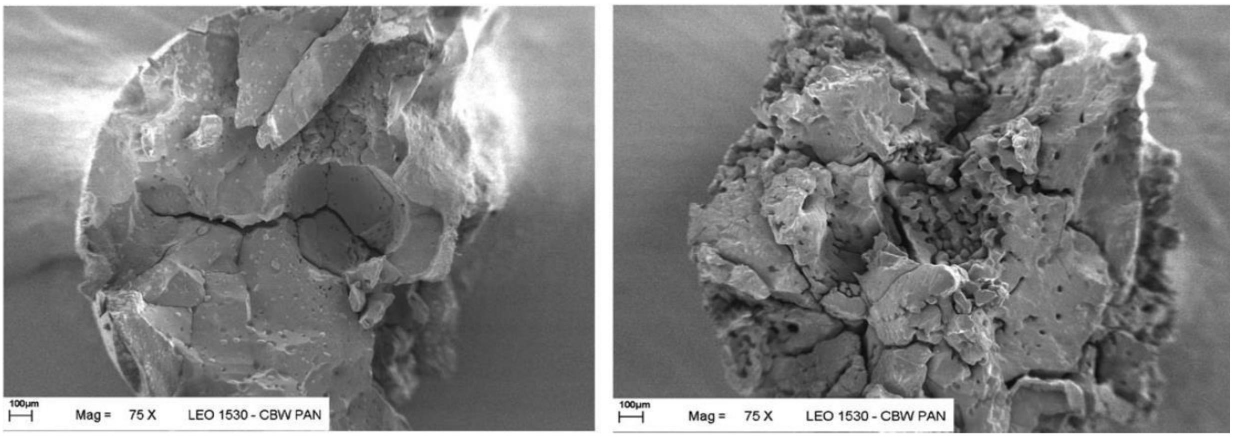



Figure 1: Fertiliser grade ammonium nitrate (LHS) and ammonium nitrate prill (RHS)

1.28. Formulation changes to ANFO are unlikely to decrease fume as the product has no water resistant characteristics however, formulation changes to the water resistant range of products could lead to reductions in fume. Explosives suppliers and mine operators need to work together to determine which product category presents the optimum chance of reducing fume in the prevailing conditions.

1.29. There is an opportunity to further explore formulations that deliver a reduction in the generation of post blast fume. Formulations that are designed and produced to be resistant to the production of fume should be tested in field trials, to safely gain optimal results from that formula. Raw materials that are used as precursors for the formulations must conform to specifications called up by the formula. The specifications should also be documented within the suppliers technical and compliance standards for that material.

1.30. Explosives products being used for fume mitigation should be fit for purpose. “Fit for purpose” should be defined in a user need specification. The procurement chain involving both supplier and end user must incorporate the user need specifications into the selection of raw materials to gain compliance for the final product.

# Ideal and non-ideal conditions

1.31. The explosive reaction that occurs in mine blasting, results in a change in the state of explosive matter from solid to gaseous. In Australian coal mines, the explosives that are most commonly employed, utilise ammonium nitrate as the oxidising agent, in the form of ammonium nitrate fuel oil (ANFO) or ammonium nitrate emulsions/ water gels. In theory, an ideal ammonium nitrate explosive reaction yields the following by-products:[6]

- $H_2O$ in the form of steam
- $CO_2$ carbon dioxide
- $N_2$ nitrogen.

1.32. The presence of nitrogen and oxygen in ammonium nitrate ($NH_4NO_3$) presents the risk of the production of nitrous oxides (NOx). Post blast fume consists of gases that can include nitric

[5] Sections 1.19 to 1.22 – JKTech Pty Ltd Report

[6] Section 1.30 to 1.31 – JK Tech Pty Ltd Report

oxide, nitrogen dioxide and carbon monoxide. Nitric oxide and carbon monoxide are toxic, colourless and odourless, and occur in smaller concentrations.

1.33. The most harmful, nitrogen dioxide, is identifiable by the generation of orange/brown clouds. There are many factors that can contribute to the generation of fume, which is an outcome of the ammonium nitrate explosives not detonating ideally.

1.34. An ideal detonation is one in which the explosive undergoes a supersonic/high order combustion (chemical) reaction, resulting in a complete conversion of the explosive to gaseous nitrogen, carbon dioxide and water. Ideal detonations do not occur in practice. Even in very large quantities, explosives can approach an ideal detonation state but never achieve it. Displayed in Figure 2 below.[7]

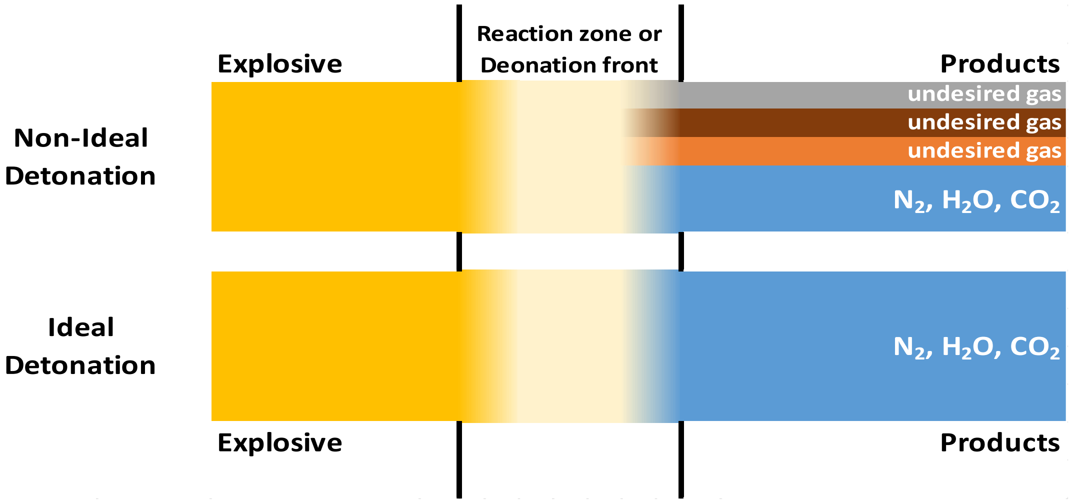



Figure 2: Ideal and non-ideal detonation

1.35. The ideal detonation reaction of ammonium nitrate and fuel oil (ANFO) or ammonium nitrate emulsions including ammonium nitrate, fuel oil and other chemicals does not release NOx. This occurs under ideal conditions where an ideal explosive reaction is assured. Conditions encountered during mine blasting are never ideal.

1.36. The ammonium nitrate converts to nitrogen, water and oxygen and the fuel converts to carbon dioxide and water.

The equation for an ideal explosive reaction is as follows:

This is an oxygen balanced explosive reaction that does not generate NOx.

$$\mathbf{3NH_4NO_3 + CH_2 \longrightarrow 3N_2 + 7H_2O + CO_2}$$

A non-ideal fuel lean detonation of ANFO explosive reaction is as follows:

$$\mathbf{5NH_4NO_3 + CH_2 \longrightarrow 4N_2 + 2NO + CO_2 + 11H_20}$$

Or

[7] Sections 1.33 – JKTech Pty Ltd Report

$$4NH_4NO_3 \longrightarrow 2NO_2 + 3N_2 + 8H_2O$$

A non-ideal, fuel rich detonation of ANFO:[8]

$$2NH_4NO_3 + CH_2 \longrightarrow 2N_2 + 5H_2O + CO$$

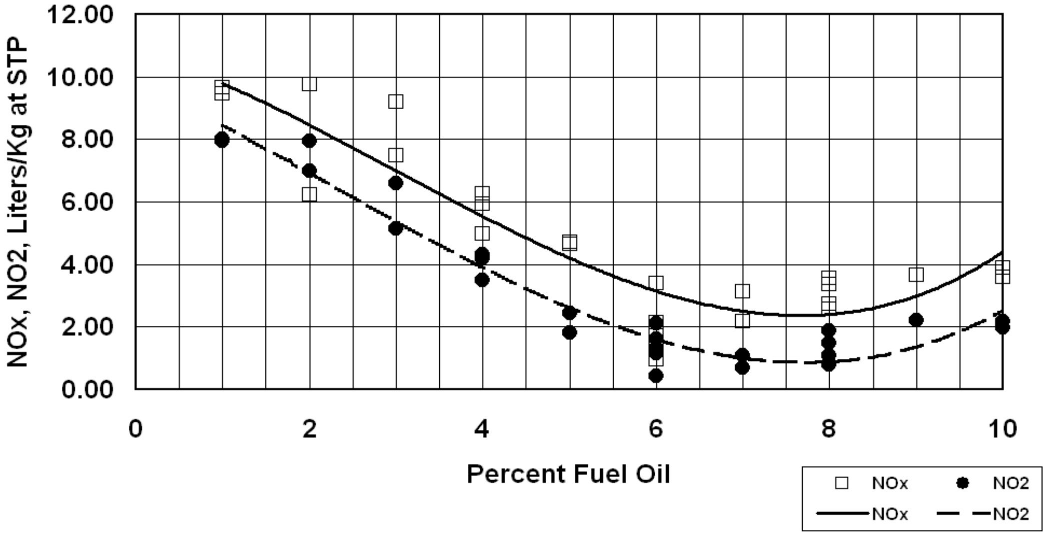
Deflagration is a subsonic/lower order combustion that occurs at much cooler temperatures and generating less pressure than detonation. Deflagrating reactions do not have the required temperatures and pressures for driving the reaction to completion and undesired gasses may be formed.[9]

Further to the reactions of detonation and deflagration, the product gasses can further react. Nitric oxide in the presence of oxygen readily oxidises to nitrogen dioxide, and nitrogen dioxide can react with itself to form dinitrogen tetroxide. Dinitrogen tetroxide also has the appearance of an orange gas.[10]

$$2NO + O_2 \longrightarrow 2NO_2$$

$$2NO_2 \longrightarrow N_2O_4$$

1.37. The basic formulation may be a factor in whether the explosive reaction is ideal or not. For instance if the mixture has too little fuel, it will produce more nitrous oxides. If it has too much fuel, it will tend to produce more carbon monoxide. Figure 3 shows the effect of fuel on the production of oxides of nitrogen in ammonium nitrate fuel oil.

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[8] Formula and description from JKTech Pty Ltd Report

[9] Formula and description from JKTech Pty Ltd Report

[10] Formula and description from JKTech Pty Ltd Report

**Figure 3: Effect of percentage fuel oil on fume in ANFO[11]**

1.38. The composition of ANFO and ANE must be correct to maximise the likelihood of achieving as close to an ideal detonation as possible. A common metric of the mix of fuel and oxidiser is the oxygen balance of the explosive. An oxygen balance describes the supply of oxygen to a fuel in an explosive reaction. If an explosive contains just enough oxygen to oxidise all the hydrogen atoms into the composition to water, all the carbon atoms to carbon dioxide, all other fuel components to the highest degree of oxidation, and all nitrogen to $N_2$, then an explosive composition is oxygen balanced. An explosive has a positive oxygen balance if more oxygen is available than required, or a negative oxygen balance if insufficient oxygen is available.[12]

1.39. The effect of oxygen balance on the production of CO and nitrous oxides in an ANFO detonation was presented by Rowland III and Mainiero (2000), shown in Figure 4.

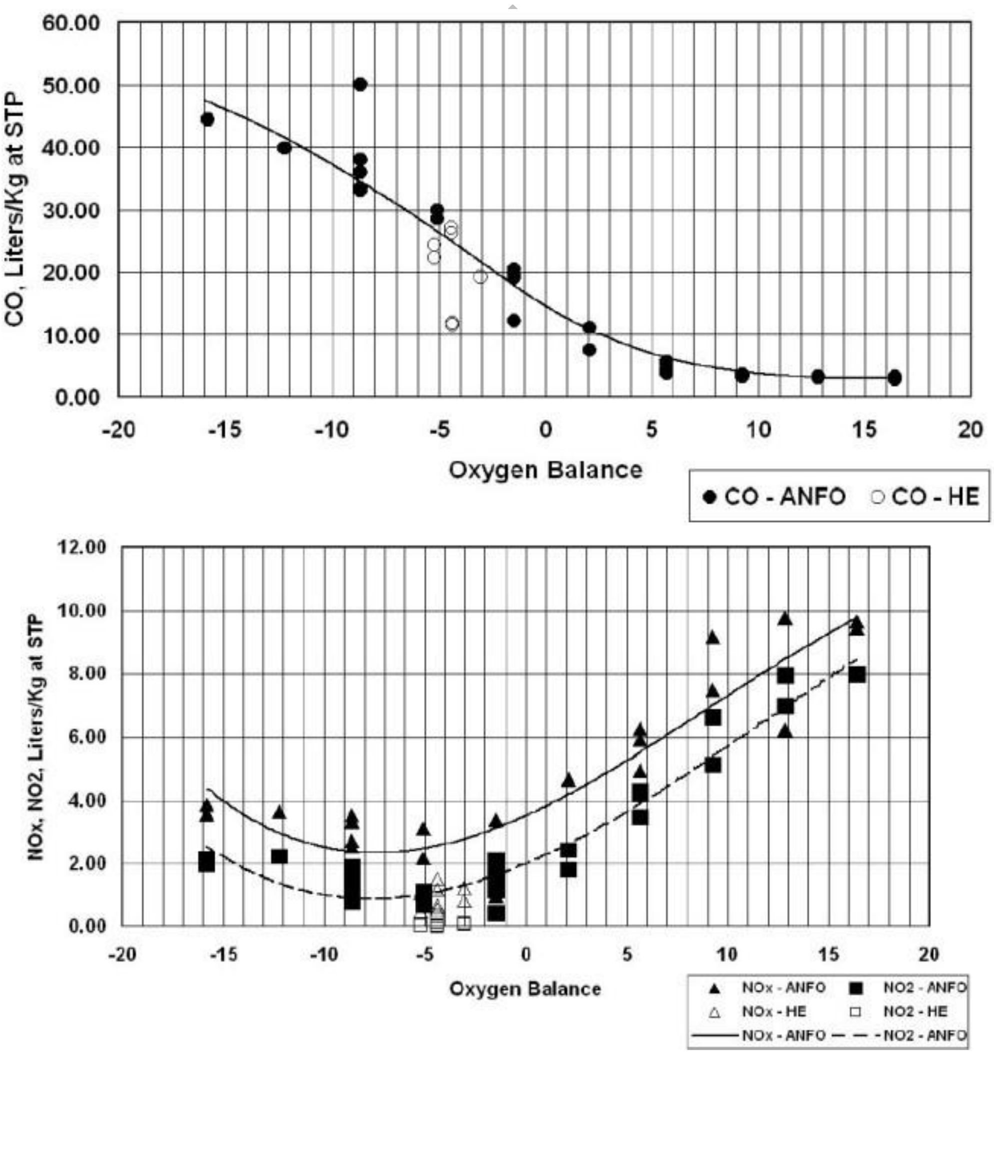


Figure 4: Effect of oxygen balance on CO and NOx production (Rowland III & Mainiero, Factors affecting ANFO fumes production, 2000)

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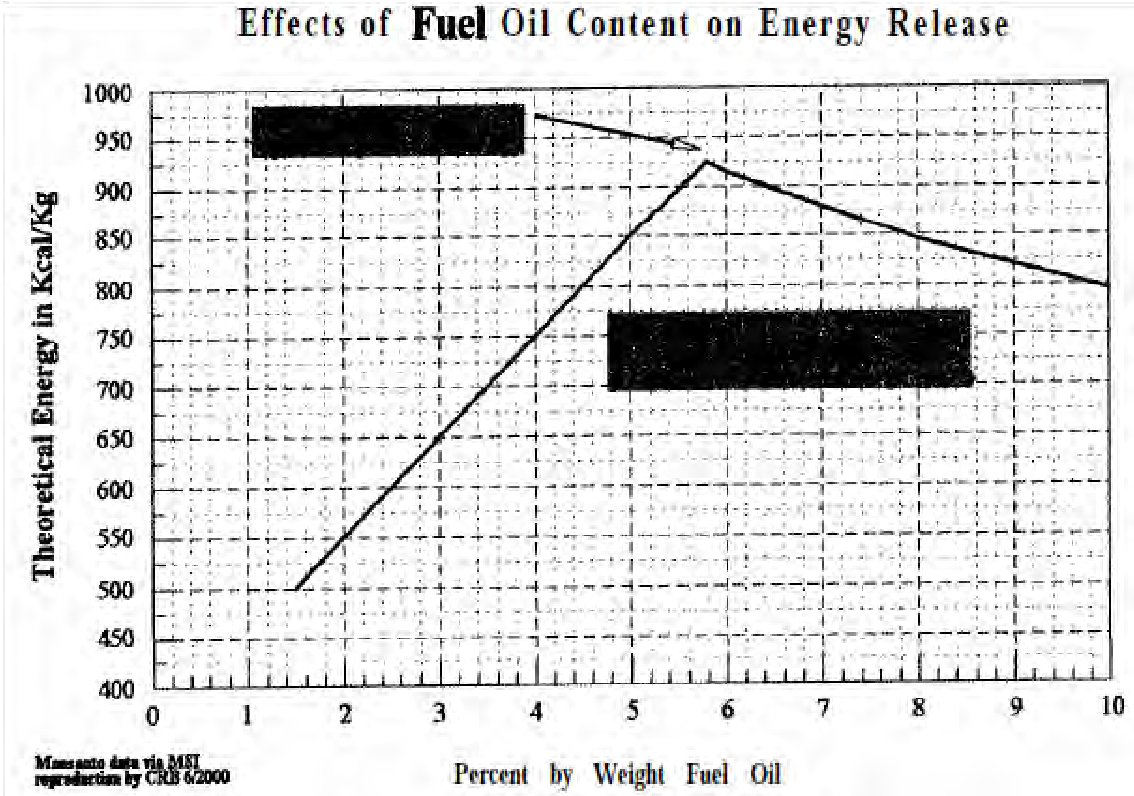
[11] Rowland, J & Mainiero, R, February 1997 'Factors affecting ANFO fumes production' 'Effect of 94/6 ANFO fuel oil content on nitrogen oxides and nitrogen dioxide production Figure 6.'

[12] Sections 1.37 – JKTech Pty Ltd Report

1.40. A decrease in the oxygen balance (greater than 5.5% fuel oil by weight), results in a moderate increase in nitrous oxides and a substantial increase in carbon monoxide. A positive oxygen balance (less than 5.5% fuel oil by weight), conversely results in a minimisation in the production of carbon monoxide emissions, and a substantial increase in the nitrous oxide emissions.[13]

1.41. The performance of the explosive is also important to consider. Decreasing the percentage of fuel more rapidly reduces the thermodynamic energy than increasing the percentage of fuel.




Given that a negative oxygen balance produces less nitrous oxides, from a thermodynamic and blast fume perspective, an oxygen lean mixture is preferred to an oxygen rich mixture.

Figure 5: Thermodynamic energy as a function of ANFO percentage fuel oil weight

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[13] Sections 1.39 to 1.40- JK Tech Pty Ltd Report

1.42. Open cut blasting is conducted in conditions where there are variables that result in non-ideal explosive reactions, which may generate fumes. This guidance note will examine the causes of non-ideal explosive reactions in more detail.

# Section 2 – Causes of fume

## The causes of fume

2.1. Fume is generated as a result of a non-ideal explosive reaction. The causes of the non-ideal explosive reaction are many and variable. This guidance note groups them into categories and further identifies the person or organisation that is best able to control the variable around the cause. The six categories that cause fume are listed below:

2.2. **Cause 1 - Explosives blends and precursors chemical design**

- Chemical formulation of the mixed explosives and/or precursors unknowingly inherently designed to generate fume.
- Formulation of explosives mixture and/or precursors having small ranges of optimal sensitivity.
- Formulation of explosives mixture and/or precursor having limited conditions of stability.
- Formulation of explosives mixture and/or precursor insufficiently resistant to conditions it is used in.
- Formulation of explosives mixture and/or precursors not suitable for the prevailing climatic or seasonal conditions.
- Generation of fume not forming part of explosives and its precursors' qualification criteria - Chemical formulation of explosives mixtures and precursors not checked for quantity and make up of fume under varied field conditions before releasing into the industry.

2.3. **Cause 2 - Explosives and precursors conformance to specification, adversely impacting on the detonation performance of the explosives.**

- Explosives product delivered down the hole out of specification.
- Precursor delivered to mine site out of specification.

2.4. **Cause 3 - Blast design inherently containing aspects increasing the likelihood of fuming.**

- Explosives – rock mass properties mismatch.
- Explosives product selected not suitable for the prevailing ground conditions (water or rock mass strength)
- Blast design (explosives product selection or initiation design) not appropriate for blast requirements.
- Sleep time for explosives form commencement of loading until firing of the blast.
- Insufficient consideration given to blast dynamics.

2.5. **Cause 4 - Explosives detonation performance negatively impacted by the adverse effects of blast dynamics.**

- Dynamic shock desensitisation of explosives
- Decoupling of explosives column
- Inappropriate burden relief
- Inappropriate confinement created by poor ground conditions or selection and placement of stemming materials

2.6. **Cause 5 - On-bench/site practices leading to explosives not performing optimally.**

- Not adequately sensitising explosive product by addition of gas bubbles or sensitising chemicals.
- Mobile Processing Units not calibrated correctly to manufacture products within specification.
- Explosives product not suitable for the bench conditions (not reconsidering product selection after changed bench condition, such as change in water conditions)
- Contamination of explosives (bottom of hole or stemming section)
- Explosives products not to specification when delivered down the hole.
- Explosives precursors not to specification when received on site.

2.7. **Cause 6 - Blasting personnel.**

- Lack of an understanding of the possible causes, and prevention techniques, of fume amongst blasting personnel (shotfirers, MMU operators, blast designers)
- Blasting personnel not consistent in defining dry and wet bench conditions
- Blasting personnel not consistent in following explosives supplier's product application guidelines

2.8. These causes are examined in detail at Annex E - Causes of NOx fume and mitigations (adapted and amended by FSG from AEISG data). This is a useful table in developing and reviewing the control of fume within an organisation. It will also be useful in assisting mine operators and regulators in the investigation of a fume event.

# Identification of persons/organisation to prevent fumes

2.9. This section is an indicative list of organisational positions and roles. The table 2.1 identifies the obligations of those parties in relation to the prevention of fume generation during blasting activities

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- Site Senior Executive (SSE)
- Production manager
- Procurement manager
- Blast designer
- Geologist
- Drill and blast superintendent
- Drilling contractor
- Driller
- Borehole profilers
- Explosives supplier
- Explosives manufacturer
- Blasting contractor
- Shotfirer
- Assistant shotfirer
- Bench assistant
- Mobile Manufacturing Unit (MMU) operator
- Dewaterer operator
- Blast controller
- Explosives Inspectorate
- Magazine keeper
- Maintenance personnel for MMU
- Designer of MMU

**Table 2.1 Persons and their responsibilities to prevent fume**

| Person / Organisation | Role | Responsibilities / Remarks |
|---|---|---|
| Geologist | Provide data on ground conditions to assist blast designer in the layout of the shot | • Accurate provision of ground data across the proposed shot.<br>• Review of data after firing to determine if data was as predicted.<br>• Determine whether any hot or reactive ground is present.<br>• Provide soil moisture index data for site |
| Mine operations planner | Plan the mine operations to extract coal overburden, plan water removal | • Ensure that extraction plan is designed to limit where possible mine geometries where blast fume has been known to be produced such as deep wet box cuts. |
| Drilling contractor | To provide drilled holes for the loading of explosives for a shot | • Accurately drill the shot plan.<br>• Report variations<br>• Report ground conditions to blast designer. |
| Blast designer | Design a blast to provide optimum extraction of material and manage blasting hazards such as fume, flyrock, overpressure | Blast designer to be cognisant of:<br>• Weather conditions<br>• Presence of water in ground and dynamic water.<br>• Ground conditions.<br>• Presence of hot or reactive ground.<br>• Review actual drill data vs design, as well as hole dip data to produce design.<br>• Select explosives product appropriate to conditions and ensure explosives design parameters are met – including sleep time for explosive products.<br>• Review actual loaded condition of blast prior to shot being fired.<br>• Ensure that mine contracts in relation to blasting ensure that products and equipment are to specifications and enable the safe effective blasting operations with minimum fume. |
| Blasting contractor | Provides a blasting service to clients | • Maintain an effective safety management system that covers the blasting activities<br>• Ensure delivery of product in accordance with blast plan |
| Drill and blast superintendent | Manage all drill and blast operations for the site. | • Investigate blasting incidents<br>• Incident advice<br>• Implement improvement<br>• Competence of blast team<br>• Adequate resourcing of blasting activities<br>• Authorisation of blast design<br>• Setting explosives inventory<br>• Storage capacity<br>• Manage significant change that may occur during the blast process involving blast designer when required. |

| Person / Organisation | Role | Responsibilities / Remarks |
|---|---|---|
| Blast supervisor | Manage day to day blasting operations | • Review the use of UN1942 vs UN3375 vs diesel vs chemicals against manufacture and load specification<br>• Review the use of gas bags against dip logs<br>• Compliance check of bench activity<br>• Stock rotation<br>• Storage environment management |
| Drill supervisor | Supervise drill activities on the bench | • Conduit from drill activity to blast designer<br>• Bench preparation prior to drilling |
| Shotfirer | Oversight all explosives activities on bench. | • Management of on-bench water<br>• Compliance with design<br>• Variations from design<br>• Recording data.<br>• On bench explosives quality<br>• Supervision of loading technique<br>• Calibration of equipment<br>• Conduit from bench to blast designer<br>• Make continual assessments prior to firing to ensure acceptable level of risk (ie pre firing review provided in Appendix F)<br>• Communicate significant change in the blast parameters to the Drill and Blast Superintendent |
| MMU designer | Design MMU to produce explosives to specification | • Equipment appropriate and produces explosives to specifications |
| MMU operator | Manufacture blasting explosives<br>On bench activities as directed by the shotfirer | • Compliance with load sheets<br>• Recording and reporting variations to blast design<br>• Calibration<br>• Precursor material quality checks<br>• Manufacturing equipment compliant<br>• Adequate and correct process chemicals<br>• Manufacture QC checks<br>• Generate delivery/production record |
| MMU maintainers | Maintenance of MMU | • Ensure equipment is maintained and calibrated as per maintenance schedule<br>• Vehicle maintenance conducted to design and operational criteria. |
| Bench assistant | Support shotfiring activities<br>On bench activities as directed by the shotfirer | • Recording of water conditions down hole<br>• Dewatering holes<br>• Measuring recharge rates for wet holes<br>• Marking of hole data<br>• Positioning of primers in blast holes<br>• Accurate placement of gas bags<br>• Measuring and recording the depth of holes<br>• QC density checks<br>• Stemming<br>• Collar protection and hole liners<br>• Preventing contamination of the explosive column<br>• Identifying hole slumping |

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| SSE | Oversight of all blasting activities.<br>Integration into mine operations | • Responsibility rests with the SSE or an appointed delegate. (Legally it remains an obligation of the SSE)<br>• Ensure that adequate resources are available to support successful blasting activities |
| Explosives manufacturer | Provide explosives fit for purpose | • Undertake development work on explosives technology to improve products ability to perform in robust conditions. Provision of precursors and formulation to ensure minimum amount of fume.<br>• Safety Management System including rigorous change management of formulation to ensure fumes are minimised in product.<br>• Design, calibration and operation of explosives manufacturing equipment to deliver consistent explosives within specification. Specification of accessories – detonators and booster to ensure efficient blast<br>• Quality Assurance and Quality Control processes – sampling and testing |
| Supplier | Provide explosives fit for purpose | • Provision of precursors and formulation to ensure minimum amount of fume.<br>• Safety Management System including rigorous change management of formulation to ensure fumes are minimised in product.<br>• Design, calibration and operation of explosives manufacturing equipment to deliver consistent explosives within specification. Accessories – detonators and boosters are suitable regarding initiation capability for the explosive product to be used.<br>• Quality Assurance and Quality Control processes – sampling and testing |
| Procurement managers | Procure blasting explosives | • Ensure supplier is providing specified product.<br>• Purchase appropriate products fit for task based on technical input.<br>• Seek industry solutions to fume problems and other explosives performance issues through contract negotiation, agreement and operation. |
| Explosives Inspectorate | Authorisation of explosives | • Ensuring explosives company have SMS that control the specification, formulation and delivery of explosives as authorised |

2.10. The positions identified in Table 2.1 above have been included in Annex E to demonstrate how these roles and responsibilities may impact on the potential contributing factors of post blast fume generation. In a review of a fume event, it is important that these persons contribute to the identification of issues from their work area that may have contributed to the generation of fume.

## Identification of activities that may contribute to fume

2.11. The activities associated with a blast are:

- Explosives research development and innovation of low fume products
- Manufacture of AN prill and emulsion
- Manufacture of gassed sensitised product
- Mixing of final product
- Manufacture of accessories initiating explosives
- Storage of AN prill and emulsion
- Selection of initiating explosives
- Procurement of explosives
- Mine production planning
- Design of the blast
- Drilling of the shot
- Loading of the shot
- Stemming the shot
- Sleeping shots
- Firing of the shot
- Post blast activities (for example, management of misfires)

2.12. These activities are examined in greater detail in Section 3.

## Factors outside the blasting activities that contribute to fume

2.13. This section identifies those areas outside the direct blasting design, preparation and firing that could contribute to a fume event. These other areas are not under the control of persons in the blasting area. Senior management should commit to:

- Ensuring that the prevention of fume is a stated objective for the organisation.
- All of the organisation’s departments recognise and treat the issues under their control that could contribute to generation of fume.
- Providing adequate and quality resources to ensure fume mitigations can be appropriately managed.
- Appoint persons with appropriate training, experience and skills to manage factors that contribute to fume.
- Ensure fume incidents are adequately investigated, the root causes identified, lessons learnt identified, communicated and systems updated in time with change management.
- Identification of leading indicators and industry trends that lead to unacceptable production of fume.

2.14. The factors outside the drill and blast area that could contribute to fume events are:

- Management not accepting that fume events can unexpectedly breach the fume management zone (FMZ).
- Procurement contracts that are locked into unsuitable products and limits the sourcing of explosives products less likely to contribute to the generation of post blast fume.
- Poor inventory management and logistics planning that results in the use of available explosives that may not be appropriate for the required application.
- Poor maintenance, calibration and availability of specialist explosives and support vehicles such as drill rigs, dewatering trucks, MMU's, and stemming vehicles.
- Inadequate resources to undertake the blasting activities to meet production requirements.
- Circumstances requiring extended sleep time.
- Inadequate preparation of bench and support areas handed over to the drill and blast process.
- Impact of mine schedule (Whole of Mine) pressures and inadequate internal communications that affect the safe, effective and efficient preparation of the blast.
- Failing to incorporate learning's from previous fume events into the process.
- Inadequate training of blast engineers, blast drillers, and shotfirers.

# Section 3 Prevention of fume

## Prevention of fume

3.1. The most effective way to manage fume, is to aim to eliminate the possibility of fume being generated. The elimination of fume requires the concerted action by all entities involved in the blasting activity. This section uses the activities that were identified in section 2.11. When reviewing these preventions, it is always better to operate at the higher levels in the hierarchy of controls.

**Explosives research development and innovation of low fume products**

3.2. Explosive suppliers, in consultation with Industry, are developing explosive product formulations for open cut mines, to prevent or minimise fume generation. This development should include a User Needs Specification, which details the overall parameters within which each explosive product is required to perform. From this process, the manufacturing parameters will be delivered and then component specifications can be detailed.

- Be safe and suitable for the range of ground conditions and operational processes found at the mine (sleep time, water, depth, confinement, reactive and or hot ground).
- Be able to be supplied in sufficient volume to meet the mine's production requirements.
- Formulated for delivery system used at the mine.
- Predictable performance in ground conditions found at the mine.
- Creation of broken ground suitable for excavating equipment.
- Product has safe and effective characteristics.
- Formulated to produce low fume.

**Manufacture of AN prill, emulsion, initiating accessories, gassed and sensitised product.**

3.3. The explosives manufacturer/supplier should have documented, change management procedures for modification and alterations to explosive and/or precursor formulations. The procedures should provide for:

- Assessing and managing risk associated with the modification/alteration of the formulation through the use of documented hazard and technical review assessments.
- Recording any modification/alteration and updating relevant authorisations, technical data sheets, safety data sheets, work procedures, and training programs as and where relevant.
- Ensuring that any modification or alteration does not affect the validity of an authorisation issued by the relevant authority.
- Notifying the user sites of changes to authorisations, technical data sheets, safety data sheets or recommendations, in relation to proper use of the explosives or precursor products.

3.4. The performance of an explosive in the field is critical to a successful blast. This relates to the performance of the explosives in both the extraction process and from a fume perspective eg a product that is resistant to water, has the ability to cope with varying levels of ground confinement and performs adequately in deep holes.

3.5. Water resistance can be affected by formulation changes and there is a general obligation on the manufacturer/supplier, to ensure that the formulation change does not lead to the generation of excessive fume. The manufacture of the explosives on the site must produce a quality, consistent product for use in the conditions. The quality control of this aspect is critical to a low fume blast.

3.6. The development of a blasting explosive must consider the generation of fume. There is no standard test for the production of fume from a particular formulation. Tests used to exist for the nitro-glycerine range of products as the sample size was small in weight and could be examined in small scale blasting chambers. Ammonium nitrate based explosives require larger samples and there are no large scale testing facilities that can accommodate this. The field trialling of blast explosives and ongoing performance of explosives, is important to ensure there is no tendency to generate fume.

**Storage of AN prill, ANFO and emulsion**

3.7. AN prill and emulsions are subject to temperature cycling which can lead to the production of fines in AN prill and crystallisation in emulsions. These adverse physical characteristics have a negative impact on the product quality, stability and explosives performance.

- The creation of fines affects the absorption of fuel in ANFO manufacture and may destabilise emulsions by initiating crystallisation.
- Increased levels of AN fines may alter the density of the products and alter the oxygen balance of the products final blend.

3.8. AN prill should be stored in well-ventilated areas under cover from direct sunlight. It should not be stored in bags under tarpaulins without ventilation.

3.9. AN prill degradation and fines generation, is promoted by temperature cycling; the use of shade roofs on the storage location will reduce the temperature cycling and increase the time taken for degradation to occur.

3.10. Temperature cycling of emulsion and water gels may decrease product shelf life. Storage in tanks with open tops or fitted with open breathers for long periods of time, may result in water loss and crystallisation.

3.11. Both prill and emulsion should not be stored for long periods of time. The shelf life will vary from a number of factors including manufacturer, seasonal time of manufacture (temperature, humidity) and whether the product is a matrix or ANFO blend. The manufacturer's recommendations on these products are specified in the technical data sheets.

3.12. General product shelf lives are as follows:

| | |
|---|---|
| • AN prill | 3 months |
| • Emulsions | 3 months |
| • Water gels | 3 months |
| • ANFO | 6 months |
| • Heavy ANFO | 3 months |

3.13. The storage conditions should be considered for other ingredients such as fuel oil, gasser solution, companion solution, etc. to prevent their degradation.

**Ensure that initiating system components are matched to the explosive product.**

**Selection of initiating explosives and explosive product**

3.14. Initiating devices must be those recommended by the explosive manufacturer. Detonators, boosters and the main charge must be appropriate to initiate and maintain the detonation wave. An inadequate booster could lead to a less optimum explosive reaction that produces fume.

3.15. The initiating explosives are critical to the blast and must be matched to the product and the conditions they are employed in. In the event of misfires of boosters or product not being given a sufficient detonation wave, there will be an increased amount of fume or perhaps a misfired column of explosives product to be appropriately dealt with after the blast.

3.16. The blast designer must design the blast to use explosives in accordance with the manufacturers recommendations and establish the suitability of the explosives and accessories for the hole depth, diameter, moisture level, presence of hot or reactive ground, ground hardness and density. See Figure 6 below.

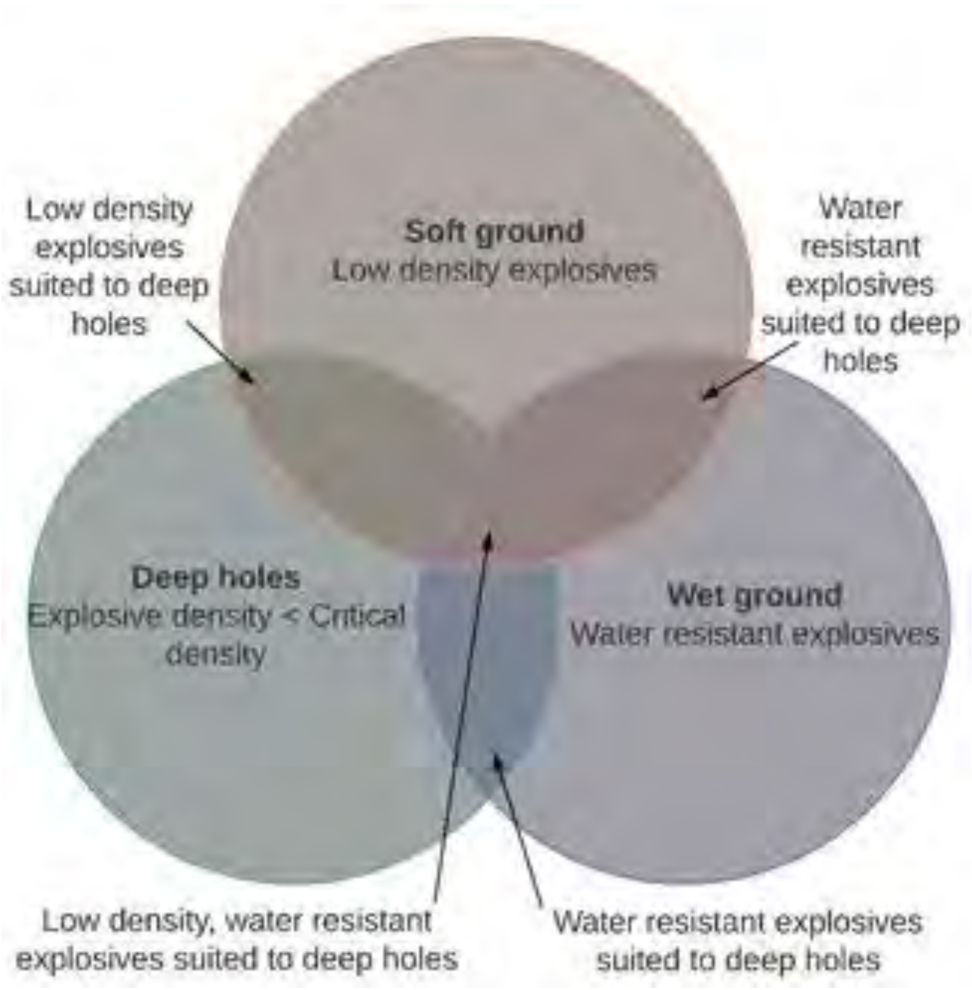


Figure 6: Explosive Characteristics in each and combinations of ground conditions[14]

[14] Figure 14 – JKTech Pty Ltd Report

3.17. The presence of water in blast holes is an issue common in most open cut coal mines. The presence of water requires the use of water resilient explosives, which can vastly increase the cost and loading time of blasting. It is imperative that both the mechanics of water ingress and the effect water has on explosives are understood.[15]

## Design of the mine shot

3.18. The objectives for a blast design should be to:

- Ensure the safety of the public, site personnel and surrounding properties.
- Identify site-specific requirements.
- Identify hazards, assess risks, establish controls and minimise residual risks.
- Control the blast process from design to initiation, evaluation and misfire treatment.
- Implement a review process to ensure that the objectives are met.

3.19. Ground conditions and geology influences the confinement of the explosives, which is a critical requirement to ensuring the explosive reaction is near ideal.

3.20. Understanding of the site geology is important to underpin the blast design, so that inter-hole distance and timing will not contribute to fume. Design of blasts must always take into account the whole rock mass, not just the point rock strength (MPa quoted strengths). The blast designer should have in place a system that enables determination of appropriate whole of rock mass strength characteristics. The system should be capable of delivering the suitable blast design parameters suitable for the specific rock mass strength characteristics.

3.21. The flow chart shown in Figure 7 below, outlines a fume mitigation process, that may assist in the decision making process when selecting the appropriate explosive product, if the ground is modelled on being soft, if the explosives are likely to be exposed to water, or if the blast contains deep holes. The appropriate explosive should be selected deductively, given the environment in which they will be loaded[16].

[15] Section 3.18- JKTech Pty Ltd Report

[16] Section 3.18- JKTech Pty Ltd Report

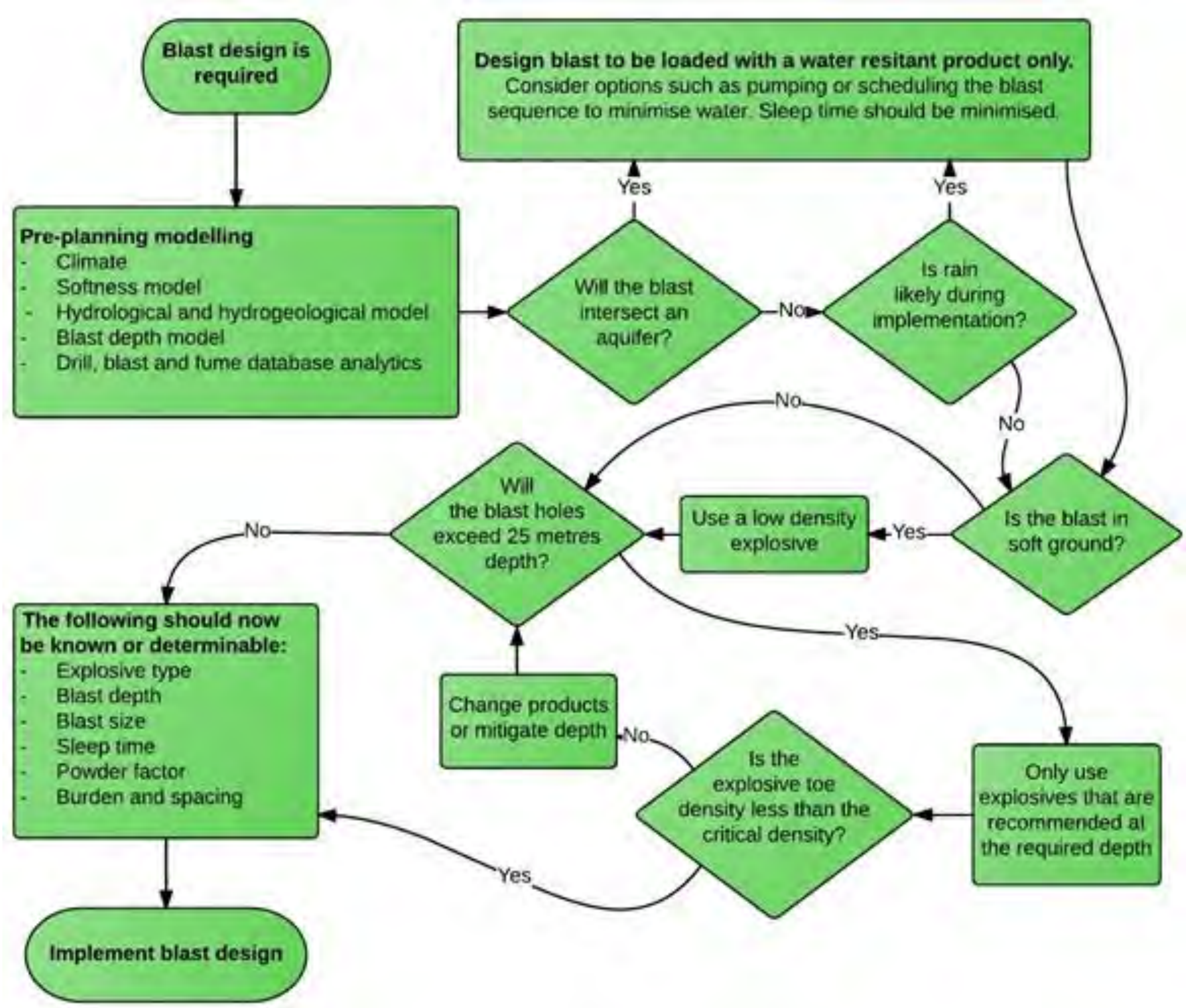


Figure 7: Fume mitigation during planning

3.22. The fume mitigation flowchart for planning should achieve two primary outcomes; identify the optimal explosive to be used and the explosives that must not be used. Modelling of the ground water, rock hardness and depth may not be accurate or be representative of the entire blast. The flow chart below, in Figure 8, seeks to identify the ideal explosive for the blast, but this may only be the case for the majority of the blast. Different products will most likely be required to address the variable conditions where they occur. Systems must exist to empower shotfirers or drill and blast engineers to identify conditions that do not suit the designed explosive and select an appropriate bulk explosive for the conditions.

The flow chart in Figure 8 prompts the reader to identify factors that could result in implementation of the blast, varying from design or if the design is inappropriate. Where changes to the design are required, the decision making process must consider the implications for fume.[17]

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[17] Section 3.5 – JK Tech Pty Ltd Report

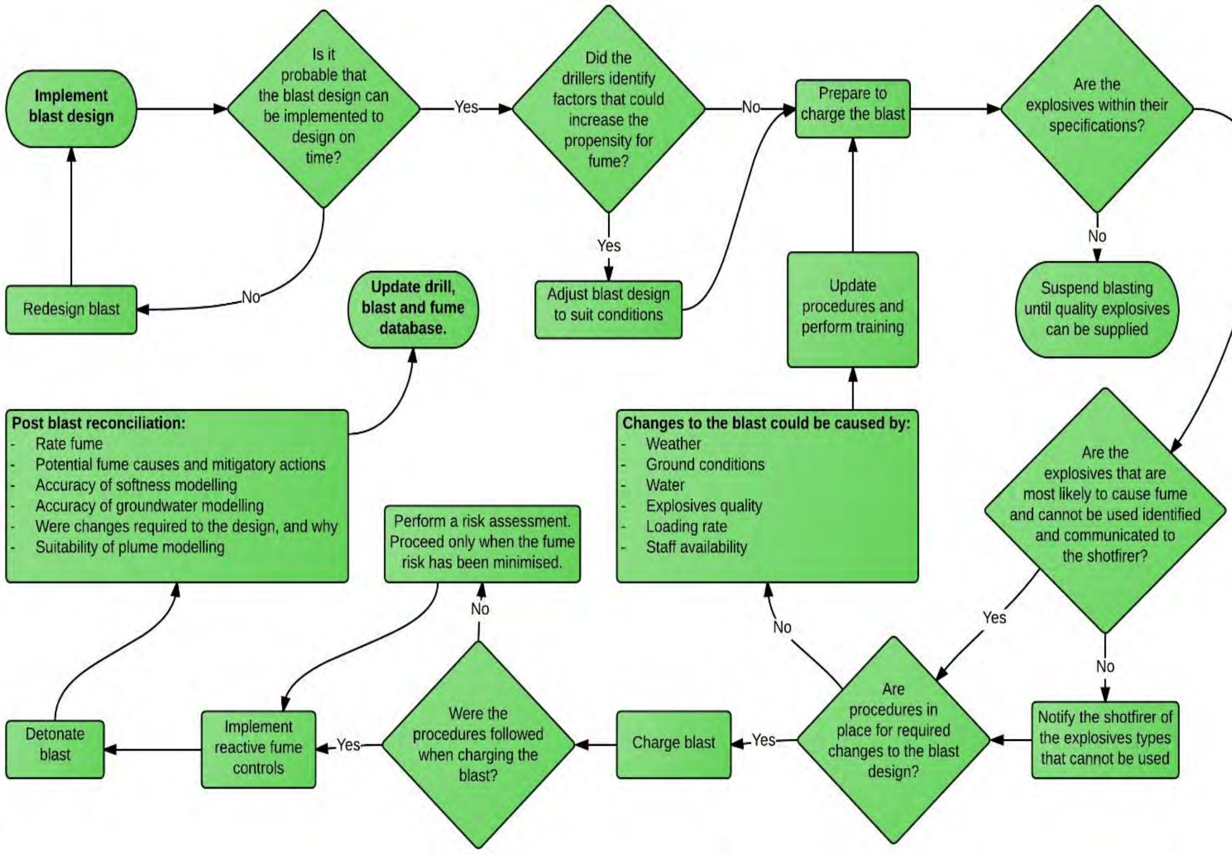


Figure 8: Mitigation of fume during implementation

3.23. An important issue is the knowledge gained from previous blasts at the mine site. This will provide vital information about ground conditions and water that will influence the blast design such as.

- Initiation sequence. This should be designed to limit the potential for desensitisation of adjacent explosives product columns, as well as allow for adequate confinement to ensure complete detonation of the explosives column and conversion of intermediary explosion gas products to their final form.
- Presence of a free face will in the majority of cases allow for controlled movement and adequate confinement of the rock mass
- Ground conditions – does the type of ground provide adequate confinement for the explosives to detonate well. If the ground is too hard, it is possible that reduced hole spacing, as well as increased ground shock from a higher powder factor, could potentially desensitise adjacent explosives columns (dead pressing), that could result in excess fume generation.

**Match the explosives to the confinement provided by the specific rock mass strength characteristics**

**Drilling of the shot**

3.24. Drilling must be to the design, with variations recorded and incorporated in all relevant post drilling activities. The drill log can provide data to the blast designer about the actual in-hole conditions.

**Loading of the shot**

3.25. Loading must reflect the design and variations recorded and reported for inclusion in the pre-blast risk assessment. During the loading of the shot, information is obtained regarding the presence of water e.g. surface or sub surface, incorrectly drilled holes, missing holes, collapsed holes, amount of product loaded, density of product, use of air bags etc. These need to be monitored and dealt with during the loading process. These recorded variations may become important considerations in the pre-firing review (refer to Annex F).

**Stemming of the shot**

3.26. Stemming is used to confine the top of the blast hole. Stemming depth and the type of stemming used, can affect the confinement of the explosives and lead to a less than ideal detonation that contributes to fume. The use of drill cuttings may result in less confinement than clean crushed rock, as the drill cuttings do not lock and hold well in place. Stemming performance will be reduced if there is water in the stemming area, there is weak ground strength in the stemming area, the relief burden is small or the explosives are very high energy.

**Pre-blast review and firing of the shot**

3.27. A review of the blast should be conducted prior to firing. The purpose is to determine if there is now an increased chance of fume as a result of the loading activities and the conditions of the shot. A thorough pre-firing review is essential. This review is to identify that all appropriate safeguards are in place. It should identify any variation in the design, drilling and loading of the shot that could contribute to fume. This review must include reviewing and adjusting firing plans to weather conditions. Each site should develop its own review process based on their procedures. Factors to be considered at a pre-firing review are outlined in Annex F.

**Sleeping Shots**

3.28. Sleep time for the blast must also be considered, as extended exposure to local, in-hole conditions can significantly affect explosive products. Correct product selection may reduce the impact of the local in-hole conditions, however, the product manufacturer's recommendations in regards to sleep time must be followed. The graph below in Figure 9, is taken from the Fume Survey Database (trended on 15th August 2016) and shows the relationship between the average fume ratings of blasts, when compared to the number of days sleep time.

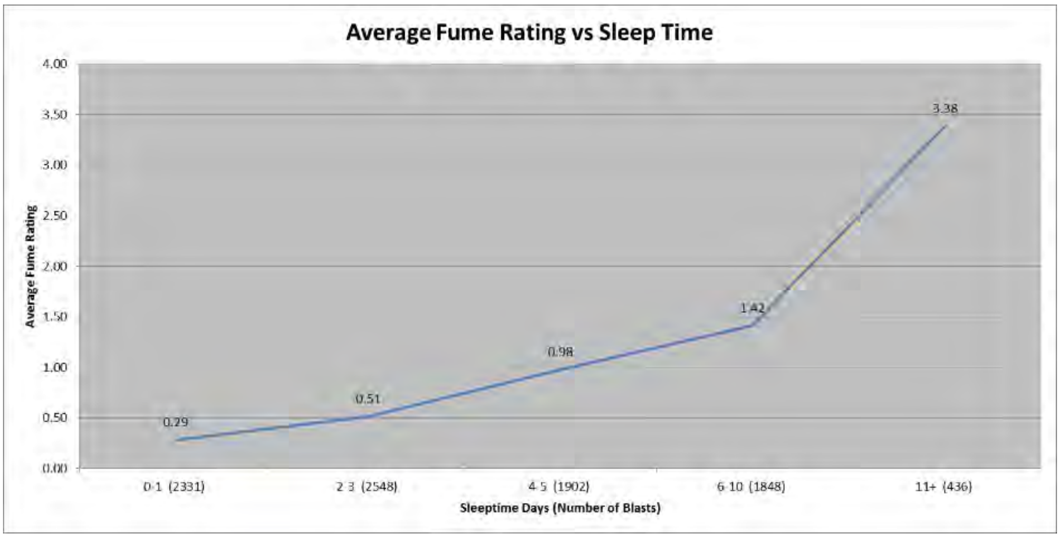


Figure 9: Average post blast fume generation when compared to the number of days sleep time (number of blasts in brackets)

**Post blast activities**

3.29. A post blast review should be carried out to verify that design/operational aspects did not contribute to excessive fume generation.

3.30. A review should be conducted after any fume event, to ensure all records and documents, such as the blast pack, video and measurements are available. This should identify issues and provide causation factors to support the investigation.

3.31. Incident reporting: A system should be in place to report to the Queensland Explosives Inspectorate and the Queensland Mines Inspectorate, any of the following fume events that cause:

- Unplanned evacuation of coal mine workers and/ or neighbours
- Exposure to post blast fume
- Any post blast fume that breaches the fume management zone (FMZ) and/ or leaves the mining lease.

**Procurement of blasting explosives**

3.32. Procurement should be based on sourcing products that are compliant to the User Need Specification (mitigation of fume should be a component of this specification). The accuracy of the User Needs Specification is critical to the tendering process, delivering a product that is suitable for the ground conditions.

3.33. Contracts for the procurement of explosives need to be flexible to deal with the ability to select a variety of products to deal with the variables that product selection is capable of mitigating against. Such examples are:

- Presence of wet holes – product needs to be available on site
- Extreme rain events
- Ground conditions

3.34. It is essential that the explosives supplier and the user develop an ongoing relationship in regards to product performance that can ensure appropriate products within specification are delivered and used within their design parameters. Either party working alone is unlikely to have the expertise to determine problems relating to performance of explosives.

### Mine planning

3.35. This planning process determines the allocation of ground to the Drill and Blast Superintendent. This planning can be fine-tuned to deliver the ground containing the material to be extracted in sections that are less conducive to fume then others. Other planning considerations include:

- Impact of mine schedules (whole of mine), pressures and inadequate internal communications that affect the safe, effective and efficient preparation of the blast.
- Recognising the ground conditions - will the drilled hole provide adequate confinement for the selected explosive.
- The presence of water in blast holes will degrade the explosive and its performance. Is the available explosives product suitable for the conditions?
- Explosives products are formulated to ensure they meet the User Need Specification.

### Training competency and certification

3.36. All persons should be adequately trained for the role they do. Competency training units, as below should be used. These are generally in place for shotfirers and assistant shotfirers. For the most recent version of the Shotfirer's competencies, refer to the following link:

https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0004/238432/competency-requirements-shotfirer-licences.pdf

Although they are trained and competent, persons also need to be trained in the local procedures and systems and mentored in their role. Only when a person has the competencies and appropriate induction training and guidance should the SSE could consider appointing the person into a role.

3.37. Persons operating MMUs should receive specific training to ensure explosives loaded are within the manufacturer's specifications and blast design parameters.

3.38. It is strongly recommended that persons performing the roles highlighted in Table 3.1 are trained in the individual competencies. The competencies will ensure that persons appointed in those roles by the SSE have a basic understanding of blast requirements.

**Table 3.1 Recommended competencies**

| Blast Designer | Blasting Supervisor/ Contractor | MMU Operator | Shotfirer (Aboveground - Open Cut metalliferous and coal) |
|---|---|---|---|
| RIIBLA402D Monitor and control the effects of blasting on the environment | RIIBLA401D Manage Blasting Operations | RIIBLA203D Conduct Mobile Mixing of Explosives | RIIBLA205D Store, Handle and transport Explosives |
| RIIRIS402D Carry Out the Risk Management Processes (or Equivalent) | RIIBLA402D Monitor and control the effects of blasting on the environment | | RIIBLA301D Conduct Surface Shotfiring Operations |
| RIIBLA601D Design Surface blasts | RIIRIS402D Carry Out the Risk Management Processes (or Equivalent) | | RIIBLA2305D Conduct Secondary Blasting |
| | RIIBLA602D Establish and Maintain a Blasting System | | |

# Section 4 - Management of a fume event

## Management of a fume event

4.1. The systems to manage fume events must be well established, so that, should a fume event occur, there is a standard response that is clearly understood by all persons. The location of people who could be exposed should be identified and the anticipated behaviour of the fume plume understood so that appropriate actions can be taken without delay. This should ensure that no further exposures occur and that any persons exposed are appropriately treated.

4.2. Prior to firing a blast, it may be evident that either a significant fume event is likely to occur or that there may be an unexpected fume event. The mine must take either situation into account whenever conducting a blast. All blasts should be regarded as a possible fume event and under certain circumstances, if the conditions are not suitable, the blast may need to be re-scheduled.

4.3. A pre firing review is required for any blast to identify and manage the possible hazards of a blast and ensure that all personnel and equipment is protected against flyrock, overpressure, heat or ground shock. Fume must also be considered.

4.4. The mine must have in place an assessment at pre-firing, which includes the identification of factors during the shot preparation that could contribute to fume. Knowledge and experience of blasts in specific areas may provide useful information on the likelihood of fume and its possible level. Factors to be considered in the pre-firing review are provided at Annex F.

4.5. Management must be clear that the review should be conducted and any specifically identified risks and proposed mitigations should have the approval of the SSE or delegate prior to firing.

**A pre-firing review must be conducted to ensure blast hazards – blast overpressure, flyrock, ground shock and fume – can be managed safely with appropriate precautions in place.**

**Meteorological conditions**

4.6. The actual meteorological conditions at the time of firing the blast will have a significant impact on the fume plume and its local effect.

4.7. If significant issues such as wet-holes etc. have been identified in the preparation of the shot indicating that a fume event is likely, an examination of the likely local weather conditions should be made, in relation to potentially exposed sites prior to firing the shot. These principles need to be developed by specialists and embedded into the standard operating procedures. It should take into account the following matters:

- Potential blasting areas and potentially exposed sites
- Meteorological conditions including;
    - temperature inversion
    - wind direction and speed
    - atmospheric stability
    - cloud cover
    - time of day
    - temperature
    - humidity
    - rain

Weather forecast models are available that can provide detailed site-specific weather predictions at fine resolution for the local area, including all necessary meteorological data for use with an air quality dispersion model.

**Time of firing**

4.8. When considering a time to initiate the blast – weather conditions must be assessed. Generally, the atmosphere is most stable early in the morning and late in the afternoon, due to the absence of direct ground heating from the sun. If a fume event occurs at these times and the wind conditions are light, it is likely to have a greater impact in terms of size, distance travelled, stability of cloud and slow dissipation.

**Potential fume exposure sites**

4.9. A master fume map such as Figure 10, should be developed and maintained for each blast site. The purpose of this map is to identify internal and external potentially exposed sites and the number of persons at that site. Examples are:

- Internal potential exposure sites
    - Offices
    - Car parks
    - Workshops
    - Administrative areas
    - Explosives storage area
    - Benches
    - Underground mine entrances and ventilation shafts
    - Wash plant and other infrastructure
    - Coal seam gas wells
    - Exploration activities

- External potential exposure sites
    - Houses and farms
    - Towns
    - Industrial Sites
    - Public Roads
    - Railways
    - Underground mine entrances and ventilation shafts
    - Coal seam gas wells
    - Exploration activities

4.10. This map should be used to identify potential monitoring sites either of a permanent or temporary nature when firings are to occur.

**Note: The map below has been developed as a guide and is indicative only.**

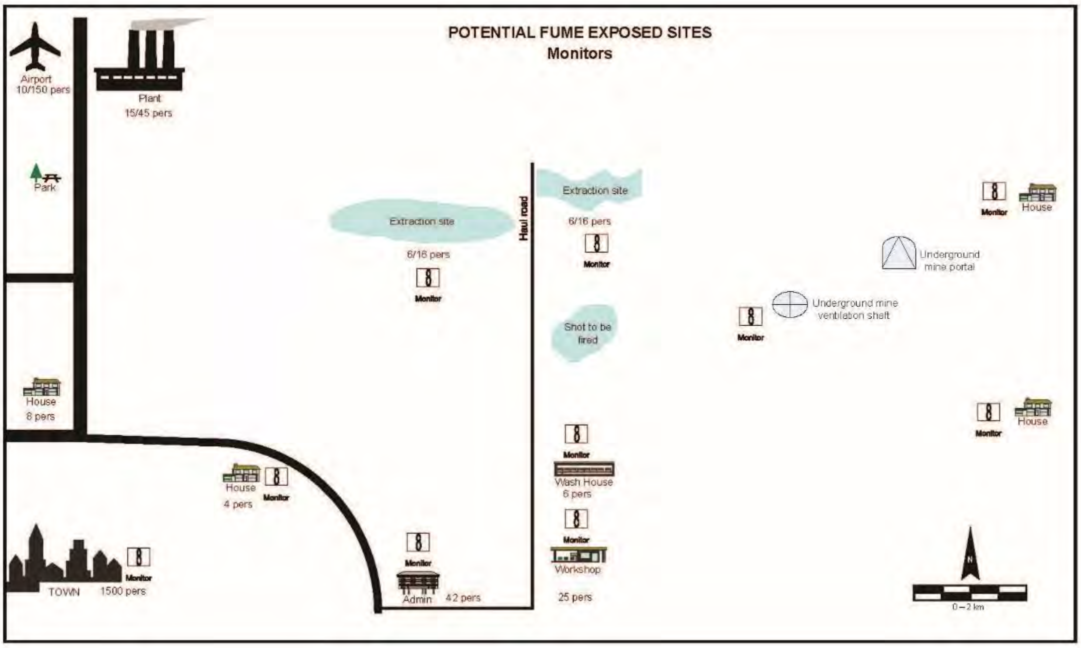


Figure 10 - Master fume map without fume prediction

The standard map, without the fume risk area, should identify potentially exposed sites, under all possible conditions, where monitors should be placed either permanently or temporarily for each firing.

## Fume Management Zone (FMZ)

4.11. When the pre-firing review is conducted, the map should have the standard blast exclusion zone (BEZ) indicated on it to cover flyrock, overpressure and ground shock. It should also have an indicated plume event trace that becomes the fume management zone (FMZ), where the blast controller has to ensure that persons will not be exposed to the plume. The background calculation of the plume, should have been developed for the site by competent people.

The area surrounding the blast likely to be exposed to the risk of fume, needs to be assessed by experienced personnel. This fume risk area will vary with:

- Fume rating of the blast
- Wind speed
- Wind direction
- Effect of topography on fume dispersion
- Time of day
- Temperature
- Humidity
- Inversion layers in the atmosphere
- Atmospheric turbulence.

A schematic of this fume map is shown in Figure 11 below.

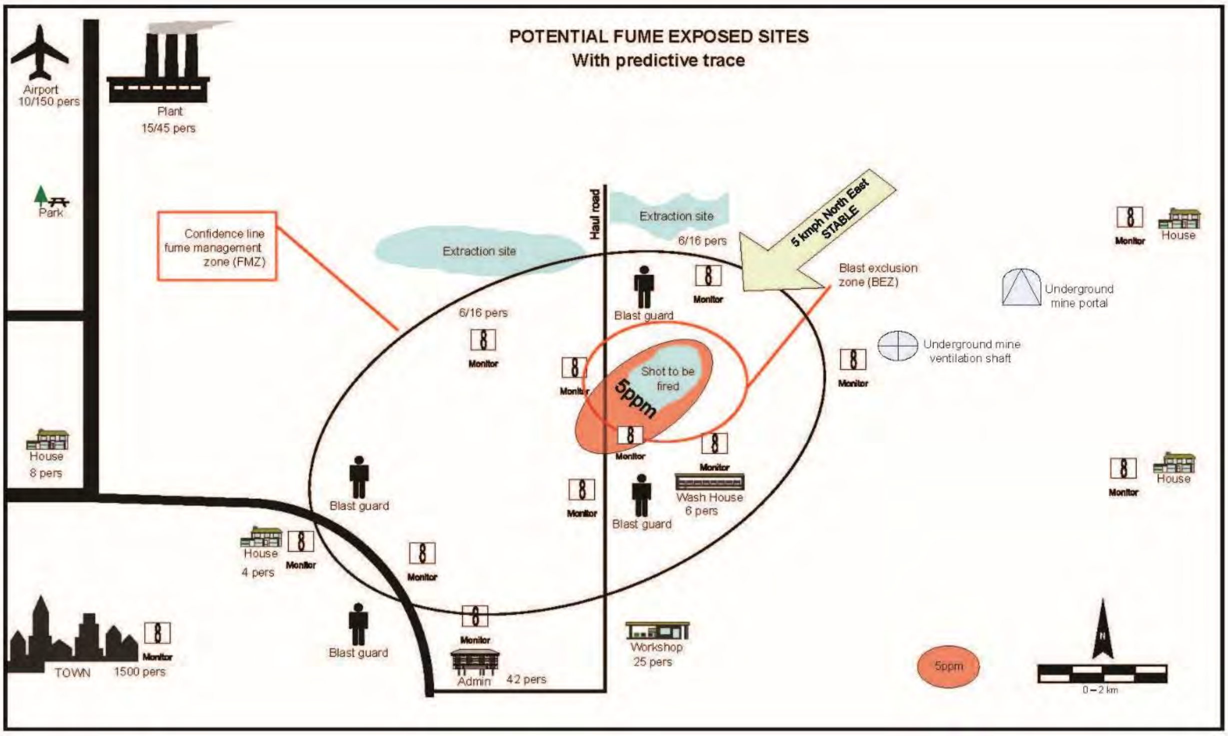


Figure 11 - Master fume map with fume prediction

Example workings to calculate expected fume management zone (FMZ) level e.g. 4 stability conditions, temperature, cloud cover and timing of cloud to travel at ground level.

**Notes**

1. Consider evacuation of wash house.
2. Advise admin, farmhouse and workshop of possible low level exposure - small only.
3. Smell may take up to 30-40 minutes to reach main roads depending on wind conditions.
4. Extraction sites to the north could continue working with personnel remaining vigilant in case of wind shift. Consider PPE for persons who cannot evacuate – dragline operator.

**Monitoring of NOx**

4.12. These effects are complex, so even experienced personnel should view their assessment of the dimensions of the fume risk area as approximate. As a guide, experience with fume events has shown that:

- In high wind conditions (>10km/h), the fume cloud is likely to be driven by the wind over a considerable distance before dispersing. This results in a large downwind fume risk area.
- In very light wind or calm conditions, the fume cloud tends to dissipate at a slower rate without travelling a great distance. NOTE: Nitrogen dioxide is heavier than air and may accumulate in low-lying areas where it may displace oxygen and/or reach toxic concentrations.
- The effect of the topography of the mine site is significant. Pit highwalls and spoil piles can influence the path of airflow through the mine and hence movement and dispersion of the cloud. This may result in an increased risk of fume exposure outside the pre-determined fume management zone (FMZ).

4.13. Monitoring NOx levels before and after a fume event is important to:

- enable background levels to be established for particular locations
- take action to safeguard personnel
- Identify exposure levels at particular sites. This information can be provided to treating medical staff
- increase the information available to investigators determining the amount of fume generated
- provide indication to treating medical staff of the possible level of exposure
- record exposure to persons and sites that may become the basis of legal claims – this should be identified in a review.

**Persons should not enter a post blast fume cloud.**
**Such fume clouds will generally be visible and have an acrid smell.**

**Monitoring equipment**

4.14. Suitable monitoring equipment (personal or fixed) varies depending on its purpose, which could include personal monitoring or site/area monitoring. Monitors should be capable of detecting multiple gases and comply with Australian Standard AS 4641 as a minimum. Specific monitors can be hired or purchased outright. When purchasing monitors, specify the target gases that you need to monitor. As a minimum this must include:

- Nitrogen dioxide
- Carbon monoxide

4.15. All fixed monitors must remain in calibration and be challenged (bump tested) prior to each use with the gases they are meant to detect. Monitors may provide a basic warning of a gas with an alert and may also log data by ppm recorded over time.

4.16. All monitor positions must be accurately recorded with GPS co-ordinates to assist in investigation of any fume event.

## Assessment of fume risk area using atmospheric modelling

4.17. The dispersion model used should:

- Allow for varying horizontal and vertical spread of the fume cloud at different locations and heights above ground.
- Allow for different rates of dispersion.
- Allow for terrain effects within and outside the pit.
- Be capable of modelling low wind or calm conditions.
- Be capable of modelling turbulence (critical for dilution rate and short-term movement of blast cloud).
- Be capable of modelling sub-hourly time intervals.
- Be a regulatory approved model (International or Australian).
- Have the capability to run using forecast meteorological data.


*Note: The information used to generate this figure does not represent a planned blast. It has been generated specifically as an example of a Master Fume Map with Fume Risk Area and possible locations of interest marked. It is based on representative blast design data and forecasted weather parameters for the date and time indicated, but does not represent any plan to actually conduct a blast at this time or location.*

Figure 12 (Figure approved by Dawson Mine for use in QGN20)

## Monitoring plan

4.18. The SHMS should develop, operate and maintain a monitoring plan in place appropriate to the site and identify potentially exposed sites. The monitoring plan should be risk based and consider, but not be limited to the following:

- Internal potential exposure sites
  - Offices
  - Car parks
  - Workshops
  - Administrative areas
  - Explosives storage area
  - Benches
  - Underground mine entrances and ventilation shafts
  - Wash plant and other infrastructure
  - Coal seam gas wells
  - Exploration activities

- External potential exposure sites
  - Houses and farms
  - Towns
  - Industrial Sites
  - Public Roads
  - Railways
  - Underground mine entrances and ventilation shafts
  - Coal seam gas wells
  - Exploration activities

4.19. Monitoring requires the following principles to be of value:

- Monitors shall be calibrated and challenge tested (bump tested)
- Monitoring data is recorded and maintained
- GPS location of monitor is accurately recorded
- Monitors need to be time synchronised with each other and other recording equipment such a videos
- Data analysis should be undertaken to verify modelling

4.20. The use of individual monitors should be considered for persons that could be inadvertently exposed to fume. Such persons would include the blast firing crew and blast guards. All other persons are unlikely to be exposed. The monitors for this use should be capable of providing a warning when high levels are encountered and holding a record of the peak exposure. These monitors are relatively inexpensive and would provide good data to support medical treatment.

4.21. The data should be recorded for further analysis. The pre-firing review is used to refine the standard monitoring plan. It should identify the persons who are most likely to be close to the blast and/or within the FMZ and hence more likely to be exposed. These persons should be evacuated or placed on evacuation standby, as appropriate.

### Personal Protection Equipment (PPE)

4.22. Being low in the hierarchy of controls, it is widely recognised the use of PPE is the least desirable option for controlling hazards. Whilst in some circumstances the use of appropriate respiratory protective equipment (RPE) may form part of the overall control strategy, the focus should always be on the prevention of blast fume.

**Recording NOx measurements (in ppm), duration and location of the fume cloud will provide data to improve the management of fume events and objectives.** Supporting information such as wind speed, wind direction and GPS coordinates, should be recorded when measuring fume concentrations. Reliable and informative monitoring data can be used to determine the likelihood and extent of any personal exposures. It may also be used to prevent or improve the management of future fume events.

### Documentation and records

4.23. The documentation and records required for the preparation and firing of a blast is important to ensure the following:

- Information is available to the Blast Superintendent or SSE to support the pre-firing review
- If a fume event occurs, there is sufficient information available to enable the investigation to find the variable or variables that contributed to the fume event.
- The following documentation must be recorded for each blast:

- Technical Data Sheets(TDS)
- Blast plan
- Tonnage calculation
- Blast mark-out report
- Face hole profiles
- Load sheets
- Tie up plan
- Firing sequence
- Timing contours map
- Explosives quantities used
- Delivery dockets
- Issues log
- Air blast printouts
- NOx monitoring records
- Pre-firing Assessment
- Post firing reviews
- Pre loading assessment
- Management of change of blast parameters
- Abnormal circumstances
- Fume Management Zone (FMZ)
- Site Data Sheet (SDS)
- Blast design
- Vibration

# Section 5 - Management of a fume exposure

## Management of a fume exposure

**Initial first aid**

5.1. Recommended actions are to get out of the cloud and seek fresh air. Use water to reduce the amount of exposure, wash out eyes and clear nose and throat. Any person exposed to fumes, should be immediately sent to be checked by medical staff. This is a precautionary measure that must be undertaken. It can be difficult to determine the level of exposure and if certain symptoms are obvious on presentation to a treating doctor – the person may need to remain under observation for at least 4-6 hours to monitor for pulmonary oedema.

5.2. If there is monitoring information available, this information should be passed to the treating medical staff. The data of exposure level in parts per million (ppm) and duration of the exposure is useful information for the treating doctor and also provides information to inform future planning of dealing with fume exposures.

**Advice to medical staff**

5.3. The treating medical staff must be aware of what likely range of gases the person has been exposed to. A standard letter for persons exposed to oxides of nitrogen is at Annex G.

5.4. The treating medical staff should provide the patient with feedback on the signs and symptoms observed when the patient was presented.

## Incident reporting

5.5. There are obligations in regard to reporting incidents under the applicable legislation. Figure 13 on the next page details the appropriate reporting circumstances. In any of the events identified in Figure 13, the following information to be provided for reporting a fume event is:

- Time of event
- Fume strength rating 0-5. A NOx rating scale can be found at Annex H. Determine the rating when the cloud was at its highest concentration
- Percentage of blast area emitting fume (0% - 100% in 10% increments).
- Wind speed and direction at time of firing
- Atmospheric conditions
- Temperature
- Cloud cover
- Pre-firing and post-firing review summary – add to incident report
- Persons exposed
- Treatment provided
- Other factors which may be useful

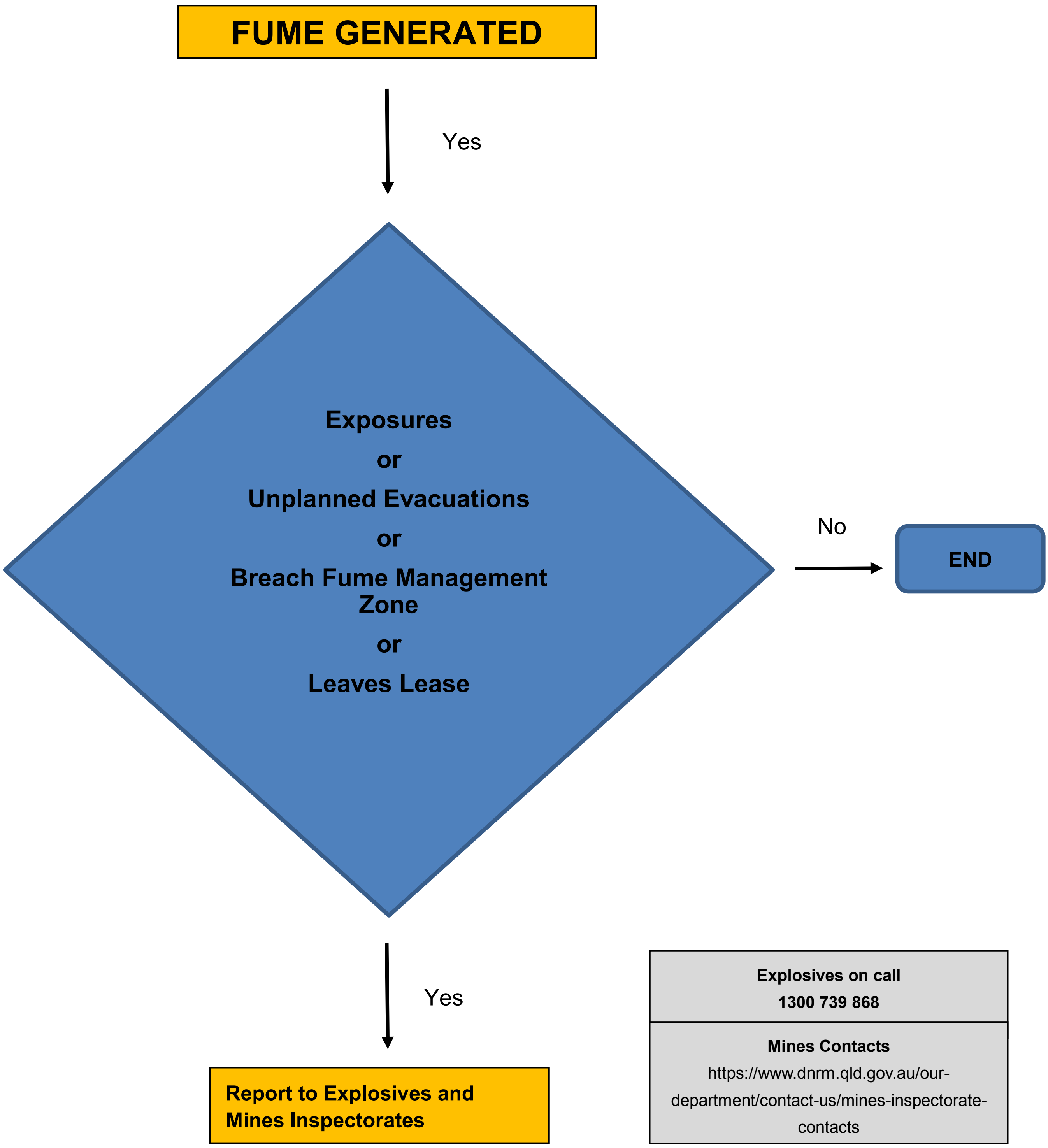


Figure 13: Reporting requirements for the Explosives Inspectorate and the Mines Inspectorate.

# Section 6 - Investigation of fume events and ongoing audit and review

## Investigation to determine contributing factors

6.1. It is important that all fume events are thoroughly investigated to determine, as accurately as possible, the contributing factors to the generation of the fume. Investigations rely heavily on the availability of accurate blast records, emphasising the importance of good record keeping.

6.2. The use of Annex E will be a valuable aid in identifying the contributing factors to the generation of the fume.

## Investigation template

6.3. A guideline to investigating fume and a fume investigation template that should be used by the mine site, explosives company or the regulator, can be found on the page from which this report was opened.

6.4. A previous review of fume investigations and the follow up, indicates that many investigations are unable to attribute an exact cause and generally list a range of potential contributing factors. This is understandable because of the variables associated with blasting but it is important that lessons learnt, are translated into procedures and practices to eliminate those identified causes. Mines and explosives companies must ensure that poor practices and inadequate procedures are identified and adequate controls incorporated into the SHMS to prevent future occurrences.

6.5. Bow tie diagrams developed around the six potential contributing factors identified in relation to fume, can be found on the DNRM website. These bow tie diagrams have been based on the AEISG causes and are in a preliminary stage only. There is some additional work to be completed on the controls associated with the management of the consequences side of the bowtie.

## Audit and review

6.6. Regular audits of the activities need to be undertaken to confirm all parties involved in blasting, ensure their part of the blast activity is well controlled. This continuous verification is essential in an activity that has significant variables to be controlled. Results of audits undertaken by supervisors, superintendents and SSEs should be recorded and retained.

6.7. Audits must review previous incidents regarding fume and ensure that the SHMS has implemented procedures ensure the explosives, application and procedures will not lead to a repeat situation. If the SHMS has not been corrected after such events' and monitored for ongoing compliance, there has been no safety gain from the incident and it is likely to be repeated.

6.8. Review of a fume event should be comprehensive and must pinpoint which particular variables were the main contributors to the fume event. The use of effective documentation and records outlined above is critical to accurately reviewing an event.

# Section 7 - Conclusion

## Conclusion

7.1. The focus of this Guidance Note is to educate relevant persons in the identification and control of potential contributing factors leading to the generation of post blast fume generation.

7.2. There are many factors across the life cycle of blasting that need to be managed in order to minimise fume. It is important to ensure that a fume management plan is in place to manage any fume events or fume exposures that do occur.

7.3. The monitoring of blasts is vital in obtaining actual data to improve modelling and understanding of plume behaviour. It is also an important issue to enable mines to verify that exposures are within the appropriate guidelines.

7.4. Exposures must be treated with a precautionary approach and medical facilities advised of the type of exposure. If there is monitoring data to support the exposure, this information should also be provided to the medical facility.

7.5. Investigations of fume events must be thorough and determine the most likely potential contributing factors of an incident. Thorough investigations will ensure that appropriate controls can be developed to reduce the likelihood of future occurrences. For investigations to be effective, all sites must keep good blast records.

7.6. All persons, supervisors and managers should understand the contributing factors to the generation of post-blast fume and how their roles and responsibilities assist in preventing fume events.

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# Annex A - Definitions

| | |
|---|---|
| AEISG: | Australian Explosives Industry Safety Group – a group of explosives companies working in a collaborative manner to improve explosives safety in Australia. |
| ANE: | Ammonium nitrate emulsions classed as UN No 3375. These include both emulsions and water gels. |
| ANFO: | A mixture of ammonium nitrate and fuel oil with or without a dye colouring agent (Definition from AS2187.0). |
| Bench assistant: | A person assisting the shotfirer on the bench in blasting activities. |
| BEZ: | Blast Exclusion Zone |
| Blast designer: | The person with direct management responsibility for the design of blasting practices in any mining situation, including the selection of explosive products. |
| Blasting supervisor/contractor | The person supervising blasting activities of the shotfirer and shot crew. May also be the lead shotfirer. |
| Burden relief: | A measure of the time delay, provided by the initiation design, between two consecutive burdens, measured in ms/m |
| Confinement: | A measure of the effort required from detonation gases to displace the fractured rock. |
| Deep hole: | A blast hole of greater than 30 metres. |
| Desensitisation: | The process of reducing or removing the sensitivity of an explosive, whether temporarily or permanent. |
| Dewatered hole: | A blast hole which has had rain or surface water removed using an in-hole pump or other mechanical means. |
| Drill and blast superintendent: | The nominated Drill and Blast Person accountable for the performance, safety as well as meeting production requirements of the Department of some mines |
| Drill and blast supervisor: | The person supervising blasting activities of the shotfirer and shot crew. He or she may be the lead shotfirer. |
| Dry hole: | A blast hole which contains no detectable water. |
| Driller: | The contractor or individual responsible for drilling the blast pattern to the blast design specification. Data and information on actual conditions encountered and variations to the pattern are to be recorded and advised to the blast designer and shotfirer. |
| Dust: | Airborne particulate matter ranging in diameter from 10 to 50 microns. |
| Dynamic water: | Water that is in motion, or flowing water. |
| FMP: | Fume Management Plan |
| FMZ: | Fume Management Zone. A predicted zone where fume is likely to be present after a blast. The FMZ is managed to ensure that persons are not exposed to fume in this area. |

| | |
|---|---|
| Fumes: | Refers in the context of this QGN to the gases belonging to oxides of nitrogen, particularly $NO_2$, the most prevalent and harmful. Fume is a combination of post blast gases, which are predominately nitrogen dioxide but may also include nitrous oxide, nitric oxide, carbon monoxide and carbon dioxide. Nitrogen dioxide is the only one of the post blast gases that is visible. |
| Gas bag: | An inflatable bladder used to block off a section of a blast hole and support explosives or stemming loaded above it. |
| Gassing: | Chemical reaction creating small gas bubbles in explosives blends with the addition of chemical gassing agents. This process increases the sensitivity of the explosives. |
| Hole liner: | A flexible plastic tube which is placed into a blast hole before product is loaded into the tube, providing some protection from water or broken ground. |
| Hole saver: | A plastic funnel, which is placed in the collar of a hole, allowing product to be loaded, but preventing fall-back of dirt, or water ingress. |
| Ideal explosion: | A chemical reaction that produces products (solids, liquids, gases) at volumes, concentrations and of type in accordance with conventional theoretical reaction equations. |
| IDLH: | Immediate danger to life and health. |
| MMU: | Mobile Manufacturing Unit. A vehicle built to strict specifications to manufacture and deliver explosives onto a bench. |
| MMU operator: | Person trained, assessed and found competent to operate an MMU, and who is authorised and appointed as the MMU operator by the company or mine site. |
| NOx: | Multiple combinations of oxides of nitrogen ($N_2O$, NO, $NO_2$, $N_2O_4$, $N_2O_3$, $N_2O_5$) with nitrogen dioxide ($NO_2$) being the principal hazardous nitrous fume. |
| Non ideal explosion: | A chemical reaction that does not produce products (solids, liquids, gasses) at volumes, concentrations and of type in accordance with conventional theoretical reaction equations. |
| NPI: | National Pollutant Inventory – provides data on pollutant emissions from inventory. |
| Oxides of nitrogen: | Nitrogen bases gases such as nitric oxide, nitrogen oxide, nitrogen dioxide, nitrogen monoxide and mononitrogen monoxide. |
| Post-blast fume: | Gases generated by the explosive reaction during blasting. |
| Potentially exposed site: | A site that is potentially exposed to the effect of a hazard. In this case 'fume'. |
| Precursor: | A material resulting from a chemical or physical change when two or more substances consisting of fuels and oxidisers are mixed and where the material is intended to be used exclusively in the production of an explosive. (Definition from AEMSC Code of good practice precursors for explosives.) |
| Recharge: | A term used to describe the re-entry of water back into a blast hole after it has been dewatered. |

| | |
|---|---|
| SDS: | Site Data Sheet |
| Sensitivity: | A measure on how easily an explosive can be initiated. Highly sensitive = easily initiated. |
| Shotfirer: | This is a statutory appointment directly responsible for the safety, security and outcomes of a blast |
| Sleep time: | The time between explosives being loaded into a blast hole and their initiation (Definition from AS2187.0). |
| SHMS: | Safety and Health Management System required by legislation for a site to operate under the Coal Mining, Quarrying and Metals Mining or Explosives Acts. |
| Stemming: | The material used to plug a blast hole. |
| STEL: | Short term exposure limit |
| Site senior executive (SSE): | The person appointed as the Site Senior Executive under mining legislation |
| TDS: | Technical Data Sheets |
| TWA: | Time Weighted Average |
| User needs specifications: | A clear and simply defined set of desired deliverables and characteristics of an explosives product, set by the user of explosives, required to suit the user’s operational requirements. |
| Wet hole: | A blast hole that contains any amount of detectable water. |
| Wet sides: | A description of a section of blast hole that is not filled with water, but is, however, wet at the sides. |

# Annex B - Properties of oxides of nitrogen

Nitrogen dioxide is produced for the manufacture of nitric acid. Most nitric acid is used in the manufacture of fertilisers, while some is used in the production of explosives for both military and mining uses.

### Substance details

Substance name: Oxides of nitrogen

CASR number: N/A

Molecular formula: NO, $NO_2$, $N_2O$ and $N_2O_5$

Synonyms: NO: nitric oxide, nitrogen oxide, nitrogen monoxide, mononitrogen monoxide

$NO_2$: nitrogen dioxide

### Physical properties

NO: sharp, sweet-smelling, colourless gas

Melting point: -163.6°C

Boiling point: -151.8°C

Relative Density: 1.6 (air = 1) – It is more dense then air and it will fill hollows, holes and cuttings

$NO_2$: reddish-brown gas with irritating odour.

Melting point: -9.3°C

Boiling point: 21.15°C

Vapour Density: 1.58

### Chemical properties

NO only burns when heated with hydrogen, and forms nitric acid (a strong acid) when dissolved in water.

$NO_2$ is sparingly soluble in water to form nitrous acid (a weak acid).

Australian National Pollutant Inventory - ‘Oxides of Nitrogen’ overview

# Annex C – Occupational exposure standards and health effects for nitrogen dioxide ($N0_2$)

## Occupational exposure standards

Occupational exposure standards represent airborne concentrations of individual chemical substances, which according to current knowledge, should neither impair the health of nor cause undue discomfort to nearly all workers. Additionally, the exposure standards are believed to guard against narcosis or irritation, which could precipitate industrial accidents. These exposure standards are guides to be used in the control of occupational health hazards. They should not be used as fine dividing lines between safe and dangerous concentrations of chemicals. (NHSC 1995)

A full list of all occupational exposure standards and the relative documentation behind them are made available from Safework Australia at the following link.

http://hsis.safeworkaustralia.gov.au/HazardousSubstance

**Table C-1 lists the current occupational exposure standards and IDLH value for $NO_2$.**

| Exposure standards | Percentage by Volume (Parts per million) |
|---|---|
| TWA (Time Weighted Average) | 3 ppm (0.0003%) |
| STEL (Short Term Exposure Limit) | 5 ppm (0.0005%) |
| IDLH (Immediately Dangerous to Life and Health)* | 20 ppm (0.002%) |

### Irritant effects

Many of the gases generated in an explosive reaction are unstable and of low toxicity. The main gases to consider are nitric oxide and nitrogen dioxide. Nitrogen dioxide is formed when nitric oxide combines with the oxygen in the atmosphere. Nitrogen dioxide is one of the irritant asphyxiant gases. At sufficient concentrations, these gases cause intense irritation to the eyes, mucous membranes and respiratory passages.

Nitrogen dioxide has a very strong acrid odour that is easily detectable by smell, at concentrations that are much lower than the current exposure standards (up to 40 times lower). In addition, concentrations from 4 ppm may anaesthetize the nose, thus creating a potential for overexposure if smell is used as an indicator of exposure.

### Pulmonary oedema

The irritant asphyxiant gases, which are less water soluble, such as nitrogen dioxide, may allow a full inhalation before their irritant nature is revealed, giving them access to the delicate membranes of the lower respiratory passages and alveoli, where they can cause severe damage. At higher concentrations nitrogen dioxide can cause severe bronchospasm (asthma) and an out-pouring of tissue fluid into the air passages, called pulmonary oedema and which, if severe, can lead to drowning due to fluid filled blisters bursting in the lungs. This reaction can be immediate or may be delayed for some hours. Since this happens rapidly when it does occur, it can be dangerous to allow people who have had significant exposure to go home before a suitable period has elapsed. Even those with minor exposure should be warned of the possibility of lung complications and directed to seek urgent attention if they become short of breath in the subsequent 24-hour period.

**Other respiratory effects**

Inhalation of raised levels of nitrogen dioxide can increase the likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. Children with asthma and older people with heart disease are most at risk.

**Long-term outcomes resulting from acute exposures**

The long-term outcome for a person, who survives the initial exposure to a significant high dose of nitrogen dioxide, can vary. Some recover with no subsequent health problems. Some continue to have a form of asthma known as RADS – (Reactive Airways Dysfunction Syndrome). This is a form of occupational asthma, that is, asthma (in a previously non-asthmatic person) caused by exposure to some substance at work. However, RADS exhibits some differences to classic occupational asthmas. For one, symptoms occur immediately after the exposure, whereas most occupational asthmas follow a variable latent period, where the person is exposed, but suffers no symptoms. With RADS, symptoms may persist for a variable period of weeks or months or may be permanent. The sufferer may find that many things such as solvent vapours, cigarette smoke and even cold air, may trigger symptoms.

The most serious long-term condition caused by nitrogen dioxide exposure, is a condition called obliterative bronchiolitis, which is a severe inflammatory condition in which the bronchioles (very small air passages) become severely scarred and the person may become progressively shorter of breath over time. The condition may eventually lead to a fatal outcome.

## Medical assessment to confirm exposure

Because $NO_2$ is a simple compound that acts locally within the lungs, there is no current useful blood test that can determine if a person was exposed. Reliance must be placed on the history (details of what happened), the person's symptoms (what they are experiencing) and signs (what the doctor finds on examination of the affected person). So for NOx, it's likely to be a story of an orange cloud passing over, followed by eye irritation and coughing. The doctor will notice red eyes that may be watering, as well as the person may cough. Listening to the person's chest may reveal squeaks and crackles, which indicate constricted air passages and the presence of excess fluid.

## Treatment

The medical treatment of persons exposed to $NO_2$ is detailed in Appendix G. Essentially, this involves treating the symptoms and signs as they arise, but for significantly exposed people, retain them for observation in cases of delayed pulmonary oedema affects, which may develop too rapid for persons at remote distances to reach medical attention. A summary of the physical/chemical properties, health effects and emergency handling procedures are attached at Annex D.

**Time Weighted Average (TWA):** are expressed as average airborne concentrations averaged over an 8-hour period.

**Short Term Exposure Limit (STEL):** are expressed as airborne concentrations of substances, averaged over a period of 15 minutes. Workers should not be exposed at the STEL concentration continuously for longer than 15 minutes, or for more than four such periods per working day. A minimum of 60 minutes should be allowed between successive exposures at the STEL concentration.

**Immediately dangerous to life and health (IDLH):** is defined as exposure to airborne contaminants that are likely to cause death or immediate or delayed adverse health effects, or prevent escape from such an environment.

*The IDLH value is not an occupational exposure standard.

With regard to exposure to $NO_2$ during blasting operations, the STEL is the most appropriate exposure standard to apply, as the characteristics of the exposures are likely to be infrequent and brief in duration and result. Adverse health outcomes are likely to be due to high intensity exposure with acute effects.

TWA is generally applied to those contaminants that are encountered over the duration of a working shift on a frequent basis (often daily) and result in chronic health outcomes, for example exposure to dust.

## Typical $NO_2$ levels recorded from blasting

Limited monitoring and measurements have been made from blasts at mine sites. The measurements have generally shown that the concentration of $NO_2$ up to the normal exclusion zone is less than the 5 ppm. The measured values are low and well beneath the threshold to cause both short term and long-term harm. The concentrations that cause harm would require a person to be very close to the blast where other hazards are more likely to cause harm, such as projections or overpressures.

$NO_2$ has previously been recorded and sighted at up to 8km from a blast. This information has been largely anecdotal and not recorded with any scientific accuracy.

## Environmental exposure to nitrogen dioxide ($NO_2$)

Most people are exposed to oxides of nitrogen by breathing in polluted air. People who live near combustion sources such as coal burning power plants or areas of high motor vehicle usage, or live in households that burn a lot of wood or use kerosene heaters or gas stoves may be exposed to higher levels of nitrogen oxides. Nitrogen dioxide and nitric oxide are also found in tobacco smoke.

# Annex D–Safety information–nitrogen dioxide

**RED**

CHEMALERT REPORT

**Full Report**

## 1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

**1.1 Product identifier**

| | |
|---|---|
| **Product name** | **NITROGEN DIOXIDE** |
| **Synonym(s)** | 073 - SDS NUMBER • DINITROGEN TETROXIDE • NITROGEN PEROXIDE • NITROGEN TETROXIDE • PRODUCT CODES: 160, 175 |

**1.2 Uses and uses advised against**

| | |
|---|---|
| **Use(s)** | CHEMICAL REAGENT |

**1.3 Details of the supplier of the safety data sheet**

| | |
|---|---|
| **Supplier name** | **BOC LIMITED (AUSTRALIA)** |
| **Address** | 10 Julius Avenue, North Ryde, NSW, Australia, 2113 |
| **Telephone** | 131 262, (02) 8874 4400 |
| **Fax** | 132 427 (24 hours) |
| **Email** | Not supplied |
| **Website** | http://www.boc.com.au |

**1.4 Emergency telephone number(s)**

| | |
|---|---|
| **Emergency** | 1800 653 572 (24/7) (Australia only) |

## 2. HAZARDS IDENTIFICATION

**CLASSIFIED AS HAZARDOUS ACCORDING TO SAFE WORK AUSTRALIA CRITERIA**

**Risk phrases**

| | |
|---|---|
| R8 | Contact with combustible material may cause fire. |
| R26 | Very toxic by inhalation. |
| R34 | Causes burns. |

**Safety phrases**

| | |
|---|---|
| S7/9 | Keep container tightly closed and in a well ventilated place. |
| S9 | Keep container in a well ventilated place. |
| S26 | In case of contact with eyes, rinse immediately with plenty of water and seek medical advice |
| S28 | After contact with skin, wash immediately with plenty of water. |
| S36/37/39 | Wear suitable protective clothing, gloves and eye/face protection. |
| S45 | In case of accident or if you feel unwell seek medical advice immediately (show the label where possible). |

**Other Hazards**

No information provided.

## 3. COMPOSITION/ INFORMATION ON INGREDIENTS

**3.1 Substances / Mixtures**

| Ingredient | CAS number | EC number | Content |
|---|---|---|---|
| NITROGEN DIOXIDE | 10102-44-0 | 233-272-6 | >99.5% |

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures**

| | |
|---|---|
| **Eye** | If in eyes, hold eyelids apart and flush continuously with running water. Continue flushing until advised to stop by a Poisons Information Centre, a doctor, or for at least 15 minutes. |
| **Inhalation** | If inhaled, remove from contaminated area. To protect rescuer, use an Air-line respirator or Self Contained Breathing Apparatus (SCBA). Apply artificial respiration if not breathing. Give oxygen if available. For advice, contact a Poison Information Centre on 13 11 26 (Australia Wide) or a doctor. |
| **Skin** | If skin or hair contact occurs, flush affected area with copious quantities of water. Use an emergency shower for large areas. Remove affected clothing as quickly as possible. Irrigate with tap or tepid water for 15 to 30 minutes. Seek medical attention. Apply sterile dressing and treat as thermal burn. Immerse large areas or limbs in tap water or tepid water for 15 to 30 minutes. Obtain medical attention immediately. |
| **Ingestion** | Due to product form and application, ingestion is considered unlikely. |
| **First aid facilities** | Eye wash facilities and safety shower are recommended. |

**4.2 Most important symptoms and effects, both acute and delayed**

No information provided.

**4.3 Immediate medical attention and special treatment needed**

Management of pulmonary oedema. Treat eye and skin burns as corrosive. Methaemoglobin may be used as a biological monitor.

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media**

Use water fog to cool containers from protected area.

**5.2 Special hazards arising from the substance or mixture**

Non flammable.

**5.3 Advice for firefighters**

Temperatures in a fire may cause cylinders to rupture. Cool cylinders or containers exposed to fire by applying water from a protected location. Remove cool cylinders from the path of the fire. Evacuate the area if unable to keep cylinders cool. Do not approach cylinders or containers suspected of being hot.

**5.4 Hazchem code**

2PE

| | |
|---|---|
| 2 | Water Fog (or fine water spray if fog unavailable) |
| P | Full protective equipment including Self Contained Breathing apparatus. |
| E | Evacuation of people in the vicinity of the incident should be considered. |

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**

If the cylinder is leaking, evacuate area of personnel. Inform manufacturer/supplier of leak. Use personal protective equipment as detailed in Section 8.

**6.2 Environmental precautions**

Prevent from entering sewers, basements and workpits, or any place where its accumulation can be dangerous.

**6.3 Methods of cleaning up**

Carefully move material to a well ventilated remote area, then allow to discharge if safe to do so. Do not attempt to repair leaking valve or cylinder safety devices.

**6.4 Reference to other sections**

See Sections 8 and 13 for exposure controls and disposal.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**

Use of safe work practices are recommended to avoid eye or skin contact and inhalation. Do not drag, drop, slide or roll cylinders. The uncontrolled release of a gas under pressure may cause physical harm. Use a suitable hand truck for cylinder movement.

**7.2 Conditions for safe storage, including any incompatibilities**

Do not store near incompatible materials. Cylinders should be stored below 45°C in a secure area, upright and restrained to prevent cylinders from falling. Cylinders should also be stored in a dry, well ventilated area constructed of non-combustible material with firm level floor (preferably concrete), away from areas of heavy traffic and emergency exits.

**7.3 Specific end use(s)**

No information provided.

## 8. EXPOSURE CONTROLS/ PERSONAL PROTECTION

**8.1 Control parameters**

**Exposure standards**

| Substance | Reference | TWA | | STEL | |
|---|---|---|---|---|---|
| | | ppm | mg/m³ | ppm | mg/m³ |
| Nitrogen dioxide | SWA (AUS) | 3 | 5.6 | 5 | 9.4 |

**Biological limits**

No biological limit values have been entered for this product.

**8.2 Exposure controls**

| | |
|---|---|
| **Engineering Controls** | Avoid inhalation. Use in well ventilated areas. Where an inhalation risk exists, mechanical extraction ventilation is recommended. Maintain vapour levels below the recommended exposure standard. |

**PPE**

| | |
|---|---|
| **Eye/Face** | Wear safety glasses. |
| **Hand** | Wear leather or insulated gloves. |
| **Body** | Wear coveralls and safety boots. |
| **Respiratory** | Wear a Type NO (Nitrogen Oxides) respirator. At high vapour levels, wear Self Contained Breathing Apparatus (SCBA) or an Air-line respirator. |

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | |
|---|---|
| **Appearance** | COLOURLESS SOLID, BROWN LIQUID OR RED-BROWN GAS |
| **Odour** | SLIGHT ODOUR |
| **Odour Threshold** | NOT AVAILABLE |
| **pH** | NOT APPLICABLE |
| **Melting Point** | -11.2°C |
| **Boiling Point** | 21.2°C |
| **Flash Point** | NOT RELEVANT |
| **Evaporation Rate** | NOT APPLICABLE |
| **Flammability** | NON FLAMMABLE |
| **Upper Explosion Limit** | NOT RELEVANT |
| **Lower Explosion Limit** | NOT RELEVANT |
| **Vapour Pressure** | 101.3 kPa @ 25°C |
| **Vapour Density** | NOT AVAILABLE |
| **Solubility (water)** | NOT AVAILABLE |
| **Partition Coefficient** | NOT AVAILABLE |
| **Autoignition Temperature** | NOT AVAILABLE |
| **Decomposition Temperature** | NOT AVAILABLE |
| **Viscosity** | NOT AVAILABLE |
| **Explosive Properties** | NOT AVAILABLE |
| **Oxidising Properties** | OXIDISING LIQUID |
| **Specific Gravity** | NOT APPLICABLE |

**9.2 Other information**

| | |
|---|---|
| **% Volatiles** | 100 % |
| **Critical Pressure** | 10133 kPa |
| **Critical Temperature** | 158.2°C |
| **Density** | 2.62 (Air = 1) |

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**
Carefully review all information in sections 10.2 to 10.6.

**10.2 Chemical stability**
No information provided.

**10.3 Possibility of hazardous reactions**
Polymerization will not occur.

**10.4 Conditions to avoid**
No information provided.

**10.5 Incompatible materials**
Nitric oxide reacts in air to form nitrogen dioxide which is highly oxidising. Reacts violently with fluorine and chlorine in the presence of moisture.

**10.6 Hazardous decomposition products**
May evolve toxic gases if heated to decomposition.

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

| | |
|---|---|
| **Health hazard summary** | Highly toxic - asphyxiant. When mixed with air the concentration of nitrogen dioxide is diluted. Nitrogen dioxide concentrations above 3 ppm may have an immediate effect of irritating the nose and throat followed by delayed onset of respiratory difficulties. Over exposure to concentrations of nitrogen dioxide above 100 ppm may result in sudden onset pulmonary oedema which can be rapidly fatal. Over exposure may result in fibrotic changes in the lungs. Possible production of methaemaglobinaemia may lead to drowsiness, dizziness and vomiting. |
| **Eye** | Corrosive. Contact may result in irritation, lacrimation, pain, redness, corneal burns and possible permanent damage. |
| **Inhalation** | Highly toxic - asphyxiant. A toxic and asphyxiant mixture if directly inhaled. |
| **Skin** | Corrosive. Contact may result in irritation, redness, pain, rash and possible burns. |
| **Ingestion** | Ingestion is considered unlikely due to product form. However, ingestion of liquid may result in burns to the mouth and throat. |
| **Toxicity data** | NITROGEN DIOXIDE (10102-44-0)<br>LC50 (Inhalation): 88 ppm/4 hours (rat)<br>LCLo (Inhalation): 200 ppm/1 minute (human)<br>TCLo (Inhalation): 6200 ppb/10 minutes (man) |

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**
No information provided.

**12.2 Persistence and degradability**
No information provided.

**12.3 Bioaccumulative potential**
No information provided.

**12.4 Mobility in soil**
No information provided.

**12.5 Results of PBT and vPvB assessment**
No information provided.

**12.6 Other adverse effects**
Nitrogen oxides react with volatile organic compounds to produce ozone, a principal factor in photochemical smog. Will form nitric acid in contact with water. Nitrates can persist for prolonged periods in water. Not expected to concentrate in the food chain.

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Waste disposal** Cylinders should be returned to the manufacturer or supplier for disposal of contents.

**Legislation** Dispose of in accordance with relevant local legislation.

## 14. TRANSPORT INFORMATION

**CLASSIFIED AS A DANGEROUS GOOD BY THE CRITERIA OF THE ADG CODE**


| | Land Transport (ADG) | Sea Transport (IMDG/IMO) | Air Transport (IATA/ICAO) |
|---|---|---|---|
| **14.1 UN number** | 1067 | - | - |
| **14.2 UN proper shipping name** | DINITROGEN TETROXIDE (NITROGEN DIOXIDE) | - | - |
| **14.3 Transport hazard classes** | | | |
| DG division | 2.3 | - | - |
| Subsidiary risk(s) | 5.1 / 8 | - | - |
| **14.4 Packing group** | None Allocated | - | - |
| **14.5 Environmental hazards** | | None Allocated | |
| **14.6 Special precautions for user** | | | |
| Hazchem Code | 2PE | | |

**Other information** Ensure cylinder is separated from driver and foodstuffs.

## 15. REGULATORY INFORMATION

**15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture**

**Poison schedule** A poison schedule number has not been allocated to this product using the criteria in the Standard for the Uniform Scheduling of Medicines and Poisons (SUSMP).

**Classifications**
C - Corrosive
O - Oxidising
T+ - Very toxic

**Inventory listing(s)** **AUSTRALIA: AICS (Australian Inventory of Chemical Substances)**
All components are listed on AICS, or are exempt.

**15.2 Chemical safety assessment**

No information provided.

## 16. OTHER INFORMATION

**Additional information** The storage of significant quantities of gas cylinders must comply with AS4332 The storage and handling of gases in cylinders.

APPLICATION METHOD: Gas regulator of suitable pressure and flow rating fitted to cylinder or manifold with low pressure gas distribution to equipment.

HEALTH EFFECTS FROM EXPOSURE:
It should be noted that the effects from exposure to this product will depend on several factors including: frequency and duration of use; quantity used; effectiveness of control measures; protective equipment used and method of application. Given that it is impractical to prepare a ChemAlert report which would encompass all possible scenarios, it is anticipated that users will assess the risks and apply control methods where appropriate.

**Product name** **NITROGEN DIOXIDE**

PERSONAL PROTECTIVE EQUIPMENT GUIDELINES:
The recommendation for protective equipment contained within this report is provided as a guide only. Factors such as method of application, working environment, quantity used, product concentration and the availability of engineering controls should be considered before final selection of personal protective equipment is made.

COLOUR RATING SYSTEM: RMT has assigned all ChemAlert reports a colour rating of Green, Amber or Red for the sole purpose of providing users with a quick and easy means of determining the hazardous nature of a product. Safe handling recommendations are provided in all ChemAlert reports so as to clearly identify how users can control the hazards and thereby reduce the risk (or likelihood) of adverse effects. As a general guideline, a Green colour rating indicates a low hazard, an Amber colour rating indicates a moderate hazard and a Red colour rating indicates a high hazard.

While all due care has been taken by RMT in the preparation of the Colour Rating System, it is intended as a guide only and RMT does not provide any warranty in relation to the accuracy of the Colour Rating System. As far as is lawfully possible, RMT accepts no liability or responsibility whatsoever for the actions or omissions of any person in reliance on the Colour Rating System.

**Abbreviations**

| | |
|---|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| CAS # | Chemical Abstract Service number - used to uniquely identify chemical compounds |
| CNS | Central Nervous System |
| EC No. | EC No - European Community Number |
| GHS | Globally Harmonized System |
| IARC | International Agency for Research on Cancer |
| LC50 | Lethal Concentration, 50% / Median Lethal Concentration |
| LD50 | Lethal Dose, 50% / Median Lethal Dose |
| $mg/m^3$ | Milligrams per Cubic Metre |
| OEL | Occupational Exposure Limit |
| PEL | Permissible Exposure Limit |
| pH | relates to hydrogen ion concentration using a scale of 0 (high acidic) to 14 (highly alkaline). |
| ppm | Parts Per Million |
| REACH | Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals |
| STEL | Short-Term Exposure Limit |
| STOT-RE | Specific target organ toxicity (repeated exposure) |
| STOT-SE | Specific target organ toxicity (single exposure) |
| SUSMP | Standard for the Uniform Scheduling of Medicines and Poisons |
| SWA | Safe Work Australia |
| TLV | Threshold Limit Value |
| TWA | Time Weighted Average |

**Report Status**

This ChemAlert report has been independently compiled by RMT's scientific department utilising the original Safety Data Sheet ('SDS') for the product provided to RMT by the manufacturer. The information is based on the latest chemical and toxicological research and is believed to represent the current state of knowledge as to the appropriate safety and handling precautions for the product at the time of issue. It is an independent collation by RMT of information obtained from the original SDS for this product. Its content has not been authorised or verified by the manufacturer / distributor of the chemical to which it relates.

This ChemAlert report does not constitute the manufacturer's original SDS and is not intended to be a replacement for same. It is provided to subscribers of ChemAlert as a reference tool only, is not all-inclusive and does not represent any guarantee as to the properties of the product. Further clarification regarding any aspect of the product should be obtained directly from the manufacturer.

While RMT has taken all due care to include accurate and up-to-date information in this ChemAlert report, it does not provide any warranty as to accuracy or completeness. As far as lawfully possible, RMT accepts no liability for any loss, injury or damage (including consequential loss) which may be suffered or incurred by any person as a consequence of their reliance on the information contained in this ChemAlert report.

**RED**

## CHEMALERT REPORT

**Full Report**

**Product name** NITROGEN DIOXIDE

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**End of Report**

# Annex E – Causes of NOx fume and mitigations (adapted from AEISG data)

| **Primary cause 1: Explosive blends and precursors chemical design (pre site delivery)** | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Chemical formulation of the mixed explosives and/or precursors unknowingly inherently designed to generate fume | • NOx fume | Reformulate explosive to meet User Needs Specification | Explosive supplier<br>Explosives Manufacturer |
| | | Change product to one that meets User needs Specification | Site Procurement<br>Senior Site Executive |
| Formulation of explosives mixture and/or precursors marginal with regards to sensitivity | • Intermittent NOx fume<br>• Inconsistent blast performance | Reformulate explosive to meet User Needs Specification | Explosive supplier |
| | | Change product to one with more sensitivity | Site Procurement<br>Explosive supplier |
| Formulation of explosives mixture and/or precursor marginal with regards to chemical stability | • Intermittent NOx fume<br>• Inconsistent blast performance | Reformulate explosive to meet User Needs Specification | Explosive supplier |
| | | Change product which has chemical stability | Site Procurement<br>Explosive supplier |
| Formulation of explosives mixture and/or precursor insufficiently resistant to conditions it is used in | • Intermittent NOx fume<br>• Inconsistent blast performance | Reformulate explosive to meet User Needs Specification | Explosive supplier |
| | | Change product to one that meets User needs Specification | Site Procurement<br>Explosive supplier |
| Formulation of explosives mixture and/or precursors not suitable for the prevailing climatic or seasonal conditions | • Intermittent NOx fume | Reformulate explosive with suitable precursors | Explosive supplier |
| | | Change raw materials | |
| | | Change product to one that meets User needs Specification | Site Procurement<br>Blast Designer<br>Senior Site Executive |

| Primary cause 2: Explosives and precursors' conformance to specification post formulation and pre use | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Precursor delivered to mine site out of specification | • Intermittent NOx fume<br>• Traceable to a precursor which has degraded between manufacture and use<br>• Poor blast performance | Investigate with supplier of explosive precursors | Explosive Supplier<br>Site Procurement Manager |
| Precursor degradation during transport and storage | • Frequent NOx fume<br>• All blasts and locations utilising explosive product(s) that incorporate a specific raw material<br>• Poor blast performance | Appropriate storage location, conditions and stock rotation management (i.e. First-in-first-out) | Site Procurement Manager<br>Explosive Supplier<br>Magazine Keeper |
| | | Appropriate transport and transfer of precursors | Drill and Blast Superintendent<br>Blast Designer<br>Explosive Supplier<br>MMU Operator |
| | | Inspection and/or testing of precursors prior to use in accordance with manufacturer's recommendations | Drill and Blast Superintendent<br>Explosive Supplier<br>Shotfirer |
| Raw material changes | • Frequent NOx fume<br>• All areas associated with loading from a specific delivery system<br>• Product appearance abnormal | Change management procedures in place by suppliers | Drill and Blast Superintendent<br>Explosive Supplier<br>Shotfirer |
| | | Prior notification to suppliers from site change management systems where precursors are supplied by sites, for example customer-supplied fuels | Drill and Blast Superintendent<br>Explosive Supplier<br>Shotfirer |
| Product past use by date | • Difficulty achieving final density<br>• Separation<br>• Crystallising<br>• Fines<br>• Colour variation<br>• Poor blast performance | Testing to ensure the product is within the manufacturers specification<br>• pH<br>• Density, viscosity | Drill and Blast Superintendent<br>Site Procurement Manager<br>Explosive Supplier<br>Magazine Keeper |
| Failure to conduct quality tests | • Incomplete documentation | • Conduct Safe Task Observations to ensure compliance with procedures. | |

| **Primary cause 2: Explosives and precursors' conformance to specification post formulation and pre use** | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| | | • All blast crew to be trained in the potential consequences of failing to ensure the quality of the product loaded | |

| **Primary cause 3:** Blast design leading to fume events | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Explosives – rock mass properties mismatch | • Intermittent NOx fume<br>• Unexpected blast results<br>• Flyrock | Follow manufacturer's recommendations on explosive product application | Drill and Blast Superintendent<br>Shotfirer<br>Explosive Supplier |
| | | Review of the site approved technical design. | Site Senior Executive<br>Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |
| Explosives product selected not suitable for the prevailing ground conditions (water, rock mass strength, etc.) | • Frequent NOx fume<br>• Poor blast performance | Follow manufacturer's recommendations on explosive product application | Drill and Blast Superintendent<br>Shotfirer<br>Explosive Supplier |
| | | Review of the site approved technical design. | Site Senior Executive<br>Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |
| Insufficient consideration given to blast dynamics | • Intermittent NOx fume<br>• Unexpected blast results<br>• Misfire product | Follow manufacturer's recommendations on explosive product application – Including sleep times | Drill and Blast Superintendent<br>Shotfirer<br>Explosive Supplier |
| | | Review of the site approved technical design. | Site Senior Executive<br>Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |
| Failure to identify potential causes of fume generation | • Inexperienced designers<br>• Inadequate analysis or records for past blasts | Use of a Pre-Design Checklist | Drill and Blast Superintendent<br>Shotfirer<br>Blast Designer |

| Primary Cause 4: Explosives detonation performance impacted by blast dynamics | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Inter-hole explosive desensitisation | • Frequent NOx fume<br>• Blast holes drilled too close together<br>• Blast hole deviation<br>• Inconsistent blast performance | Change design | Drill and Blast Superintendent<br>Blast Designer |
| | | Product selection | Drill and Blast Superintendent<br>Blast Designer |
| | | Increased control on drilling with deeper designs | Drill and Blast Superintendent<br>Blast Designer<br>Driller |
| Intra-hole explosive desensitisation in decked blast holes | • Frequent NOx fume<br>• When using decks only<br>• Inconsistent blast performance | Appropriate separation of explosive decks. Initiator timing. | Drill and Blast Superintendent<br>Blast Designer<br>Explosive supplier |
| Explosive desensitisation due to the blast hole depth | • Frequent NOx fume<br>• Poor blast performance | Reduce bench height | Site Senior Executive<br>Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |
| | | Ensure adequate relief in deep holes | Drill and Blast Superintendent<br>Blast Designer |
| | | Follow manufacturer's recommendations on explosive product selection and blast design for deep holes, for example decking where appropriate. | Drill and Blast Superintendent<br>Blast Designer<br>Explosive Supplier |
| Inappropriate priming and/or placement | • Intermittent NOx fume<br>• Residue product<br>• Inconsistent blast performance | Follow manufacturer's recommendations on explosive product initiation. | Drill and Blast Superintendent<br>Shotfirer<br>Explosive Supplier |
| | | Review of the site approved technical design. | Site Senior Executive<br>Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |
| Initiation of significant explosive quantities in a single blast event | • Intensity of post-blast fume proportional to explosives quantity used | Reduce blast size in order to reduce total explosive quantity being initiated in the one blast event | Site Senior Executive<br>Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |

| Primary Cause 4: Explosives detonation performance impacted by blast dynamics | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| | | Reduce powder factor | Drill and Blast Superintendent<br>Blast Designer |
| Desensitisation of explosive column from in-hole detonating cord initiation | • Frequent NOx fume<br>• Only in areas where in-hole cord initiation is used<br>• Inconsistent blast performance | Follow manufacturer's recommendations on compatibility of initiating systems with explosives | Drill and Blast Superintendent<br>Blast Designer |
| Primer of insufficient strength to initiate explosive column | • Frequent NOx fume<br>• All blasts using a particular primer type / size<br>• Poor blast performance | Follow manufacturer's recommendations on compatibility of initiating systems with explosives | Drill and Blast Superintendent<br>Blast Designer |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Use of out of specification manufactured bulk explosives | • Intermittent NOx fume<br>• No column rise<br>• Stock take of raw materials use out of line with manufacturing requirements<br>• No MMU calibration records<br>• No QC records on pumpable explosive<br>• Poor blast performance | Review quality process controls during the loading and through post blast audits | Drill and Blast Superintendent<br>Blast Designer<br>Explosive Supplier<br>MMU Operator |
| Inadequate mixing of raw materials | • Frequent NOx fume in all areas associated with loading from a specific delivery system<br>• Product appearance abnormal | Visual check | Shotfirer<br>Bench Assistant<br>MMU Operator |
| | | Density check | MMU Operator |
| Delivery system metering incorrectly | • Increased frequency of NOx | Regular calibration of metering systems | MMU Operator<br>Equipment owner |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| (on bench incorrect manufacture of product) | • All blasts and all locations utilising explosive product(s) that incorporate a specific precursor<br>• Inconsistent blast performance | Quality control of explosive products conducted in accordance with manufacturer's recommendations | Explosive Supplier<br>MMU Operator |
| Delivery system settings for explosive product delivery overridden | | Do not override calibration settings on manufacturing systems | Drill and Blast Superintendent<br>Equipment Owner<br>MMU Operator |
| Explosive product incorrectly loaded into blast hole | • Intermittent NOx fume<br>• Poor blast performance | All blast crew to be trained in the correct method of delivery of all products | Shotfirer<br>Bench Assistant<br>MMU Operator |
| Incorrect product used wet/dry | • Intermittent NOx fume<br>• Poor blast performance<br>• Misfires | All blast crew to be trained in the potential consequences of incorrect product usage | Shotfirer<br>Bench Assistant<br>MMU Operator |
| MMU operator not yet competent | • Intermittent NOx fume<br>• Misfires<br>• Inconsistent blast performance | • Unsure only competent personnel operate MMU's unsupervised<br>• Conduct Safe Task Observations to ensure compliance with procedures | Drill and Blast Superintendent<br>Equipment Owner<br>MMU Operator |
| Excess product loaded | • Intermittent NOx fume | All blast crew to be trained in the potential consequences of failing to ensure the correct quantity of product is loaded | Drill and Blast Superintendent<br>MMU Operator |
| Rainfall on a sleeping shot. | • Slumping of holes<br>• Poor blast performance | Review rainfall forecasts for planned sleep time of shot and select explosive products according to manufacturer's recommendations. | Production Manager<br>Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Explosive Supplier |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| | | Minimise sleep time for dry blast hole explosive products if rain is predicted. Consider early firing of blast. | Production Manager<br>Drill and Blast Superintendent<br>Shotfirer |
| | | Bench design for water runoff | Drill and Blast Superintendent<br>Blast Designer<br>Production Manager |
| | | Seal top of blast holes to prevent water ingress e.g. with gas bag | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer |
| | | Consider removing water affected product | Production Manager<br>Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Explosive Supplier |
| Explosive product seeping into cracks<br>Dynamic water in holes | • Slumping<br>• Intermittent NOx fume<br>• In specific areas known to contain a high incidence of faulted/fractured ground only<br>• Unexpected blast performance | Follow manufacturer's recommendations on explosive product selection | Drill and Blast Superintendent<br>Shotfirer<br>MMU Operator |
| | • Hole loading larger than planned | Use blast hole liners | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Geologist |
| | | Maintenance of accurate drill records which are used to map geological conditions | Driller<br>Drill and Blast Superintendent<br>Geologist<br>Blast Designer |
| | | Record and monitor blast holes which have slumped or require excessive explosive product to reach stemming height, but where water is not present | Shotfirer<br>MMU Operator<br>Bench Assistant |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| | • Intermittent NOx fume<br>• Slumped blast holes<br>• Usually when using non water-resistant explosive products | Minimise sleep time of shot | Production Manager<br>Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer |
| | • Poor blast performance | Follow manufacturer's recommendations on explosive product selection | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer |
| | | Measure recharge rates if dewatering, and choose explosive products according to manufacturer's recommendations | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>MMU Operator<br>Bench Assistant / Dewaterer Operator |
| | | Record slumped holes and use this information to build understanding of pit hydrology | Blast Designer<br>Shotfirer<br>MMU Operator<br>Bench Assistant / Dewaterer Operator |
| | | Understand hydrology of pit and plan blasting to avoid interaction between explosives and dynamic water (either natural or from other pit operations) | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Geologist |
| | | Use hole liners | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Geologist |
| Moisture in clay | • Frequent NOx fume<br>• In clay strata only | Consider water resistant explosive products and how this may impact sleep time. | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Geologist |
| | | Hole liners may be required for ANFO. | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Geologist |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Blast hole deterioration between drilling and loading | • Intermittent NOx fume<br>• Traceable to specific geological areas<br>• Inconsistent column rise while loading | Minimise time between drilling and loading | Drill and Blast Superintendent<br>Blast Designer |
| | | Use blast hole cameras to ascertain hole condition in critical areas | Explosive Supplier<br>Geologist |
| | | Use hole savers | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Geologist |
| | | Mine planning to ensure benches are unaffected by back-break from earlier blasts, for example presplits, buffers etc. | Production Manager<br>Drill and Blast Superintendent<br>Blast Designer |
| | | Optimise drilling practices to minimise hole damage though rock cracking etc. | Drill and Blast Superintendent<br>Driller |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Contamination of explosives (bottom of hole, stemming section, etc.) | • Intermittent NOx fume<br>• Blasts containing wet/dewatered blast holes only<br>• Dynamic water | Load wet blast holes first and dip remaining holes prior to loading. Adjust explosive product selection according to manufacturer's recommendations. | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Bench Assistant |
| | | Eliminate top loading into wet blast holes | Shotfirer<br>Bench Assistant |
| | | Ensure all primers are positioned in undiluted explosive product | Shotfirer<br>Bench Assistant |
| | | Use of gas bags in dewatered blast holes | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Bench Assistant |
| | | Seal top of explosives column to prevent water ingress | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Bench Assistant |
| | | Use hole liners | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Bench Assistant |
| | | Reduce excessive hose lubrication during charging | Operator<br>Bench Assistant |
| | | Measure water recharge rate after dewatering. | Shotfirer<br>Bench Assistant |
| | | Adjust explosive product selection according to manufacturer's recommendations for wet environment. | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Bench Assistant<br>MMU Operator |
| | | Decking to eliminate contact with known dynamic water | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>Bench Assistant |

| Primary Cause 5: On-bench/site practices | | | |
|---|---|---|---|
| **Potential Cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| | | Select explosive products for wet blast holes according to manufacturer's recommendations. | Drill and Blast Superintendent<br>Explosive Supplier<br>Blast Designer<br>Senior Site Executive |
| | | Verify correct hose handling practices are in place | Shotfirer<br>MMU Operator<br>Bench Assistant<br>Explosives Supplier |
| | | Load low blast holes last where practical | Shotfirer<br>Bench Assistant |
| | | Use suitable, safe dewatering techniques | Shotfirer<br>Bench Assistant |
| | | Minimize sleep time | Production Manager<br>Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer |

| Primary Cause 6: Blasting Personnel (Technical and Operational) | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| Blasting personnel (Technical and Operational) | • NOx Fume while primary causes 1, 2, 3, 4 and 5 have been ruled out as possible contributing factors | As below | |
| Lack of an understanding of the possible causes, and prevention techniques, of fume amongst blasting personnel (shotfirers, MMU operators, blast designers) | • Frequent NOx fume | All blasting personnel to be trained in the potential consequences of incorrect product usage | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>MMU Operator |
| Blasting personnel not consistent in defining dry and wet bench conditions | • Frequent NOx fume | All blasting personnel to be trained in the potential consequences | Drill and Blast Superintendent<br>Blast Designer<br>Shotfirer<br>MMU Operator |

| Primary Cause 6: Blasting Personnel (Technical and Operational) | | | |
|---|---|---|---|
| **Potential cause** | **Likely indicators** | **Control measures** | **Responsibilities** |
| | | of incorrect product usage | |
| Blasting personnel not following site SOPs | NOx Fume | | |

# Annex F – Pre-firing review

(**Fume specific requirement**)

Prior to the firing of any blast, a review must be conducted to determine if there are likely to be adverse fume effects, as a result of deviations from the blast plan and other issues encountered during the preparation and loading of the shot. A blaster has to account for a number of hazards such as flyrock, overpressure, and ground shock however, must also include fumes such as oxides of nitrogen and carbon monoxide. This section relates to fume especially NOx.

This review is conducted just prior to the firing of the blast. It assumes that persons involved in the loading activity have to keep accurate and effective records to assist in this pre-firing review. The person who conducted the loading, needs to be present to speak about problems encountered and records made, in relation to those issues so that a reasonable deduction can be made on the likelihood of fume occurring.

These factors must be considered and recorded, and mitigations planned, where appropriate, prior to a shot being undertaken.

- presence of ground water in the holes
- moist borehole sides
- dynamic water (is the water in motion/flowing?)
- excessive sleep time for the product concerned (if a dry product has any exposure to water it will likely fume)
- rock and ground type, including stemming material that gives the explosives poor confinement
- blast design potential for inadvertent dynamic desensitization of surrounding holes
- potential that product has been damaged by water
- loading took place in wet conditions
- poor drainage on the bench exposing product to water
- substituted product unable to manage water conditions or hole conditions
- product specification and calibration issues on the MMU
- product top loaded from auger into wet hole
- blast design not followed insufficient use of gas bags, primers, decks etc
- MMU gross ingredient usage check indicates an imbalance in the manufacture process e.g. under fuelled.
- record the blast design deviations.
- Monitors
- Identify potential level of fume
- Review of weather conditions

Pre-firing outcome should not be used to replace the Blast Fume Management Plan.

- BEZ – Blast Exclusion Zone
- FMZ – Fume Management Zone
    - Location of monitor
    - Evacuations
    - Consideration to topography and local weather conditions

# Annex G – Information for treating medical staff

This is a sample of the information that should be provided to a treating doctor. Organisations should ensure that regular meetings are held with the local medical doctors, that would be treating their personnel for exposures to oxides of nitrogen and other typical injuries or exposures that could be expected from their employees.

INFORMATION FOR TREATING DOCTOR

Dear Doctor

This patient has been exposed to NOx. This is a gas usually produced on mines after the use of explosives. NOx consists of multiple combinations of nitrogen and oxygen ($N_2O$, NO, $NO_2$, $N_2O_4$, $N_2O_3$, $N_2O_5$). Nitrogen Dioxide ($NO_2$) is the principal hazardous nitrous fume.

NOx irritates the eyes and mucous membranes primarily by dissolving on contact with moisture and forming a mixture of nitric and nitrous acids however, this is not the only way injury can occur.

Inhalation can result in both respiratory tract irritation and pulmonary oedema. High-level exposure can cause methemoglobinemia. Some people, particularly asthmatics, can experience significant bronchospasm at very low concentrations.

The following effects are commonly encountered after NOx exposure:

ACUTE

- cough
- shortness of breath
- irritations of the mucous membranes of the eyes, nose and throat

SHORT TERM

- pulmonary oedema, **which may be delayed from 4 to 12 hours**

MEDIUM TERM

- RADS (Reactive Airways Dysfunction Syndrome)
- in rare cases, bronchiolitis obliterans, which may take from two to six weeks to appear

LONG TERM

- chronic respiratory insufficiency

High-level exposure, particularly associated with methemoglobinemia, can cause chest pain, cyanosis and shortness of breath, tachypnoea and tachycardia. Deaths have been reported after exposure and are usually delayed. Even non-irritant concentrations of NOx may cause pulmonary oedema. Symptoms of pulmonary oedema often show until a few hours after exposure and are aggravated by physical effort.

Before transfer to you, the patient should have been advised to rest and, if any respiratory symptoms were present, should have been administered oxygen.

The patient will need to be treated symptomatically, but as a base line, it is suggested that the following may be required:

- spirometry
- chest x-ray
- methaemoglobin estimation

Because of the risk of delayed onset pulmonary oedema, it is recommended that as a precaution the patient be observed for up to 12 hours. As no specific antidote for NOx exists, symptoms will have to be treated on their merits.

Information provided by Dr Vern Madden, Health Advantage Toowoomba

# Annex H – NOx rating scale

The following table together with the Field colour chart on the next page details how NOx fumes from a surface blast can be assessed. (Provided by AEISG)

| Level | Typical Appearance |
| --- | --- |
| Level 0<br><br>No fume |  |
| Level 1<br><br>Fume |  |
| Level 2<br><br>Minor yellow/orange fume |  |
| Level 3<br><br>Moderate orange fume |  |
| Level 4<br><br>Significant orange fume |  |
| Level 5<br><br>Major red/purple fume |  |

### Field colour chart

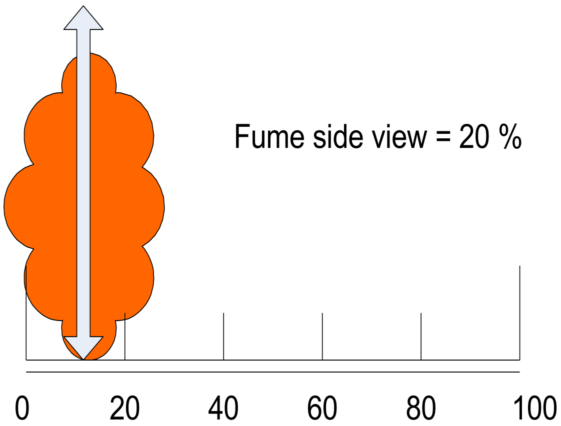
Assessing the amount of NOx produced from a blast will depend on the distance the observer is from the blast and the prevailing weather conditions. The Field Colour Chart can be used to assess the level of NOx that is produced in a surface blast.

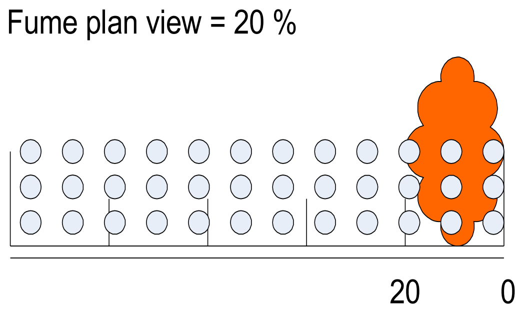
Pantone colour numbers have been included in the Field Colour Chart to ensure colours will always be produced correctly thereby ensuring a reasonable level of standardisation in reporting fume events across the mining industry.

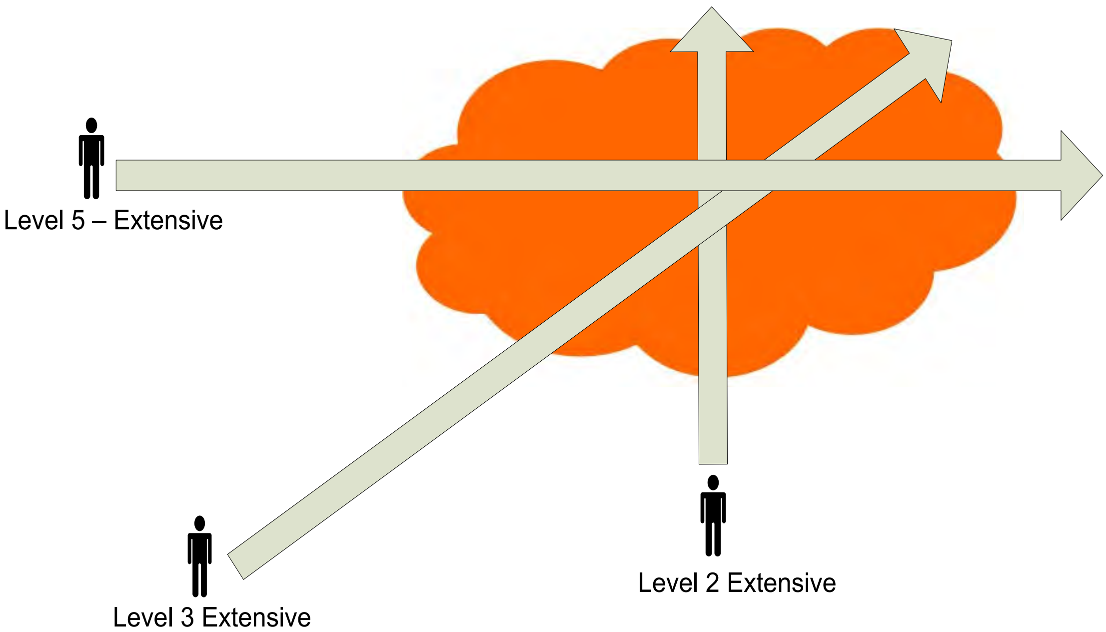
| Level | Colour | Pantone number |
|---|---|---|
| Level 0<br>No Fume | | Warm Grey 1C<br>(RGB 244, 222, 217) |
| Level 1<br>Fume | | Pantone 155C<br>(RGB 244, 219, 170) |
| Level 2<br>Minor yellow/orange fume | | Pantone 157C<br>(RGB 237, 160, 79) |
| Level 3<br>Moderate orange fume | | Pantone 158C<br>(RGB 232, 117, 17) |
| Level 4<br>Significant orange fume | | Pantone 1525C<br>(RGB 181, 84, 0) |
| Level 5<br>Major red/purple fume | | Pantone 161C<br>(RGB 99, 58, 17) |

### Observation issues

The category should be determined when the fume cloud is at its greatest concentration.
The angle of the person to the fume event will influence the assessment. Where possible and without placing persons in the path of a fume cloud there should be a number of observers to record the level. This can be moderated to give a more accurate indication of the cloud.
The issue is that the observer position and fume cloud orientation may influence the rating given.




**EFFECT OF ANGLE TO FUME CLOUD AFFECTING ASSESSMENT**

- Assessment can also be affected by light conditions as this will vary appearance of fume cloud.
- Significant temperature variations can also affect fume cloud colour.

# Annex I – Statistical Analysis by JKTech Pty Ltd

A fume steering group was created by the Chief Inspector of Explosives in 2011 to specifically investigate and report on blast fume in Queensland. The Fume Steering Group (FSG) is comprised of key explosives industry stakeholders, including mining companies, explosives suppliers, the mines inspectorate and the CFMEU. A critical development of the FSG was to commence collecting and managing blast data from all Queensland coal mines. This data was provided to JKTech for analysis.

**INTRODUCTION**

The fume database commenced in 2011; the earliest blast listed in the database was fired on the 3/01/2011. For each blast, 48 characteristics were required to be submitted from each mine site, although most entries were not complete when submitted. The characteristics were:

- Shot ID
- Pit
- Date fired
- Time fired
- Sleep-time (days)
- Fume rating
- Fume visibility after blast
- Fume location (spatially)
- Fume location (with respect to product)
- Proportion of blast that fumed
- Weather during initiation
- Cloud cover
- Wind speed
- Wind direction
- $NO_x$ concentration
- If the blast was reported to the Inspectorate
- Shot type
- Hole inclination
- Confinement
- Tie-up
- Type of stemming
- Material strength
- Burden
- Spacing
- Depth
- Stemming
- Powder Factor
- Toe charge product type
- Middle deck product type
- Top deck product type
- ANFO total
- HANFO total
- Pump product total
- Total of all products
- Proportion of water resistant product
- Emulsion type
- Presence of slumping
- Presence of water in holes
- Presence of damp sides
- If the holes were dewatered
- If it rained during or after loading
- If the blast was loaded to design
- If the blast was filmed
- If hole by hole data was recorded
- Manager of loading services

Each the characteristics listed for each blast contained multiple responses. This significantly increased the number of potential combinations that could occur in a relationship with fume. For the purposes of this report, the database was analysed to determine the influence of soft ground, wet ground and deep holes only.

The fume database provided by the FSG contained 5035 blasts collected over 3.24 years. A total of 42 mine sites contributed data, and these were supplied by 6 explosive suppliers. Over 1,465,826 tonnes of explosives are recorded as blasted. Assuming each kilogram of explosives equates to 1000 litres of gas, approximately 1.5 trillion litres of gas was created by blasts reported during this time period.

The strength of the fume database is its size. Generally speaking, the greater the sample size the lesser the error. The site survey in ACARP report C20016 contained only 108 blasts, which limits the analysis that can be undertaken and the confidence with which conclusions can be drawn. A limiting factor of the fume database was the freedom of contributing personnel to write customised entries. Data listed in the wind speed column for example contained various units and subjective measurements.

The subjectivity of the data in the fume database introduces an unknown degree of variability. A fume cloud can vary in rating for example due to the perspective of the viewer, daylight, opinion and how the cloud is viewed, for example in the field or on a computer monitor. Subjectivity also limits the analysis available on the effect of ground hardness. Only three hardness categories are listed in the database – soft, medium and hard. This would vary significantly between sites subsequently limiting the efficacy of the study. Irrespective of this, the hardness data was used. Ultimately, the integrity of the data is subject to each sites honesty and diligence. An example of a perceived discrepancy between the data and reality is shown in Table J1.

| Response | Blasts | % |
|---|---|---|
| Yes | 4876 | 97 |
| No | 116 | 2 |
| N/A | 43 | 1 |

Table I1: Was the blast loaded to design?

The purpose of this study was to identify the change in fume rating under certain conditions. This study is univariate only, and could misrepresent the true nature of blast fume where fume is influenced by multiple variables, as is likely the case. The ultimate goal of this project and the fume steering group is to eliminate post blast fume. To achieve this, the focus is to achieve a fume rating of zero more frequently. As such, fume performance is primarily assessed by the proportion of blasts that record a rating of zero.

In this analysis, heavy ANFO refers to ANFO mixed with up to 50% ammonium nitrate emulsion and pump product refers to ANFO mixed with at least 70% ammonium nitrate emulsion.

In the analysis, the effect of water is assessed. Dry blasts were identified as blasts that had dry holes, that did not have wet walls, were not dewatered and rain was not reported during or after loading. Wet blasts conversely were reported as wet, had wet walls and required dewatering.

## OVERVIEW OF THE DATA

The data was first summarised in terms of fume rating, shown in Figure 14. Approximately 75% of blasts recorded a level 1 or less.

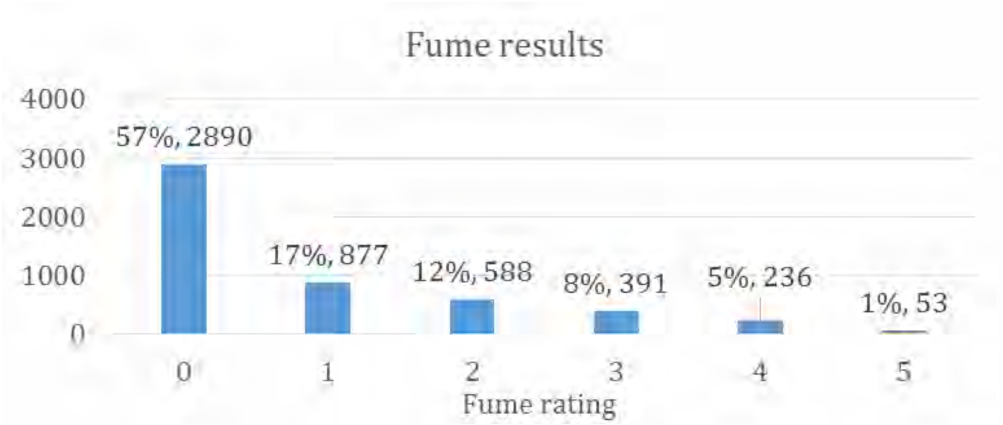



Figure 14: Distribution of blasts by fume rating

To assess how each product performed, the performance of blasts that contained 95% or more of a single product was compared. This is shown in Figure 15, where *Other* refers to blasts loaded with mixed products.

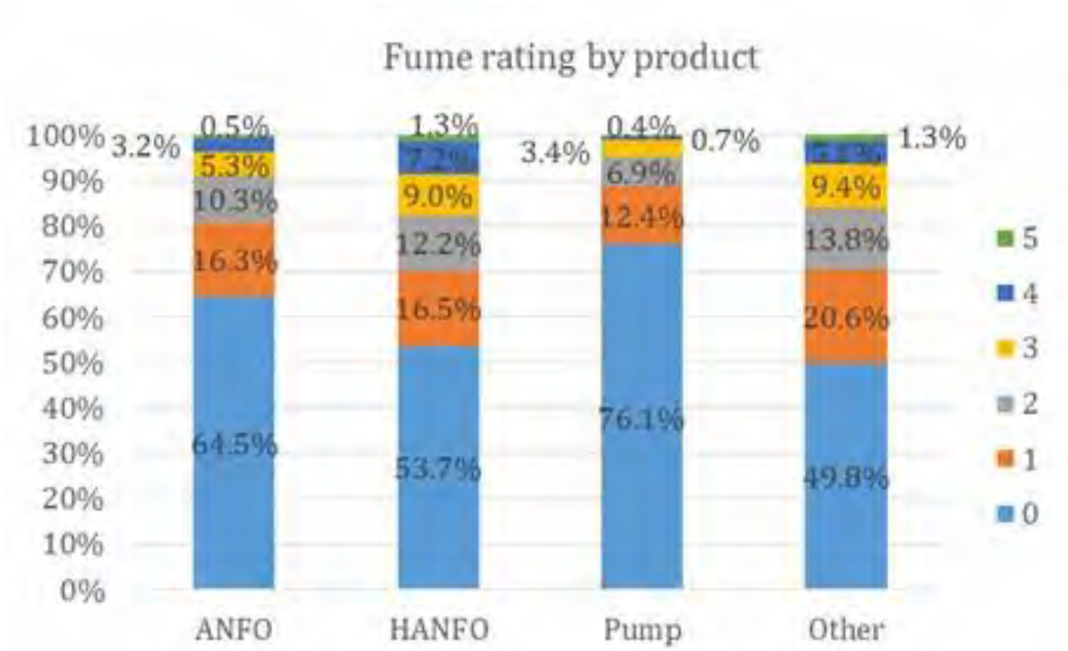



Figure 15: Fume rating by product

The effect of product selection becomes more apparent when each rating is subdivided by product, as shown in Table I2. This table summarises all blasts in the database loaded with 95% or more of either ANFO, HANFO or Pump product. For this dataset, the percentages list the probabilities that the blast was loaded with a given product type given the resulting fume rating. The probability that a blast that rated 1 or greater is most likely HANFO.

Pump product and ANFO both have physical characteristics that restrict their widespread use. ANFO for example cannot be used in wet conditions and Pump product is very slow to deliver. It is likely that HANFO is applied in more testing conditions and used more frequently as the alternatives cannot be applied.

| Rating | ANFO | HANFO | Pump |
|---|---|---|---|
| 0 | 13% | 44% | 43% |
| 1 | 14% | 57% | 29% |
| 2 | 13% | 62% | 24% |
| 3 | 11% | 71% | 18% |
| 4 | 9% | 85% | 6% |
| 5 | 8% | 77% | 15% |

Table I2: Product selection by rating

The conditions in which ANFO and HANFO are applied were then compared.

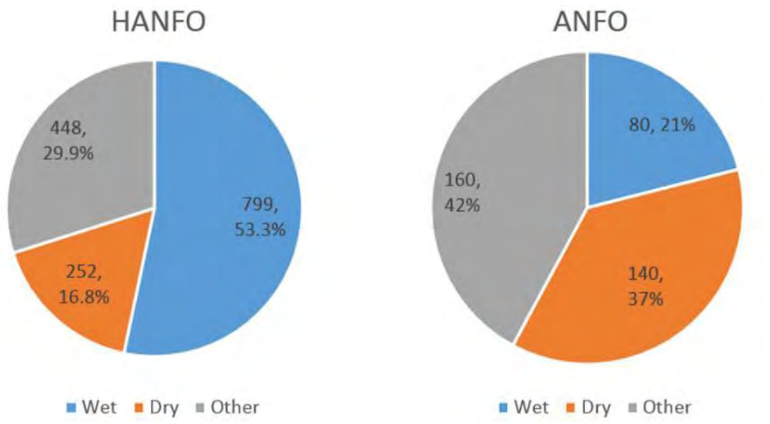



Figure 16: Application of HANFO and ANFO

In more than 53% of cases, HANFO was applied in wet ground compared to 21% for ANFO. The conditions in which the explosives are applied vary and most likely causes variations in the explosives fume performance.

Due to explosives' different chemical, physical and detonation characteristics, each explosive group was assessed individually. The potential influence of the explosive supplier or individual mine sites were not investigated.

## FUME PERFORMANCE OF ANFO

The fume performance of ANFO was assessed by selecting all blasts in the database that were loaded with 95% or more ANFO. The distribution of ANFO fume rating was first calculated.

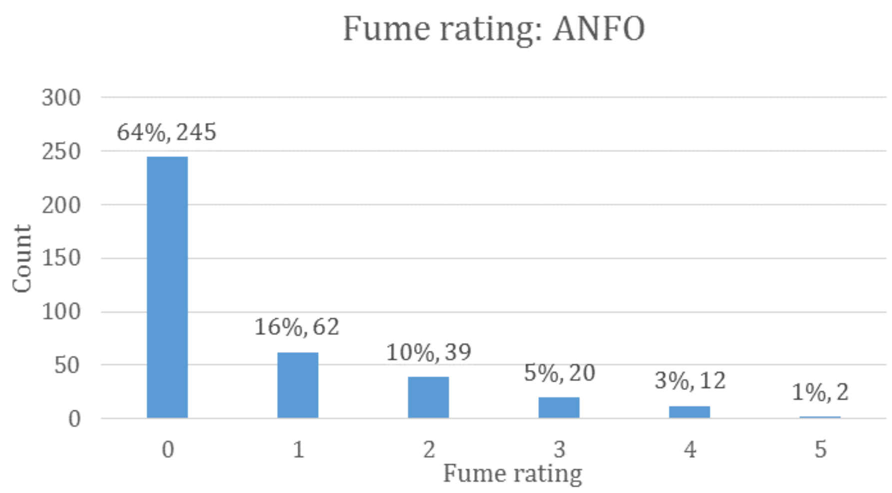



Figure 17: Fume performance of ANFO

The effect of water is dependent on time. The longer an explosive is exposed to water the greater it will degrade. For this reason, the effect of water on ANFO was compared over time.

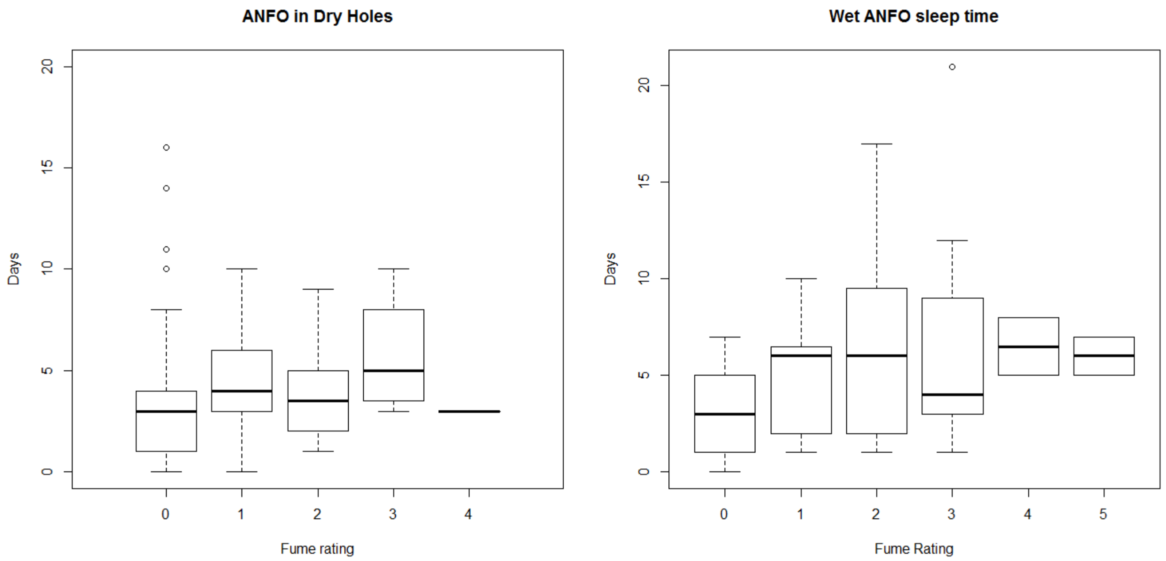



Figure 18: Fume performance of ANFO in wet and dry conditions

In dry holes, no level 5 fume events were recorded for ANFO, unlike for wet holes. The distribution of sleep time for dry ANFO blasts that recorded a fume rating of zero is more spread in dry holes than in wet holes.

The effect of depth on ANFO fume propensity was calculated by using fume results for dry ANFO blasts only. The data was then split between low fume blasts, blasts that ranked 0 or 1, or high fume blasts, blasts that ranked 2, 3, 4 or 5. The proportion of blasts that were low fuming was then plotted, shown in Figure 19. There is no distinct trend in the data that indicates that ANFO fume propensity is influenced by depth.

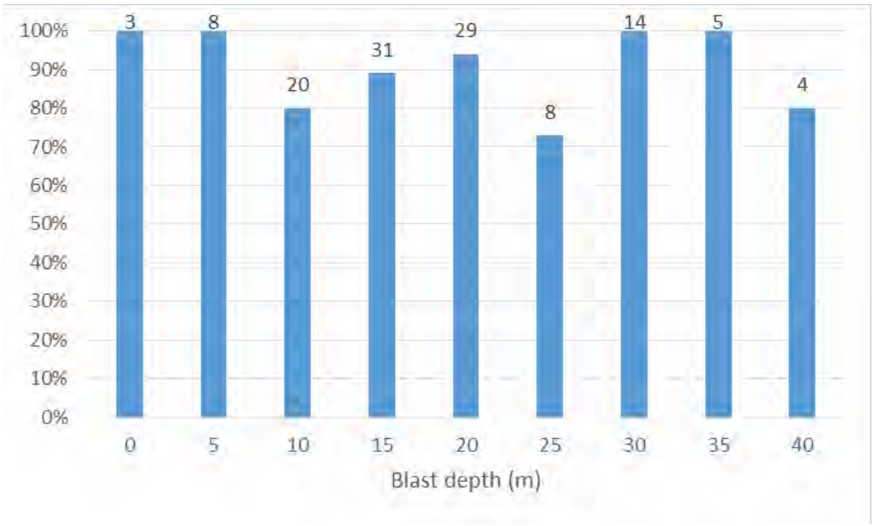



Figure 19: Fume rating by depth

The effect of ground hardness was investigated by plotting ANFO fume results showing the proportion of blasts that were fired in a specific rock type.

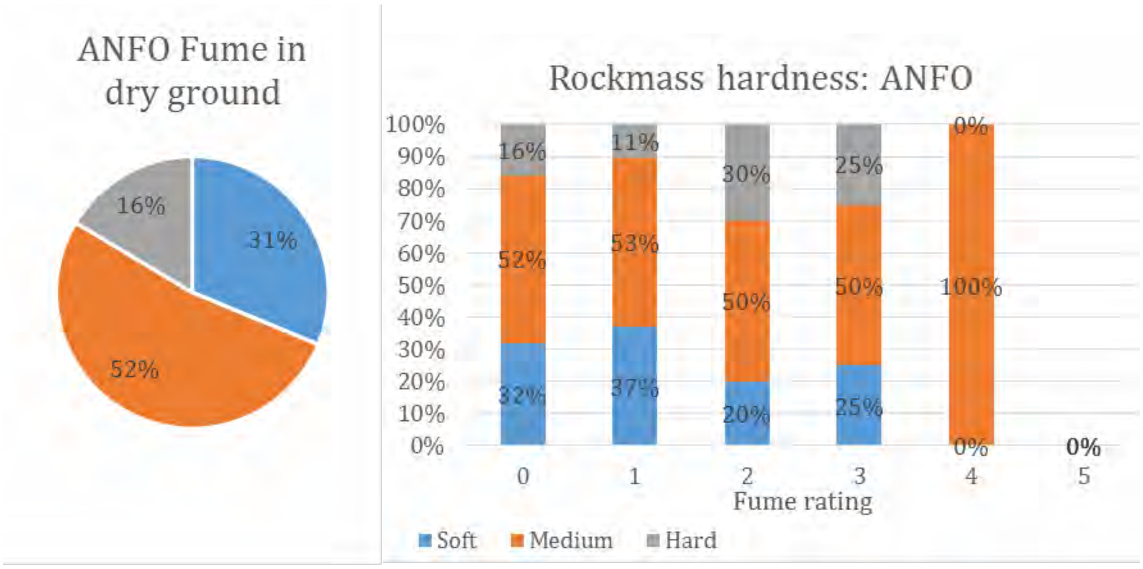



Figure 20: ANFO fume results showing ground hardness

ANFO fume events that rated 0 – 3 inclusive were comparably distributed and similarly distributed to the overall fume ratings for ANFO. This indicates that there ground hardness does not have a significant effect on the fume propensity of ANFO.

## FUME PERFORMANCE OF HANFO

Heavy ANFO blasts were determined as blasts that had been loaded with 95% or more of a single type of product. Despite various types of HANFO in common use, a blast was only used if it was loaded with a single type. The distribution of fume ratings by blast was first assessed.

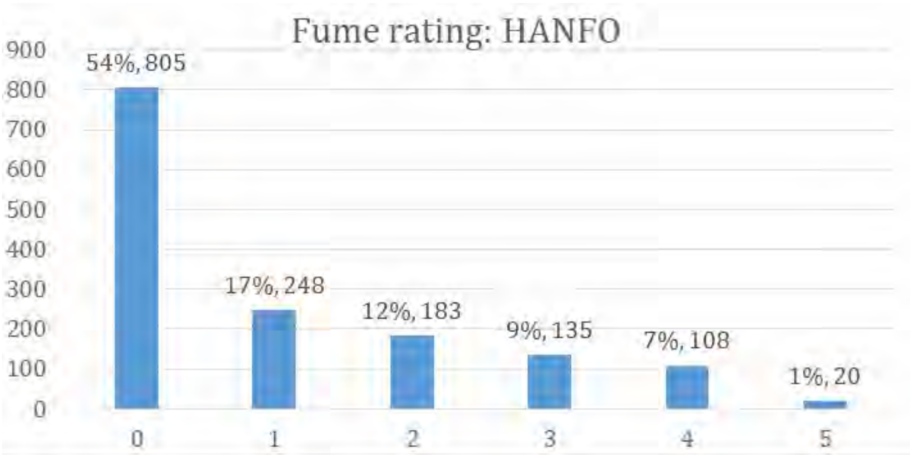



Figure 21: Distribution of all HANFO fume rating

The proportion of HANFO blasts that rated a 0 or 1 was significantly less than ANFO. However, both product types had the same proportion of blasts that rated a 5.

To investigate the effect of water, the data was then divided in to wet and dry datasets. Boxplots were then used to plot each subset.

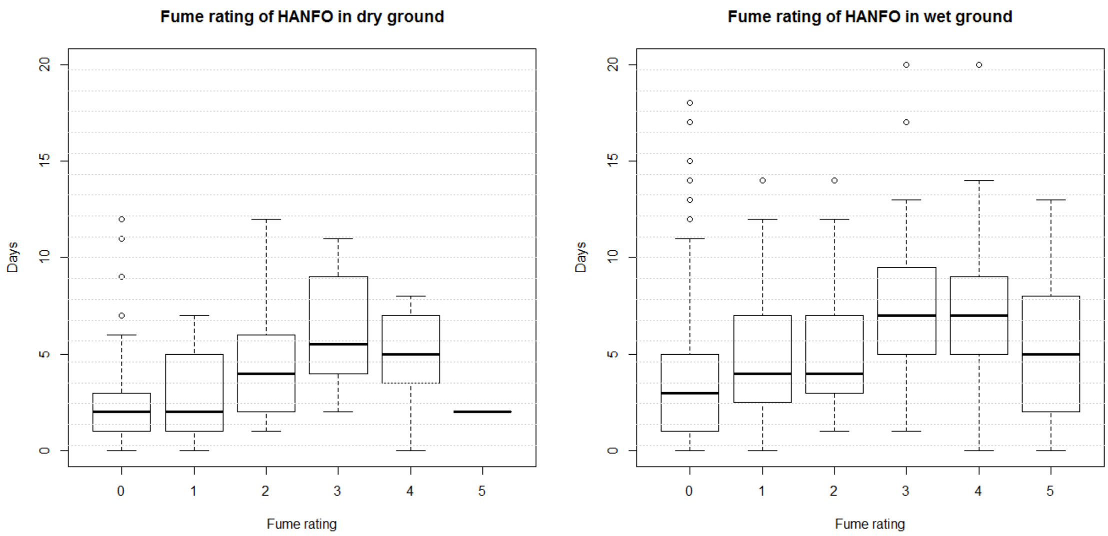



Figure 22: Effect of water on HANFO fume rating

The most apparent difference between the two HANFO subsets is the spread of the data. The fume rating of HANFO blasts in wet ground is spread out of a greater number of days than dry HANFO blasts. Unlike dry ANFO blasts, dry HANFO blasts rated highly within day 0.

The effect of depth on HANFO fume propensity was calculated using the dry HANFO subset. The proportion of blasts that rated less than 2 were plotted, see Figure 23. The smallest proportion of blasts occurs at 25 metres.

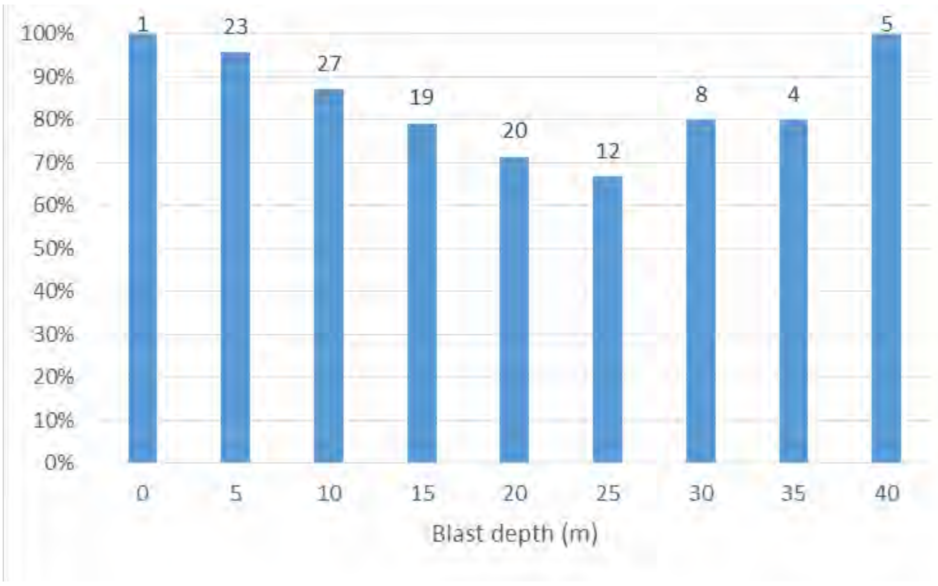



Figure 23: HANFO fume performance by depth

The dry HANFO dataset was also used to investigate the effect of rock hardness on HANFO fume propensity. The fume rating recorded for every dry HANFO blast for each rock classification was plotted.

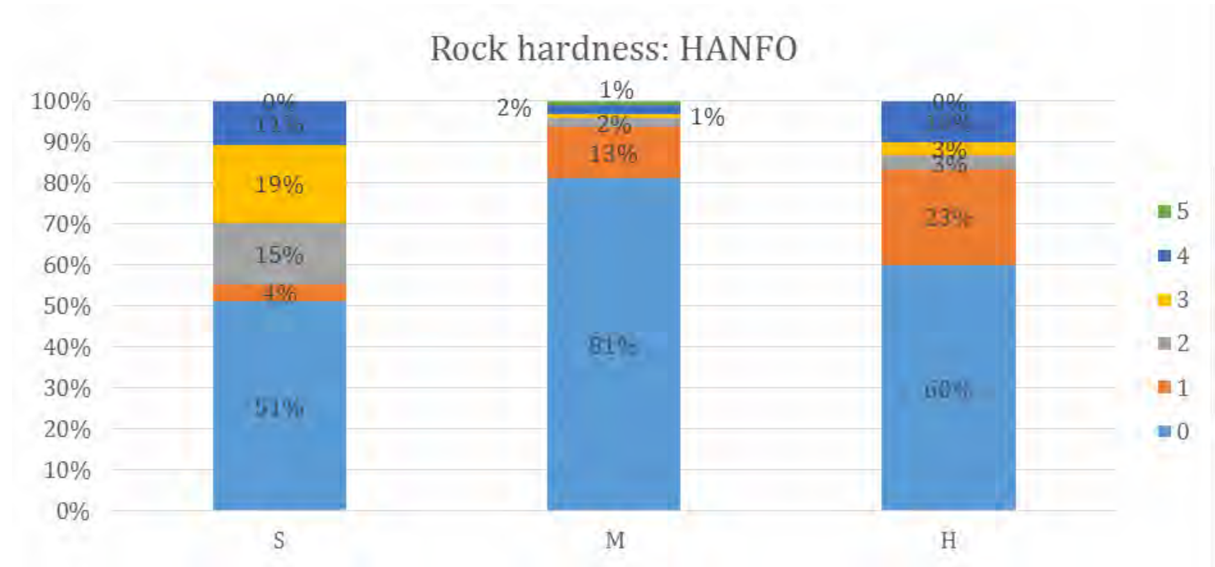



Figure 24: HANFO fume rating by ground hardness

HANFO performed best in ground of medium hardness and worst in soft ground.

Only three types of HANFO were available in sufficient quantities to be assessed individually. The fume distribution of these products was plotted for both wet and dry conditions.

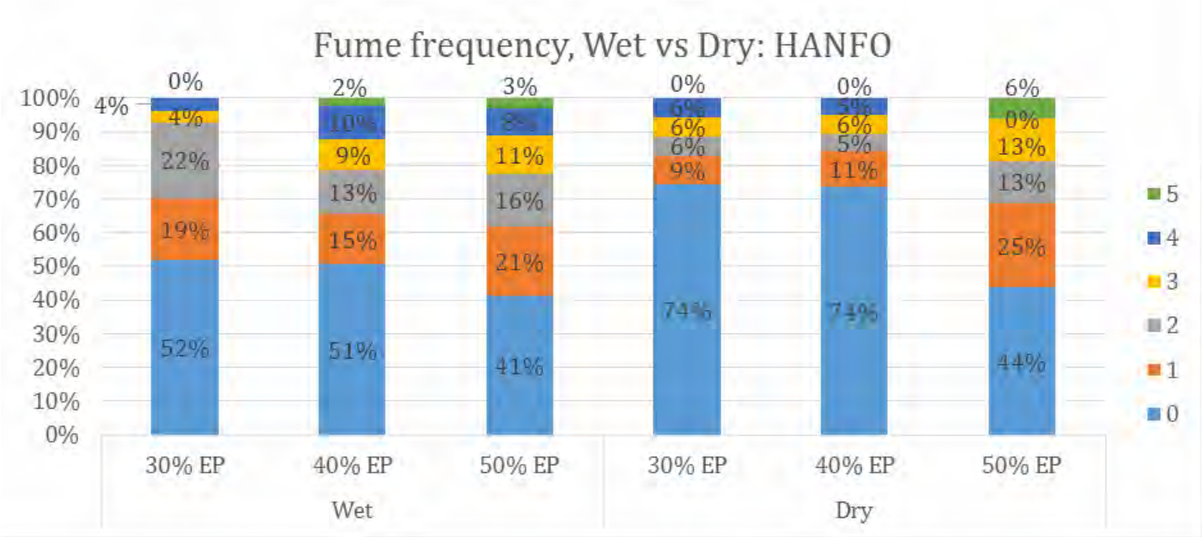



Figure 25: Fume rating distribution for various HANFO products in wet and dry conditions

**FUME PERFORMANCE OF PUMP PRODUCT**

To enable the comparison of explosive performance, blasts were compared that were loaded with more than 95% of a single product type. This methodology resulted in the exclusion of the significant proportion of pump product tonnes. It is likely that the slow delivery of pump product limits it's wide spread use, however there were sufficient blasts to investigate the role of soft ground, wet ground and deep holes of the propensity of pump product to fume.

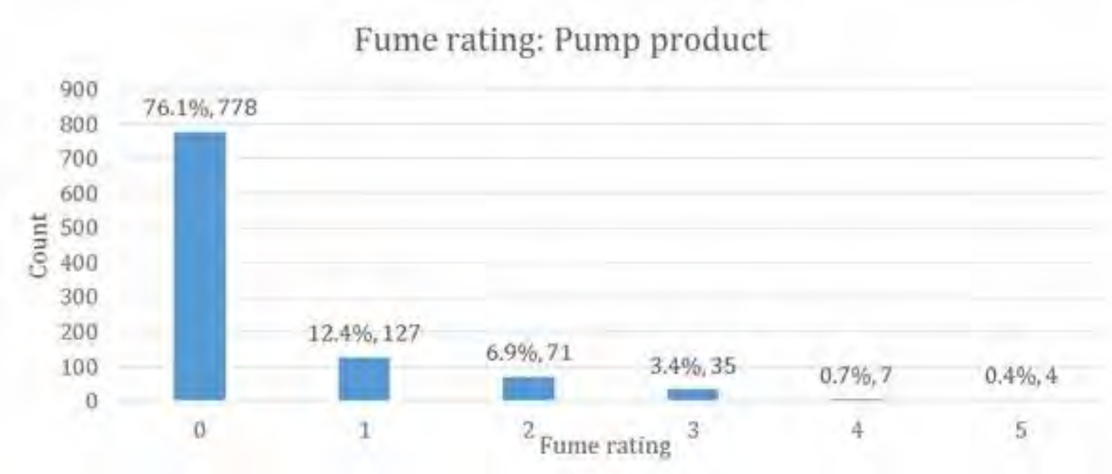



Figure 26: Fume rating distribution of blast loaded with 95% or more pump product

The distribution of fume rating of blasts fired with greater than 95% pump product was the best of the three explosive types assessed. A considerable bias exists to the right, resulting in predominantly in fume events that rate 0.

Due to the bias and limited size of the dataset, the comparison of fume performance in wet and dry ground yielded limited results, as shown in Figure 27.

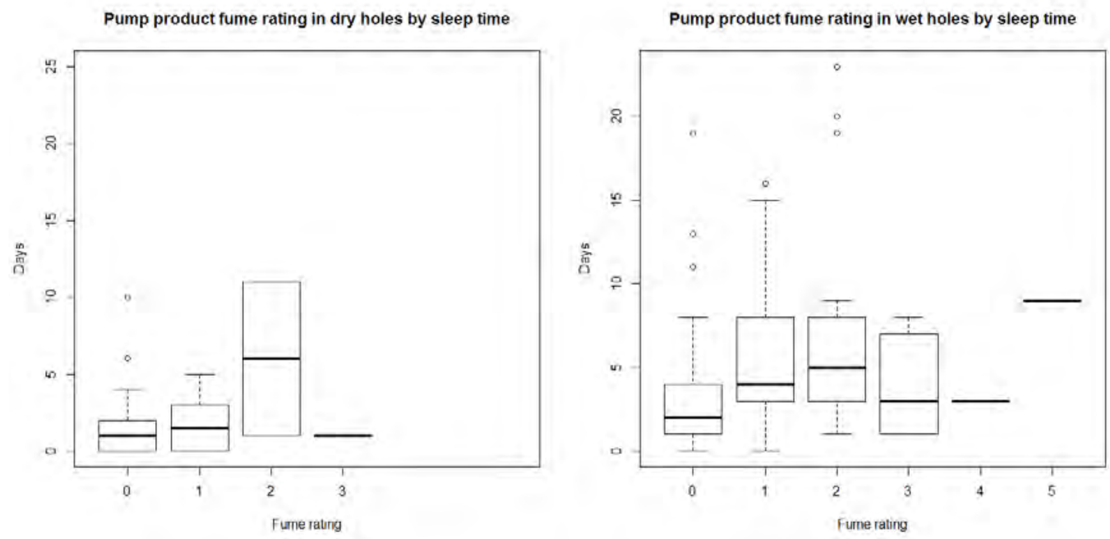



Figure 27: fume performance of pump product in wet and dry ground

## OVERVIEW OF THE EFFECT OF WATER

The substantial effect of water on the propensity of an explosive to fume is demonstrated in Figure 28. Where water is present in a blast the likelihood of that blast resulting in a fume rating of zero reduces significantly.

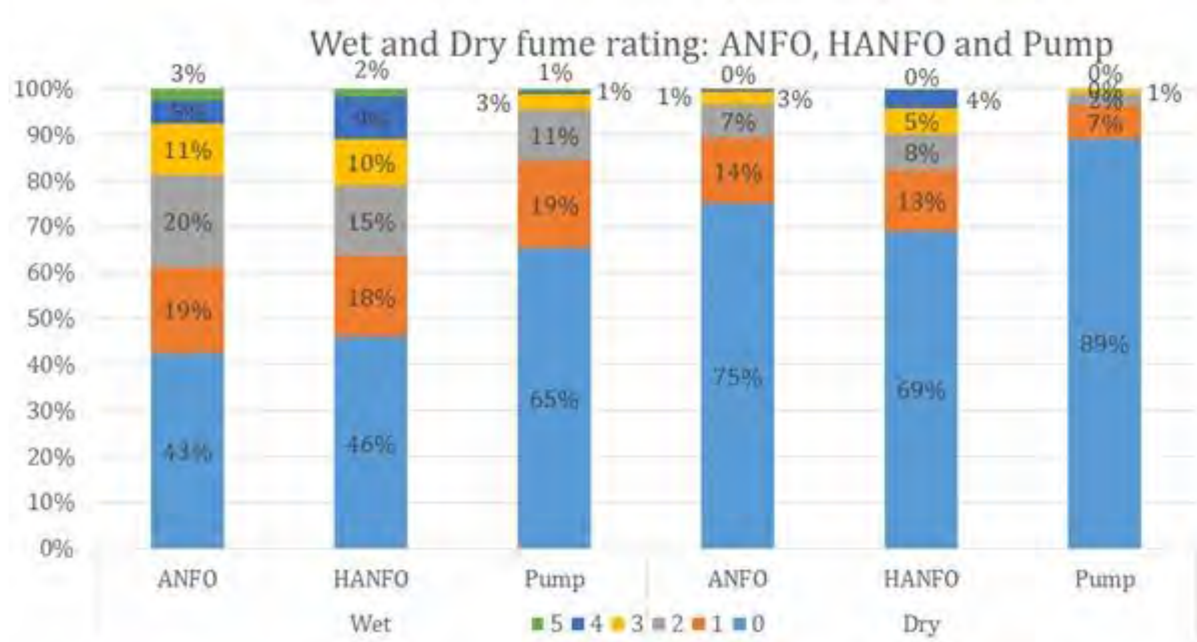



Figure 28: Fume distribution of explosive products in wet and dry conditions

The effect of rain on a blast was investigated by comparing the fume rating distribution for blasts in ground with those in dry ground that experienced rain during and after the loading process. This is shown in Figure 29.

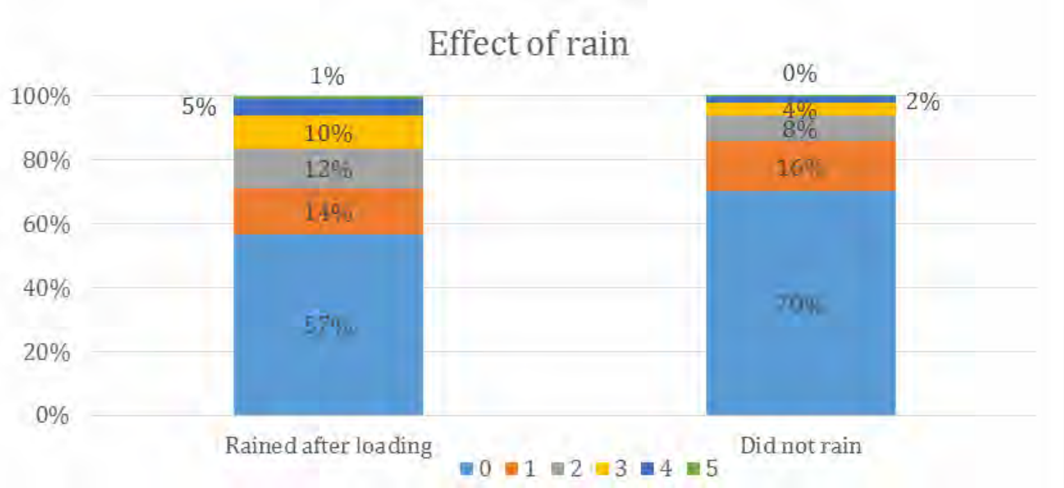



Figure 29: Fume rating distribution of explosives in dry ground compared to fume in dry ground and rain

To demonstrate the cyclic nature of blast fume, mean monthly fume rating was calculated and plotted over the duration of the database. The use of a mean fume rating is not suitable for categorical variables however in this situation it neatly summaries the seasonal fluctuation of blast fume ratings. For comparison, the monthly rainfall recorded at Comet, Queensland was plotted. Comet was chosen as it is centrally located in the Bowen Basin. Considering the area, this of course cannot accurately represent rainfall over all of Queensland's coal mines.

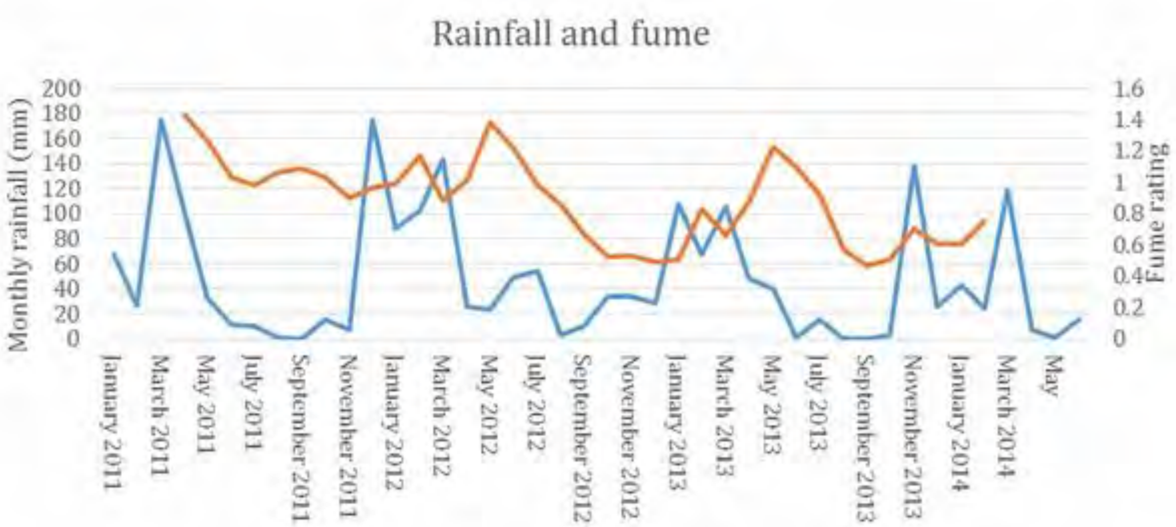



Figure 30: Cyclic nature of fume

**SLEEP TIME**

The time an explosive is exposed to the conditions in hole can result in the degradation of the product. To assess the effect of sleep time, the proportion of each fume rating was plotted per day slept and plotted. This is shown in Figure 31. The most distinct trend is the daily reduction in the likelihood of a blast rating 0. If a blast was selected at random from the database that had slept for 5 days, it would only have a 50% chance of rating 0.

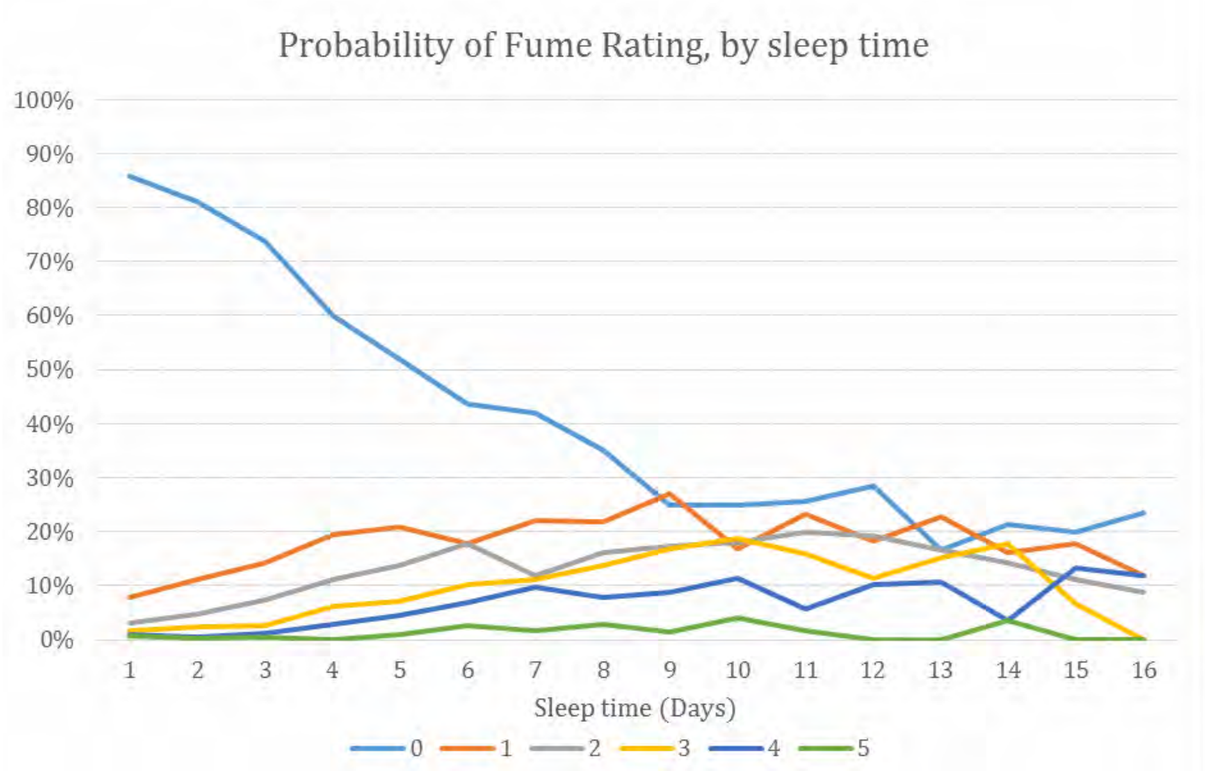



Figure 31: Probability of each fume rating by sleep time