

ICMM

International Council
on Mining & Metals



Good practice guidance on occupational health risk assessment

second edition



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Executive summary

Healthy workers are essential to the success of mining and metals companies, and ICMM company members are driven in their protection of the health and well-being of both workers and local communities by ICMM's Sustainable Development Principle 5: 'Pursue continual improvement in health and safety performance with the ultimate goal of zero harm.'

Workforce protection should be seen in the context of a vision of 'zero harm' – ensuring that a workplace culture is embraced that recognises occupational illnesses are preventable, ensures repeat occurrences of occupational disease do not occur, and promotes the setting and implementing of a consistent set of standards to prevent occupational illness.

In 2009 ICMM developed the *Good practice guidance on occupational health risk assessment* to help site practitioners assess and address the risks posed by hazards in the mining and metals sector. It provides those practitioners with the information and tools they needed to assess the health and well-being of employees and contractors.

In 2016 a review was undertaken to bring the text and advice up to date with changes in the field of occupational health risk assessment and align this document with the terminology and approaches proposed in ICMM documentation published since the first edition, principally the prioritised approach to risk management including the identification of material unwanted events (MUEs) and managing those through the use of critical controls.

This guide identifies the occupational health impacts of mining and metals processing, outlines good practices in the identification of hazards and exposed workers, assists practitioners in estimating exposure levels and assessing the effectiveness of controls and explains the importance of quality analysis and reporting.

ICMM has defined an MUE as an unwanted event where the potential or real consequence exceeds a threshold defined by the company as warranting the highest level of attention (eg a high-level health or safety impact). A critical control is a control that is crucial to preventing the event or mitigating the consequences of the event. The absence or failure of a critical control would significantly increase the risk despite the existence of the other controls. In addition, a control that prevents more than one unwanted event or mitigates more than one consequence is normally classified as critical.

It is our intention that this publication provides a practical tool to assist companies in protecting the health and well-being of their workforce and it aims to represent good practice for companies operating in the mining and metals sector today. This document is titled guidance on occupational health risk assessment, but since the process of risk assessment involves assessment of controls and is an ongoing, continuous process it necessarily involves elements of risk management.

Where possible, alignment has also been attempted with the ISO 45001 international standard 'Occupational health and safety management systems – requirements with guidance for use'. This was in draft at the time of review but it is not anticipated that major changes will take place in the final version. Many organisations may be aligning their internal documentation with this standard in time, and some of the terminology in the new ISO standard has changed. The main change has been the alignment of terms between health and safety and the environmental standards in accordance with Annex SL, Appendix 2 of the ISO/IEC Directives, Part 1, Consolidated ISO Supplement, 2015. However, in the context of this guidance the changes are not significant.

'It is our intention that this publication provides a practical tool to assist companies in protecting the health and well-being of their workforce.'



Introduction

1.1

Purpose of the guide

This guide is an information resource for conducting occupational health risk assessments (HRAs). It is intended for mining and metals managers and advisers who are responsible for ensuring the occupational health and well-being of employees and third party contractors. Though the guidance focuses on the occupational health risks to employees and contractors in a mining and metals operation, it is important to note that these risks can also affect the wider community living around that operation. HRA is an integral part of the process of health risk management and often the two may be indistinguishable. It is important to note that health risk management is not synonymous with hazard identification and risk assessment. The latter forms only part of the more comprehensive management approach.

The aim of occupational HRAs is to systematically and proactively identify health hazards, assess their potential risks to health, prioritise these, including the identification of material unwanted events (MUEs), and determine appropriate control measures (including the identification of critical controls to prevent MUEs) to protect the health and well-being of workers. The HRA process is a partnership between occupational health advisers, occupational/ industrial hygiene advisers, managers and operational staff with each – depending on the circumstances – using their knowledge, experience and skills to support the HRA process.

A key component to the success of health risk management is the commitment and visible leadership from senior and executive management.

HRAs within the mining and metals sector are especially complex because of the breadth and range of the mining life cycle, which includes (see Figure 1):

- exploration
- design
- construction
- operation/extraction
- processing
- engineering services and maintenance
- closure
- rehabilitation/remediation.

This life cycle also encompasses the movement of products, equipment and personnel by road, rail, air and sea and the associated transportation networks and distribution facilities (eg ports and warehouses), as well as the manufacturing, recycling and disposal of goods made from the metals and minerals extracted from mines.

There are no specific figures for the international mining and metals sectors but every year, across all industries around the world, it is estimated that there are 2.3 million deaths from occupational injury and disease with 1.9 million of these due to disease.¹

Workers are an important and valued part of the mining and metals sector and that places a moral obligation on the sector, alongside the legal obligations placed on it, to protect the health and well-being of its workers.²

This moral obligation is increasingly being embedded within the sector through the adoption of the vision of zero harm (ie zero exposures above occupational exposure levels) and zero serious illness or fatal events from occupation health-related exposures within a wider health and well-being at work policy.

This vision encompasses four key aspects:

- developing a workplace culture across an organisation that recognises that the prevention of long-term serious disease is just as important as the prevention of serious safety events
- making a consistent and sustained effort to ensure that there are no repeat occurrences of occupational diseases in any workplace setting of an organisation
- setting and implementing a simple, consistent and non-negotiable set of health and safety standards across an organisation that aims to prevent occupation-related illnesses
- for businesses to identify their 'material unwanted health events' and manage these in accordance with ICMM's *Health and safety critical control management: good practice guide* (2015).

1. 'Global estimates of occupational accidents and work-related illnesses 2014'.

Available at <https://www.wsh-institute.sg/files/wshi/upload/cms/file/Global%20Estimates%20of%20Occupational%20Accidents%20and%20Work-related%20Illness%202014.pdf> [accessed 31 October 2016].

2. See ICMM Sustainable Development Principle 5 – www.icmm.com.

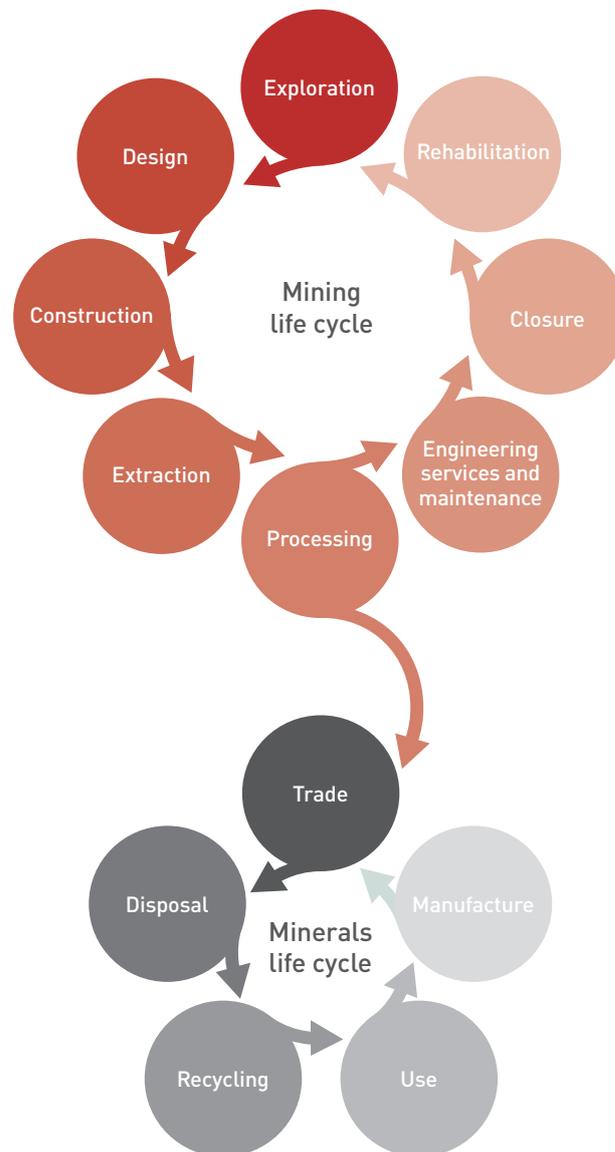
In addition to the cost of occupational ill health in terms of preventable human suffering, which affects not just workers but their families and communities, work-related illness also directly impacts on the productivity and bottom line of companies in the mining and metals sector. This is usually through:

- higher presenteeism and absenteeism
- lower worker morale
- higher turnover rate
- loss of skilled and experienced workers
- loss of investment in training and development
- difficulties in recruiting new high-quality workers.

Alongside this, companies in the sector will also have to bear the costs of:

- healthcare for the affected workers
- compensation and/or damages to sick or disabled workers or to the families of workers that are killed
- higher insurance premiums
- legal advice
- regulatory fines
- damage to premises and equipment
- disputes and protracted negotiations with trade unions, public authorities and/or local residents
- loss of reputation
- loss of business
- loss of competitiveness
- in high-profile cases the complete or partial loss of the licence to operate.

Figure 1: The mining and minerals lifecycles³



3. Adapted from Stephens, C and Ahern, M (2001). *Worker and community health impacts related to mining operations internationally: a rapid review of the literature*. Mining, Minerals and Sustainable Development project, no 25. London: International Institute for Environment and Development, World Business Council for Sustainable Development and London School of Hygiene and Tropical Medicine. Available at <http://pubs.iied.org/pdfs/G01051.pdf> (accessed 31 October 2016).

Introduction continued

1.2

Occupation health impacts of mining and metals

Introduction

There are a large number of hazards in the mining and metals sector that can pose a potential risk to health and well-being.

This section illustrates the range of health problems that can occur in relation to the various types of exposure in mining and metals workplaces. The list is not exhaustive and the risk profile of any particular worker will depend on the exact nature of their role and their individual exposures.

The physical environment

The physical environment where exploration, mining, ore extraction and processing takes place can cause health impacts in the following ways:

- physical injury from accidents involving moving machinery, movement of mining products and working with explosives and detonating devices
- musculoskeletal disorders associated with various work activities, for example where manual handling is a feature, repetitive motion is required or whole-body vibration occurs
- noise-induced hearing loss associated with occupationally related excessive noise exposure
- hand-arm vibration syndrome and other musculoskeletal consequences from hand-arm transmitted vibration
- skin cancer from working outdoors in direct sunlight
- effects from both ionising and non-ionising radiation, for example cataracts
- heat exhaustion, hypothermia and various other health effects from exposure to extremes of temperature.

The effects of hazardous substances

Exposure to some of the major hazardous substances encountered in the mining and metals sector can result in a number of important health effects. These are listed below to illustrate the range of potential problems.

- Skin disorders (burns, contact dermatitis, cancer) from contact with a wide range of chemicals including acids, alkalis, solvents, fuels, lubricants and resins. For example:
 - Irritant contact dermatitis from some fuels, solvents, lubricating oils and greases.

- Allergic contact dermatitis from epoxy resins used in adhesives and the salts of some metals including nickel and chromium (eg in cement).
- Intoxication, through to asphyxiation and death, can result from the inhalation of some gases and vapours including the toxic gases hydrogen sulphide, carbon monoxide and sulphur dioxide.
- Acute pneumonia may result from exposure to blasting fumes.
- Damage to the respiratory system from exposure to airborne chemicals (dusts, gases, aerosols, mists and fumes), for example silicosis, coal worker's pneumoconiosis and asbestosis arising from exposure to crystalline silica, coal dust and asbestos respectively; lung cancer and mesothelioma from exposure to asbestos; and nasal sinus cancer from exposure to nickel subsulphide and acid mists. Welding is a common process in mining and often performed in areas with poor ventilation. Exposure to welding (metal) fumes is known to cause metal fume fever, is associated with cancer, and can cause acute pneumonitis and metal toxicity such as manganism.
- Damage to internal organ systems such as the lung, kidney, liver, bone marrow and brain from the absorption of chemicals and metals through the skin, respiratory and digestive tracts.

‘The mining and metals sector, as with all employment sectors, will on occasions encounter cases of ‘stress’ and other adverse mental health and well-being effects that are attributable to, or contributed to by, occupational factors, including shift work.’



Onset of symptoms in relation to exposure

When considering how to monitor for the development of adverse health effects from exposures in the workplace, it is important to consider the time frame over which the health effects manifest themselves.

Acute health effects are those that are more likely to be immediately obvious to the individual and where it is often possible to attribute cause and effect. Acute health effects usually appear within hours of exposure. For example, contact with an irritant vapour may lead to watering eyes, sneezing, coughing, irritation and, in extreme cases, respiratory distress.

Chronic health effects are ones that can develop over a longer period of exposure. On occasions these will be conditions where the severity of the symptoms or disease, or the risk of harm, is related to the cumulative exposure to the hazard over a period of months or years. Chronic health effects usually occur after repeated exposure over days, weeks and months. Examples of such conditions would be noise-induced hearing loss and hand-arm vibration syndrome.

Long latency is a feature of many occupationally acquired diseases where the development of the signs and symptoms of the condition occur many years after the exposure that is implicated in causation. Examples include the development of mesothelioma (following asbestos exposure), other lung cancers (eg from diesel exhaust exposure) and pneumoconiosis (silicosis, coal worker's pneumoconiosis, asbestosis), which can occur decades after exposure has ceased.

Other occupational hazards to health

The mining and metals sector, as with all employment sectors, will on occasions encounter cases of 'stress' and other adverse mental health and well-being effects that are attributable to, or contributed to by, occupational factors, including shift work. A further potential adverse health effect is chronic fatigue brought about by the intense physical demands of mining and metals activities.

'Chronic health effects usually occur after repeated exposure over days, weeks and months. Examples of such conditions would be noise-induced hearing loss and hand-arm vibration syndrome.'

Introduction continued

1.3

Occupational health risk assessment

Introduction

Health risk assessment involves four key elements:

- identification of hazards and their sources
- estimation of the potential for exposure and the related health effects
- quantification of exposures
- assessment of the risk through:
 - use of techniques such as the bow-tie analysis
 - identification and assessment of the effectiveness of current controls.

An occupational health risk assessment (HRA) is therefore the structured and systematic identification and analysis of workplace hazards with the aim of reducing the risks of exposure to these hazards through the development and implementation of measures to prevent release of the hazard and mitigate the effects of exposure should it occur. In the occupational setting, it is the first step in health risk management.

Health risk management is the decision-making process involving considerations of political, social, economic and engineering factors combined with risk assessment information to develop, analyse and compare options and to select between them.⁴

The HRA process (see Figure 2) ensures that factors influencing health are fully understood and adequately quantified so that decisions are taken in a consistent and cost-effective manner.

Steps in an HRA

An HRA is a cyclical and iterative process rather than a simple linear one and is generally made up of the steps shown in Table 1.

Table 1: Steps in an HRA

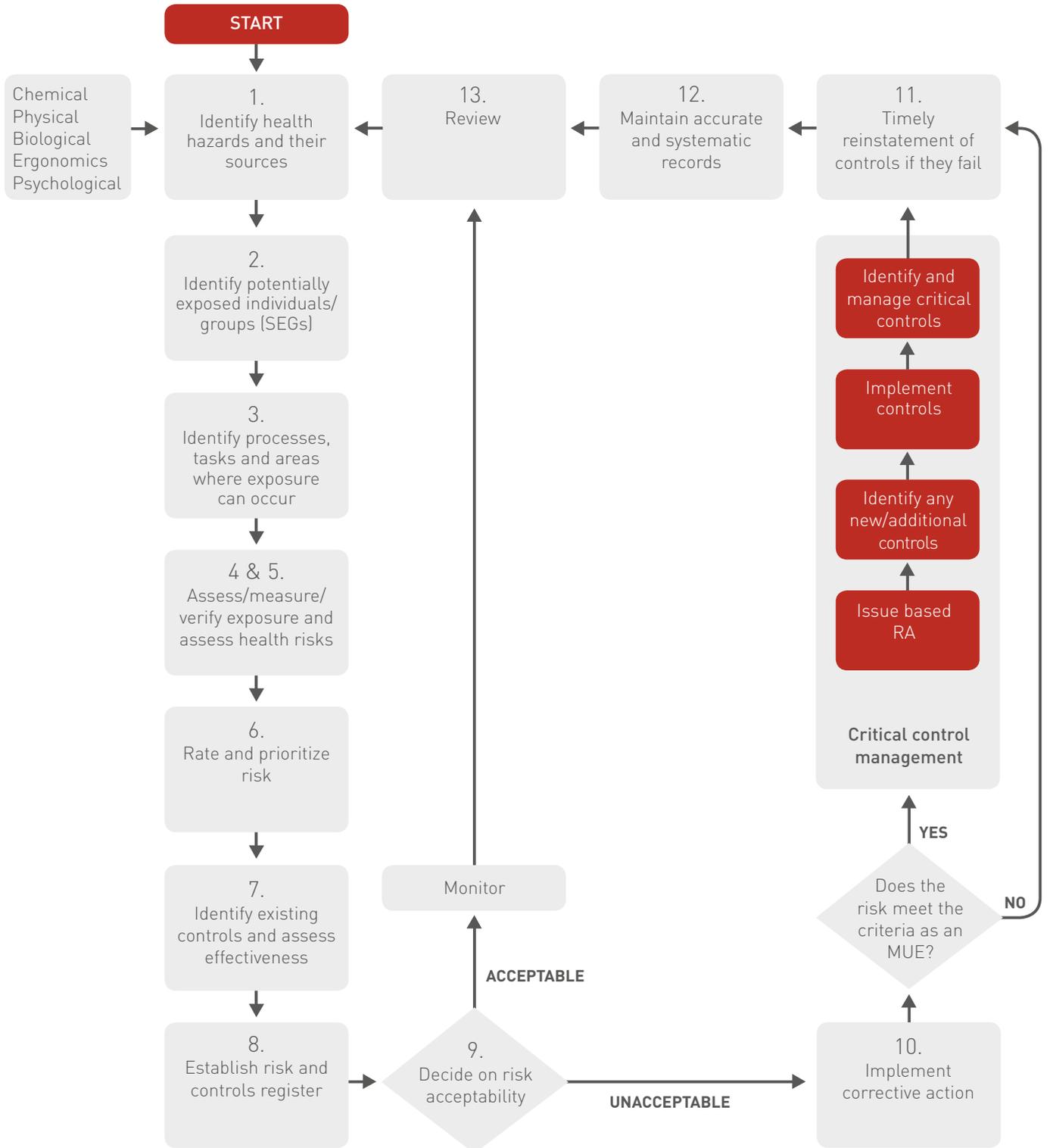
Step	Description
1	Identify the health hazards and the sources of these health hazards in the workplace and the harmful health effects associated with the identified hazards. Consider potential new and emerging health risks as well.
2	Identify the potentially exposed individuals and groups (ie similar exposure groups). ⁵
3	Identify the processes, tasks and areas where hazardous exposures could occur.
4	Assess, measure or verify the exposures.
5	Assess the potential health risks of the hazardous exposures (eg duration of exposure, frequency of exposure, level of exposure compared against occupational exposure limit, etc).
6	Rate and prioritise the health risks (high, medium and low), including the identification of potential health MUEs.
7	Identify existing controls and assess the effectiveness of these control measures. For MUEs determine if any of the identified controls meet the criteria for a critical control.
8	Establish a risk and controls register.
9	Decide on risk acceptability and set priorities for action.
10	Implement corrective action – develop, implement and monitor a risk control action plan or review existing risk control action plan. For identified MUEs this involves the use of a control framework that is aligned with ICM's <i>Health and safety critical control management: good practice guide</i> (2015).
11	Timely reinstatement of controls if they fail (particularly critical controls).
12	Maintain accurate and systematic records of the HRA or amend existing risk control action plan and use alternative and/or additional control measures.
13	Review and amend at regular intervals or earlier if changes to processes or new developments are proposed.

4. Gray, GM, Jeffery, WG and Marchant, GE (2001). *Risk assessment and risk management of non-ferrous metals: realizing the benefits and controlling the risks*. Ottawa: International Council on Metals and the Environment.

5. A similar exposure group (SEG) is a group of workers having the same general exposure profile for the agent(s) being studied because of the similarity and frequency of the tasks they perform, the materials and processes with which they work and the similarity of the way they perform those tasks (Mulhausen, J (2015). 'Establishing similar exposure groups'. Chapter 4 in Jahn, SD, Bullock, WH and Ignacio, JC (eds), *A strategy for assessing and managing occupational exposures* (4th edn). Falls Church, Virginia: American Industrial Hygiene Association). An alternative view is workers who are protected by a common critical control for a hazard.



Figure 2: The health risk assessment process



Introduction continued

Steps in an HRA

An HRA is a cyclical and iterative process rather than a simple linear one and is generally made up of the steps shown in Table 1.

Types of HRA

There are three broad types of HRAs that are each conducted at different levels and at different times:

- baseline HRAs
- issues-based or targeted HRAs
- continuous HRAs.

A baseline HRA is used to determine the current status of occupational health risks associated with a facility, and a set of risk profiles is obtained. This tends to be a very wide-ranging assessment that encompasses all potential exposures, the sources of health risks and the controls associated with the identified risks and sources and their effectiveness. It allows for a prioritisation of interventions to remedy those conditions that are found to be unacceptable.

An issues-based or targeted HRA is designed to more distinctly and clearly delineate and quantify health risks associated with particular aspects of the work activity, processes or sources. Where significant risks are identified, the output should be clear management recommendations for control. Control measures (including critical control measures) for unacceptable health risks (that could include MUEs) are identified and defined according to bow-tie or similar principles.

A continuous HRA is an ongoing monitoring programme for controls and exposure and a schedule of regular reviews to determine whether conditions have remained the same, whether changes in processes, tasks or areas have occurred and whether these changes have modified any hazardous exposures and hence any potential health risks. A management of change programme can also be considered as being part of a continuous HRA programme.

Continuous HRA is part of an effective health risk management programme and includes learning from incidents, which is linked to continuous improvement.

An HRA can be qualitative involving a qualitative assessment of exposures and/or risks (eg baseline HRAs) or quantitative involving the measurement of exposures and/or the quantification of the potential health risks (eg issues-based HRAs).

The HRA must be a living document, and the distinction between baseline, issues-based and continuous becomes blurred once the process of health risk management is under way. The continuous HRA is the ongoing checking of the baseline HRA and monitoring of controls and their effectiveness through the detection of control failures (principally critical controls) and the effects on the exposed workers.

‘Continuous HRA is part of an effective health risk management programme and includes learning from incidents, which is linked to continuous improvement.’



Introduction continued

When to do an HRA

All three types of HRA are generally undertaken in the mining and metals sector although each is conducted at different points in time during the HRA cycle. A baseline HRA is conducted first – this identifies priority hazards, risks and areas that need additional assessment. An issues-based or targeted HRA is then instigated. The development of a health risk management (HRM) programme that will include an exposure sampling strategy and control monitoring programme provides data that further informs the HRA. A new issues-based HRA may then be undertaken as issues are identified, and so on, in an ongoing and iterative process.

An HRA, or the review of an existing HRA, should be considered in the following situations:

- all new routine and non-routine activities and developments (exploration, design and construction)
- all existing operations (operation and extraction)
- where there are changes to existing activities (expansion, replacing an old process with a new one)
- post-operating activities (closure and remediation/rehabilitation)
- following an incident/accident.

New developments, processes, activities and working methods

A baseline or issues-based HRA, undertaken at the conceptual and detailed design stages of new developments, processes and activities, provides an opportunity for the implementation of the most cost-effective approaches for the elimination and reduction of hazards in the workplace.

This HRA should generally focus on the plans and process descriptions and discussions with design engineers, occupational health and occupational hygiene practitioners and operational staff to identify:

- potential health hazards and potential sources of health hazards in the workplace
- tasks and activities where workers might be exposed to these hazards
- the current controls to prevent the release of the hazard into the work environment and, in the event of release, prevention of exposure of employees
- likely levels of exposure
- appropriate exposure limits
- likely baseline health and well-being of potential workers.

This information should then be used as a key input into the overall design of a mine, allowing the design of exposure controls, the implementation of appropriate standards for such controls and the development of operating procedures.

‘Changes in processes and tasks, as well as additional development, should trigger a review of the existing baseline and continuous HRAs.’



Existing operations

A continuous HRA is more suitable for existing operations with a focus on the effectiveness of existing controls and potential exposures during both routine and non-routine operational activities as well as normal, abnormal and emergency conditions. It is important that the possibility of long latency diseases is assessed and that adequate data is collected to ensure appropriate controls, in the first instance, and to provide for the follow-up of employees upon closure.

Change to existing activities

Changes in processes and tasks, as well as additional development, should trigger a review of the existing baseline and continuous HRAs. This review would generally focus on whether there is a need to conduct a full HRA of the whole operation, an HRA of that specific process or task, or the incorporation of the change into the existing HRA through minor amendments to the HRA and the HRM plan.

Closure and post-operation

An issues-based HRA should generally be undertaken when a mine or other facility is closed. Closure brings a different set of hazards concerned with the dismantling of plants, buildings and equipment. These include residues, hazardous materials, naturally occurring radioactive substances, asbestos, etc. There is also likely to be a need to clean up any contaminated land before divestment. The closure HRA should also consider the possibility of long latency diseases and provide for the follow-up of employees with the relevant exposures. Lastly, workers are likely to lose their jobs and this may lead to anxiety, stress, depression and other mental health and well-being effects.

Following an incident

The definition of a health-related incident can vary according to the approach used by the company. In its simplest form, an incident may be the failure of a control or critical control resulting in the uncontrolled release of the health hazard into the work environment. A more severe incident may be the detection of a health effect caused by exposure to the hazard with detection of occupational disease likely to cause severe incapacity or even death being the most severe. The investigation and management of incidents at all levels is likely to lead to information that can be used to drive continuous improvement and inform the HRA.

Should there be an incident, for example failure of a control measure, an investigation of the cause of failure should be undertaken to prevent future occurrences or repeats. This information should also be used to update the HRA.

New versus existing operations

A baseline HRA will be needed for all new operations. However, for existing operations it is likely that a baseline HRA has already been done – this should be reviewed and continuous and issues-based HRA instigated as necessary. It is worthwhile for new operations to review HRAs conducted for similar existing operations. This can fast-track the progression from baseline to continuous and issues-based HRA though conducting a baseline HRA for any new operation is vital.

‘Should there be an incident, for example failure of a control measure, an investigation of the cause of failure should be undertaken to prevent future occurrences or repeats.’

Introduction continued

Scope of an HRA

It is important to define the objectives and boundaries of the HRA. This judgment should be made after discussions with managers and worker representatives.

The major boundaries for any HRA are the physical boundaries. Some examples of physical boundaries are:

- a complete operational site with a well-defined activity, such as an individual mine, a set of clustered mines or an office block or operational complex
- an individual process unit within a large mining complex
- a group of functions that support a single business process.

Other aspects that should be considered include whether the focus is on specific processes, tasks or workers and whether exposures will be estimated qualitatively or measured and quantified (ie whether the HRA will be qualitative or quantitative), which is very dependent on past experience and exposure data collection from similar processes or tasks. Section 3.1 provides further guidance.

Setting up an HRA team or advisory group

Ideally, the HRA should be carried out by a multidisciplinary team with a range of specialist skills, including those associated with the process or task being assessed. The exact number of people involved in the HRA and the range and level of skills required depends on:

- the size and complexity of the facility, process or area being assessed
- the nature and severity of the hazards and health risks involved.

In some circumstances there may be only one occupational health or hygiene practitioner on-site and in this case an advisory group should be established to support the process and scope of the HRA. In general, where an HRA team or advisory group is set up it should include:

- an occupational health or hygiene adviser with experience of conducting HRAs
- a management representative from the facility, process or area being assessed
- a worker representative with knowledge of the facility, process or area being assessed
- other specialist staff as required, for example designers, engineers, toxicologists or ergonomists.

A management representative is highly desirable as early engagement can ensure that the findings of the HRA are acted upon quickly. Worker representatives are often an invaluable part of an HRA team or advisory group as they can bring detailed knowledge of the process, activity or area being examined, as well as insights as to how tasks are actually performed and can advise on the frequency of control failures. This helps to ensure that the analysis of the potential health risks is accurate. In addition, their involvement in the HRA is likely to increase their understanding and appreciation of health hazards and support the development of a zero harm mindset among workers.

Additional specialists can be part of the core HRA team, can be part of the wider support base that are consulted when needed, or may act as peer reviewers of the final draft HRA before it is finalised.

‘Ideally, the HRA should be carried out by a multidisciplinary team with a range of specialist skills, including those associated with the process or task being assessed.’



Key competencies needed to conduct an HRA

The key individual and team competencies needed to undertake HRAs successfully are shown in Table 2.

Table 2: Key competencies for undertaking occupational HRA

Domain	Competency
Knowledge	An understanding and experience of conducting HRAs.
	An understanding of the workplace operations being assessed.
	An understanding of the methods for controlling exposures and reducing risks in mining and associated workplaces.
Organisational	The ability to collect information systematically and comprehensively.
Scientific	The ability to predict any potential departures from expected or observed practice and understand its significance.
	The ability to undertake simple diagnostic tests, for example using a smoke tube to test air movement, simple sound level metering or using colorimetric tubes, etc.
	The ability to identify and review the relevant scientific and technical literature.
	The ability to look critically at existing arrangements.
	The ability to observe so that they can clearly appreciate the activity being performed and the significance of what is being witnessed, particularly where written procedures are not being followed.
	The ability to assess exposures and estimate the potential health risks arising from them.
	The ability to develop credible, statistically valid and robust conclusions from the analysis of health risks.
Medical	Knowledge and understanding of the health effects of major physical, chemical, biological, ergonomic and psychological exposures in the mining and metals sector. An ability to integrate this knowledge with the control strategy.
Managerial	The ability to investigate, and pursue with management, the opportunities to eliminate hazardous exposures at source.
	The ability to perceive the range and limitations of possible control measures and their relative reliability.
Communications	The ability to ask the right questions to operational staff, managers and advisers and understand the significance of the answers.
	The ability to specify and follow up on the type of control measures needed and their implementation.
	The ability to record findings in an understandable manner.
Personal	An awareness of the limits of own competence and the confidence and persistence to be able to ask for, and get, specialist assistance when required.



2

Identification of issues



Identification of issues

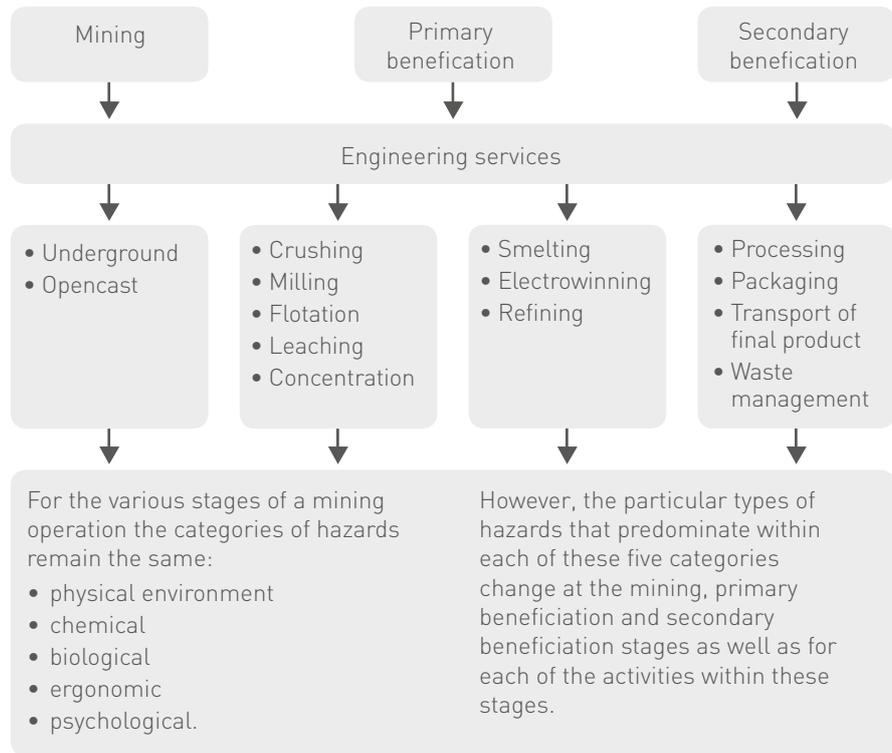
2.1

Occupation health impacts of mining and metals

Introduction

A mine is a complex workplace involving the entire spectrum of exploration, extraction, crushing, milling, flotation, smelting and refining as well as engineering processes from the operation of chemical processes, heavy equipment and electrical maintenance to electronics. Operations are often located in remote environments and it will be important to also consider issues around security, the potential for natural catastrophes, travel risks, medical evacuation capability, the standards of local health facilities, etc. The range of potential exposures is therefore extensive. Figure 3 illustrates the main elements of the mining and mineral process and how they influence the types of hazards found.

Figure 3: Illustrative flow chart for a mining operation



Step 1: desktop analysis

The first step in identifying health hazards is a desktop analysis. This is particularly useful where records of previous HRAs and other employment records are available. Some examples of the types of records that might be available are:

- incident reports
- audit reports
- previous HRAs
- occupational illness and injury reports
- equipment maintenance and fault reports
- health surveillance records⁶
- sickness absence reports
- previous occupational hygiene surveys

- site inspections
- minutes of health and safety meetings
- material safety data sheets.

A review of the design of the facility, together with blueprints and schematics of the individual area or process, and related health records will help to systematically identify the potential health hazards that are present or might occur.

6. Health surveillance can vary from simple questions from trained supervisors to comprehensive medical supervision undertaken by an occupational health physician. It is important to assess the strength of evidence and determine the appropriate weighting given to the information that is available. An adverse report from a responsible person undertaking screening skin inspections will generally have less weight than that of an occupational physician or a dermatologist who diagnoses an occupational skin disorder.

2

Step 2: walk-through survey

A walk-through survey of the area, process or task enables the assessor to get a sense of the types of potential health hazards, the levels of exposure, the types of workers and workers' general levels of health, physical and mental functioning through the careful use of the senses – vision, hearing, smell and feel.

Some key aspects to be considered

Physical environment issues

- What noisy equipment or processes are present?
- Are cutting and welding activities carried out that emit infrared or ultraviolet light radiation? Is any equipment used that emits ionising radiation?
- What tasks involve exposure to hand-arm transmitted or whole-body vibration?
- Are there any working areas where extremes of heat, cold or humidity are present or could occur?
- Are there any specialist tasks involving changes in atmospheric pressure, for example tunnelling work under compressed air?
- Is ventilation adequate? Is there a of potentially harmful gases?
- Are employees potentially exposed to non-ionising radiation?

Chemical agents

- Are workers exposed to chemicals that could affect normal physical or mental functioning in the short or long term?
- What chemicals are being used? Review the site hazardous chemicals register if available.
- Does the process allow for chemicals to be mixed, and could that give rise to a hazard?
- What products, by-products and wastes (gaseous, liquid or solid) are being produced?
- What potentially hazardous building construction materials have been used?
- Are there any safety or health hazards related to the compatibility of chemicals stored together?

Biological issues

- What systems are present for drinking water, effluent, sanitation and sewage? What is the potential for pathogenic microorganisms?
- What washing facilities are present? Are they adequate for the number of workers and are they cleaned regularly?
- Does the site have a legionella management and control programme?
- In restaurants and canteens and eating places, what is the potential for insects, rodents and microorganisms?
- Are there air conditioning systems? What is the potential for pathogenic microorganisms?
- Are there any disease-carrying insect or rodent vectors in the local environment, for example malaria-carrying mosquitoes, leptospirosis and plague-carrying rats, etc?
- Are there any cultural practices that may increase the risk of infectious disease, for example eating bushmeat?

Ergonomic issues

- Do workers have to carry out heavy manual tasks?
- Are workers involved in repetitive, awkward or unnatural movements; or do they have to remain in a static position for long periods?
- Is work performed under extreme environmental conditions (heat, cold, wet)?
- Do they wear occlusive protective clothing that restricts free movement or requires greater exertion?
- Does the job require immediate mental alertness and agility? Could fatigue, distraction and the use of medication create a hazard?

‘A walk-through survey of the area, process or task enables the assessor to get a sense of the types of potential health hazards, the levels of exposure, the types of workers and workers' general levels of health, physical and mental functioning’

Identification of issues continued

Psychological issues

- Is the job organisation, in terms of shift patterns, rotations, resources and workload, likely to lead to sleep disturbance and/or mental stress?
- Is there harassment, discrimination, bullying or violence either explicit or implicit?
- Is there restructuring of the organisation or business unit and/or a change or redeployment of workers?
- Are workers isolated from family, friends and other social support networks or working alone?
- Are there culture, faith and language issues?
- Is there a lack of leisure and recreation opportunities?
- Is there a system in place for workers to pass on issues and complaints? How well is it used?
- Is there access to a formal rehabilitation programme? On remote sites this could be on-site or via telephonic or internet access.

Step 3: rating hazards

Hazards can also be numerically rated in terms of their likely health effects as shown in Table 3. This supports the accurate assessment and prioritisation of risks by highlighting those hazards that could give rise to significant harm to workers.

Within the process of rating hazards is a consideration of the toxicity of the agent and the time and dose required for harm to occur.

Table 3: Illustrative example of criteria to rate hazards

Hazard rating	Definition
1 – Minor health effects	Exposure at this level is unlikely to lead to harm.
2 – Reversible health effects	Non-life-threatening reversible health effects.
3 – Adverse health effects	Adverse health effects that are permanent but do not significantly affect quality of life or longevity. Health effects that may be mildly limiting or disabling and therefore could lead to a change of occupation and lifestyle.
4 – Significant and severe health effects	Adverse health effects that are generally permanent and could lead to a significant reduction in quality of life and/or longevity. Continued exposure is generally likely to lead to permanent physical or mental disability or a long-term limiting illness.

‘Hazards can also be numerically rated in terms of their likely health effects. This supports the accurate assessment and prioritisation of risks by highlighting those hazards that could give rise to significant harm to workers.’



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Identification of issues continued

2.2

Identifying exposed workers

Introduction

Where there are large numbers of workers it may not be practical to assess the risks for each individual worker. In such cases it is more effective and efficient to identify groups of workers with similar exposure levels. These groups are generally referred to as similar exposure groups (SEGs).

Identifying exposed workers by SEGs

A sensible approach is to divide workers by process or areas of work and then to subdivide them by occupation and generate groups of workers with similar exposures, that is SEGs. In this way the exposure and risks to workers can be better captured and assessed accurately. SEGs may be based upon tasks or area of work depending on the structure of the working environment, and should include third party contractors where exposed.

It is important to develop a reasonable number of SEGs, not too many and not too few, as too few will not differentiate the exposures of workers narrowly enough and too many will become difficult to manage. The exact number will depend on the ranges of different processes and hence categories of exposure under consideration.

Typical examples of occupational groups by process or area of work are:

- ore extraction workers
- ore transfer truck drivers
- smelting plant maintenance staff
- office administrative staff
- laboratory technicians
- mine geologists and engineers.

It is important when developing SEGs to list all the key processes and tasks that are undertaken by workers doing similar jobs so that hazards can be systematically and comprehensively identified. It is useful to draw on workers' own experiences and to discuss with workers the activities that they are undertaking in a particular area of work to ensure that all the potential exposures have been identified. As a general rule, workers should be assigned to an SEG based on which areas and/or processes they spend 80 per cent of their time.

Identifying exposed workers by susceptibility

It is also worthwhile identifying whether there are any workers that are potentially more susceptible or vulnerable to some hazards than other workers such as:

- pregnant women and nursing mothers
- new recruits or temporary workers because they do not know what hazards are present and how to avoid or deal with them
- workers with pre-existing occupational and non-occupational illness and any other form of physical or mental limitation identified by the medical surveillance programme
- workers operating in high hazard areas or processes
- ageing workforce
- smokers or other substance users, including medications, where this may increase the health risk from an occupational hazard.

‘It is useful to draw on workers’ own experiences and to discuss with workers the activities that they are undertaking in a particular area of work to ensure that all the potential exposures have been identified.’

2

2.3

Identifying potentially hazardous processes, tasks and areas

Introduction

To systematically identify and assess processes, tasks and areas where exposure to hazardous agents may occur, and to assign workers to the most appropriate SEGs, it is important to review:

- processes and tasks
- equipment and machinery
- environment and location
- medical surveillance records and trends.⁷

Processes and tasks

When reviewing processes and tasks, some important things to consider are:

- routine, non-routine and emergency situations
- hours of work
- shift rotation
- sources of hazard
- worker positioning in relation to sources
- control measures already in place.

Equipment and machinery

When reviewing equipment and machinery, some important things to consider are:

- its design and condition
- how it is used and the training being provided
- whether it is malfunctioning or inoperable
- whether it is being maintained
- its location in relation to other activities
- associated hazards, for example dust, noise, vibration, radiation, heat or exhaust emissions and the points of release.

Environment and location

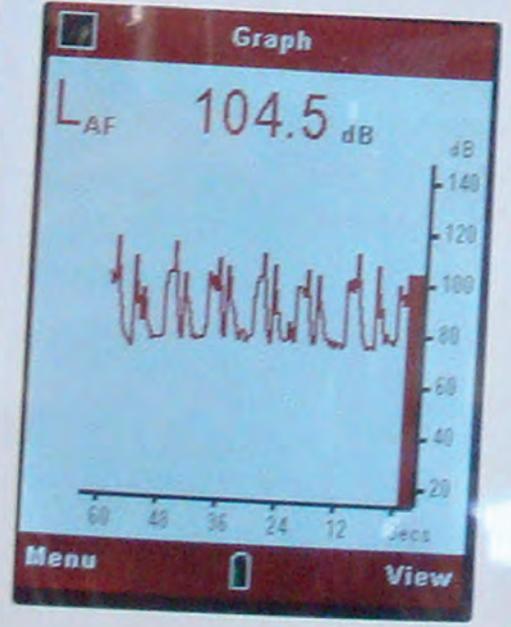
When reviewing the environment and location, some important things to consider are:

- adequacy of ventilation
- appropriate temperature regulation
- humidity
- ergonomic design of the workspace
- lighting
- physical space available to move around in
- the possibility of the hazard spreading outside the area in question, to other departments or the community.

Controls

- What controls are in place?
- At what level in the hierarchy of control are they? (see Section 3.4)
- Are they effective?
- Are they being maintained?
- For MUEs, what are the critical controls?
- Has the purpose and performance parameters of each critical control been defined?
- Have the control objectives, expected performance and management information been defined?
- Is there a system for the monitoring of and reporting on the performance (ie availability, effectiveness and efficiency) of the identified critical controls?
- If personal protective equipment is used:
 - Is it appropriate and effective?
 - Have employees been trained on the correct use of the provided personal protective equipment?
 - Is its use monitored?
 - Is it maintained?

7. These records are held by the occupational health clinic and only concern medical examinations and tests done in relation to exposures in the workplace. They thus differ from personal medical records that are held by the employee's personal doctor or primary care records that may be held by the occupational health clinic. Personal medical records are confidential, but there may be some access to anonymised medical surveillance records. In general, consolidated data or information that has had the identification removed may be viewed. Should it be necessary to view an individual's record without removing their identity then the employee's permission will need to be sought.



3

Assessment



Assessment

3.1

Assessing exposure levels

Introduction

The aim of estimating exposure levels is to characterise exposures in terms of their intensity, frequency and duration for SEGs, processes, tasks and areas. Exposures can be estimated indirectly and qualitatively, or quantified by direct measurement. All exposure measurements should follow a validated statistical sampling and assessment methodology as well as quality control procedures. Figure 4 provides a decision flow chart to aid decision-making on which exposure measurement strategy to use in a particular context.

Indirect qualitative assessment of exposures

Indirect qualitative assessment of exposures can be made either during a walk-through survey to identify the potential health hazards, or based on previous direct quantitative measurements of exposure, or a combination of the two. The level of exposure is assessed by taking into account the hazards that have been identified; the SEGs that have been defined; and the processes, tasks and areas that have been considered through the review of documents, the walk-through survey and discussions with managers and workers.

Direct quantitative assessment of exposures

Direct measurement of exposures to health hazards should be considered when:

- doubts arise about compliance with recognised exposure limits
- excessive exposure could involve serious health effects
- justification is needed to implement control measures
- the choice of control measures depends on the levels of exposure
- the effectiveness of a control measure needs to be evaluated
- workers' concerns need to be alleviated
- it is, or has become, a regulatory requirement
- investigating or responding to reported health effects.

Key matters to consider when estimating exposures

The following points can help in estimating exposure levels:

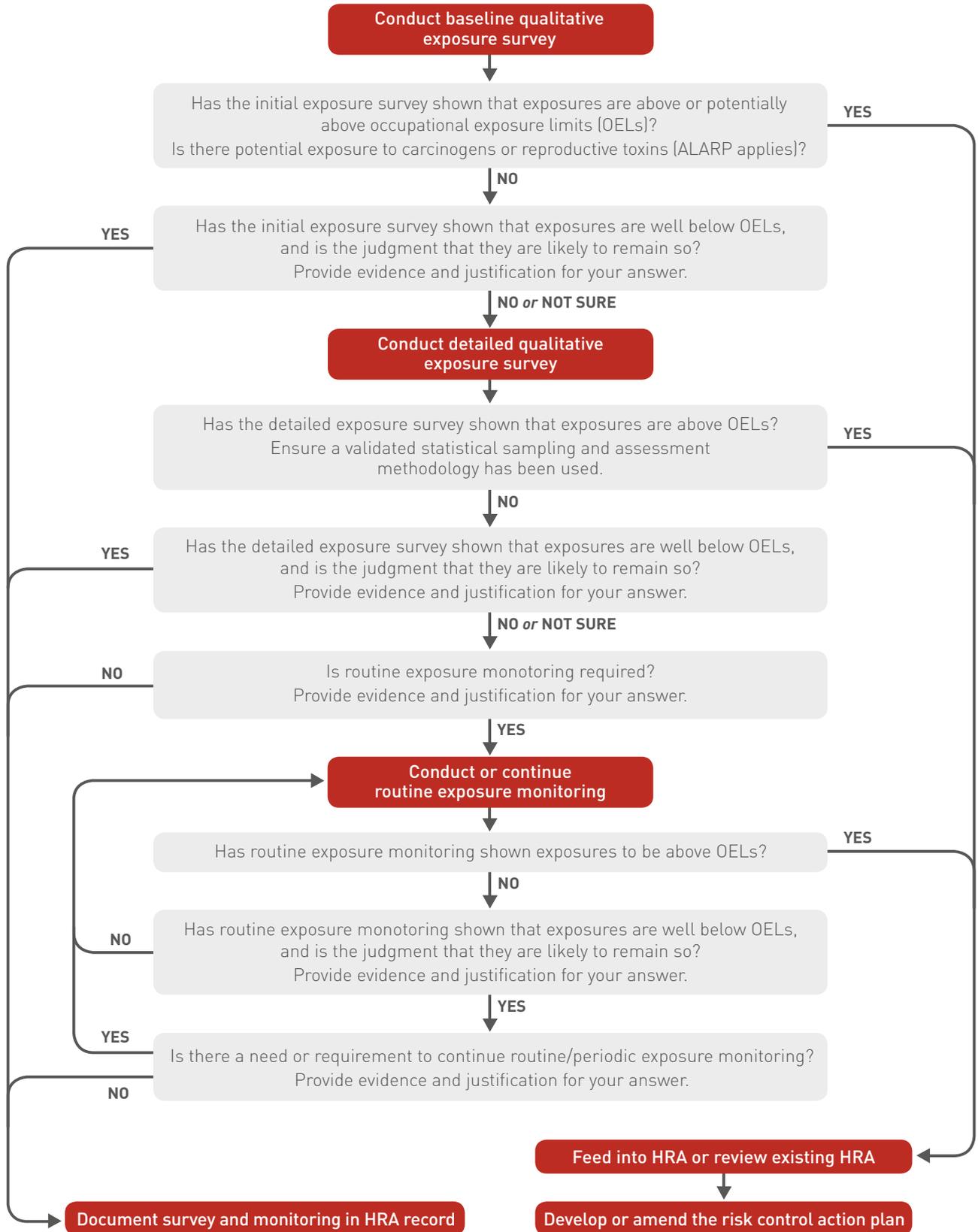
- Are levels of exposure consistently high or low, are there peaks and troughs in the levels of exposure and are they continuous or intermittent?
- Note any aspects of processes and tasks that may increase exposure.
- Speak to staff to understand their perceptions and experience of the task and the associated hazards.
- Are there any controls in place? Are they effective?
- Is a programme in place that monitors the effectiveness of the controls?
- Are employees familiar with the controls, their performance criteria and limitations?
- Review control maintenance and inspection records.

- Review non-routine and intermittent activities, for example maintenance operations, loading and unloading and changes in production cycles.
- Take account of unplanned but foreseeable events such as interruptions in work activity, potential for accidental exposure and machinery failure.
- Review whether the medical emergency response arrangements are appropriate, for example first aid measures and transfer of victims to specialist facilities.
- Consider whether workers not directly involved in a particular activity but present in the vicinity are exposed to a hazard.

'All exposure measurements should follow a validated statistical sampling and assessment methodology as well as quality control procedures.'

3

Figure 4: When to use the different types of direct exposure measurement surveys



Assessment continued

3.2

Risk rating

Introduction

Once the exposures have been estimated by hazard, by SEG and by process, task or area, then it is time to analyse the potential health risks and the significance of those health risks categorised.

Risk rating or characterisation is the process for estimating the incidence and severity of adverse health effects likely to occur due to actual or predicted exposures to workplace health hazards. It is the final product of the HRA that can be used to develop and prioritise controls and to communicate risks.

The decision on the risk rating and priority for action that is attached to a particular risk is an internal company decision. Generally, a materiality level for risk acceptance is set and a start is made with the most serious risks, working downwards as these are brought under control. This process of setting priorities determines what is a material risk for which an MUE is identified. That is then fed into the bow-tie analysis and a management programme developed. Inherent in this is the identification of critical controls that will be carefully managed so as to prevent the consequences of the unwanted event at the centre of the bow tie (ie the MUE).

Identifying material unwanted events

The new step in the HRA process is the identification of MUEs, unwanted events where the potential or real consequence exceeds a threshold defined by the company as warranting the highest level of attention. By their very definition they must be relatively few in number, because otherwise 'if everything is important, nothing is important'. It is not the intent to replicate the guidance contained in ICMM's *Health and safety critical control management: good practice guide* (2015), but simply highlight a few key points.

Materiality criteria

Materiality criteria define the threshold that a risk must exceed before being considered a material risk. The perceived likelihood of an event by any one individual might be inaccurate, especially for low-probability/high-consequence events. It is recommended that materiality should be defined based on consequences, such as the maximum foreseeable loss.

Maximum foreseeable loss (MFL)

It is usual to assume there are no controls in place.

With respect to health risks, where due to the long latency that exists between first exposure (eg carcinogenic agent) and onset of disease (eg lung cancer), it can be difficult to attribute the disease to the workplace and the worker may well be long retired. Therefore, the perception of risk is likely to be very low or discounted altogether, reinforcing the need to evaluate based upon MFL.

The business will need to also consider how MFL is to be calculated with respect to the plausibility of no controls being in place for the duration of exposure identified as being necessary for the event to occur. It is therefore critical how the business actually defines the risk event.

Examples from ICMM company members on health MUEs include:

- the exposure of large numbers of workers to carcinogenic agents at levels that exceed occupational exposure limits (OELs) (discounting the protection afforded by personal protective equipment – as required in defining materiality)
- the exposure to silica in a workforce with high prevalence of HIV and the associated risk of silicotuberculosis.

Section 3.4 describes the principles associated with the good management of controls in general. However, MUEs require an additional level of management focus and therefore should be managed in accordance with ICMM's *Health and safety critical control management: good practice guide* (2015).

3

Risk rating approaches

One of the most important steps is to determine whether the level of risk is acceptable by assigning a risk rank level to the situation under review.

There are numerous methods of rating risks to assist in the prioritisation of management action. Most of these use a two-dimensional matrix with either three or five levels of impact and likelihood. However, health risks often have a third dimension to them and that is the uncertainty surrounding exposure, toxicity, the biological effect and individual idiosyncrasy in biological response.

The estimations can be defined in qualitative, quantitative or semi-quantitative terms:

Qualitative – judgment is used and a simple ranking mechanism of low, moderate or high is utilised. This is especially useful when performing the baseline-type risk assessment where the objective is simply to identify the significant health risks that are then more comprehensively measured and/or analysed. It is difficult to prioritise interventions with this method.

Quantitative – involves the use of mathematical equations that are the extension of the low, medium and high scenarios and describes risk as the consequence of severity of harm or damage that can occur and the proportion of time exposed to the hazard.

Semi-quantitative – involves the use of a matrix based on the consequence of exposure and likelihood of exposure. Exposures can then be rated using a scale based on an OEL or other health standard (see Table 3).

When rating exposures, it is important to consider:

- all the relevant routes of exposure
- potential cumulative exposures
- any limitations in health standards if the standard does not consider all routes – for example, potential dermal or ingestion risks are generally not taken into account when OELs are set.⁸

NB: For carcinogens and reproductive toxicants (known and suspected), meeting an OEL is not adequate; exposures must be ‘as low as reasonably [achievable or] practicable’ (ALARP).⁹ There must be an annual documented review of exposure controls for these substances.

The following are some examples of how the qualitative, quantitative or semi-quantitative approaches can be applied.

‘Risk rating or characterisation is the process for estimating the incidence and severity of adverse health effects likely to occur due to actual or predicted exposures to workplace health hazards.’

8. ICMM and Institute of Environment and Health (2007). *The setting and use of occupational exposure limits: current practice*. London: ICMM.

9. HSE UK. ALARP ‘at a glance’. Available at www.hse.gov.uk/risk/theory/alarpglance.htm (accessed 31 October 2016).

Assessment continued

Qualitative

Table 4 uses a qualitative/simple exposure rating system for illustrative purposes. In practice, exposure ratings can range from negligible through low, medium/moderate and high to very high/critical.

In Table 4 the exposures in the A category are regarded as being certain to produce an adverse health effect, exposures in the B category may result in an adverse health effect (depending on the sensitivity of the individual) and exposures in the C category are unlikely to cause an adverse health effect.

The classification can be used to assist management decisions about control of the risk associated with the exposure. In the A category an intervention must be made to reduce exposure to below the OEL. In the B category there may be no intervention required beyond monitoring or active management of controls to ensure that the exposure remains at this level or lower. In the C category periodic monitoring is required.

In the example in Table 4, all A category exposures would have a bow-tie analysis completed and critical controls identified. Because of the inherent uncertainty regarding exposure, toxicity, the biological effect, etc, B category exposures identified in the baseline risk assessment should be monitored on a regular basis. Hazards that are in the B category because they are well controlled should be managed as though they are in the A category.

‘In practice, exposure ratings can range from negligible through low, medium/moderate and high to very high/critical.’

3

Table 4: Qualitative/simple exposure rating system

Exposure rating	OEL exposure band	Definition	Risk category	Action approach
Low	Less than 50% of OEL (<0.5 x OEL)	<p>Frequent contact with the potential hazard at low concentrations, or infrequent contact with the potential hazard at moderate concentrations.</p> <p>Frequently can expect the exposure to be less than 10% of the OEL, or infrequently can expect the exposure to meet or exceed 10% of the OEL, but less than 50% of the OEL.</p> <p>Exposures are at or well controlled to below the OEL, there are less likely to be breaches of the OEL and this level of exposure is likely to cause little or no adverse health effect.</p>	C	<p>Supervisory</p> <p>Do not need active controls. Verify periodically.</p> <p>Sampling strategy is aimed at routine checks.</p>
Medium/moderate	Between 50% and 100% of OEL (>0.5–1 x OEL)	<p>Frequent contact with the potential hazard at moderate concentrations, or infrequent contact with the potential hazard at high concentrations.</p> <p>Frequently can expect the exposure to meet or exceed 10% of the OEL, but less than 50% of the OEL, or infrequently can expect the exposure to meet or exceed 50% of the OEL, but less than 100% of the OEL.</p> <p>Exposures are at or controlled up to the OEL, there is a potential for breaches of the OEL and this may cause an adverse health effect in some workers, eg vulnerable groups.</p>	B	<p>Control</p> <p>Need active monitoring of controls to ensure exposure remains below OEL.</p> <p>Workplace sampling strategy is aimed at quality control and checking on controls.</p> <p>Medical surveillance of workers exposed at >50% of OEL.</p>
High	At or greater than OEL (>OEL)	<p>Frequent contact with the potential hazard at high concentrations, or infrequent contact with the potential hazard at very high concentrations.</p> <p>Frequently can expect the exposure to meet or exceed 100% of the OEL.</p> <p>Exposures are above and/or not controlled to the OEL and are likely to cause adverse health effects in the majority of workers exposed either in the short or long term.</p>	A	<p>Intervention</p> <p>Need active intervention to reduce exposure to below OEL.</p> <p>Control may be identified as critical.</p>

Assessment continued

Quantitative

An illustrative example of a quantitative approach is provided. It produces a numerical result, as illustrated in the following method:

Risk rating = consequence rating x likelihood rating

where:

- consequence is based on severity of harm or damage that can occur
- likelihood rating is based on the chance of exposure and the proportion of time exposed to the hazard
- the likelihood rating is based on both level of exposure to a hazard and the frequency and duration of exposure.

Thus,

Risk rating = consequence x probability of exposure x period of exposure

The values allocated to the various elements are based on some form of grading system illustrated in Table 5.

The numerically calculated risk rating is then assessed against a tabulated risk classification and the appropriate action is undertaken (see Table 6).

It should be noted that the values provided by the equation could potentially lead to a large number of issues being identified as 'intolerable', which could hamper efforts to prioritise the key risks to control.

Table 5: Example risk factor values for use in a quantitative approach

Risk factor		Value
Probability of exceeding OEL	Continuously exceeding	10
	Intermittently	6
	Unusual, but possible	3
	Only remotely possible (has happened somewhere)	1
	Conceivable, but very unlikely	0.5
Period exposed	Continuous for 8-hour shift	10
	Continuous for between 2 and 4 hours per shift	6
	Continuous for between 1 and 2 hours per shift	3
	Short periods of time (a few times per month)	2
	Unusual (a few times per year)	1
	Rare (once per year)	0.5
Consequence	One or more fatalities	100
	Major disability	50
	Serious illness – absent for longer than 14 days	15
	Major illness – absent for longer than 7 days but less than 14 days	7
	Minor illness – absent for 7 days or less	1

Table 6: Example appropriate actions as per calculated risk

Calculated risk	Risk classification	Action
400 and above	Intolerable risk (MUE)	Consider discontinuation
200–399	Very high risk (MUE)	Immediate action required
70–199	High risk	Correction required
20–69	Potential risk	Attention necessary
Under 20	Tolerable risk	Monitor

Semi-quantitative

As previously stated, the most common way companies undertake risk rating is to use a two-dimensional matrix with either three or five levels of consequence and likelihood.

Table 7 provides an example matrix, adapted from an ICMM company member, to illustrate how a risk rating can be derived.

3

Table 7: Semi-quantitative 5 x 5 risk matrix

Risk matrix		Consequence <small>(where an event has more than one 'consequence type', choose the consequence type with the highest rating)</small>				
Consequence type		1 – Insignificant	2 – Minor	3 – Moderate	4 – High	5 – Major
		Exposure to health hazard resulting in temporary discomfort	Exposure to health hazard resulting in symptoms requiring medical intervention and full recovery (no lost time)	Exposure to health hazards/agents (over the OEL) resulting in reversible impact on health (with lost time) or permanent change with no disability or loss of quality of life	Exposure to health hazards/agents (significantly over the OEL) resulting in irreversible impact on health with loss of quality of life or single fatality	Exposure to health hazards/agents (significantly over the OEL) resulting in irreversible impact on health with loss of quality of life of a numerous group/population or multiple fatalities
Likelihood		Risk rating				
5 – almost certain 1 year	The unwanted event has occurred frequently, occurs in order of one or more times per year and is likely to reoccur within 1 year	11 (Medium)	16 (Significant)	20 (Significant)	23 (High)	25 (High)
4 – likely 3 years	The unwanted event has occurred infrequently, occurs in order of less than once per year and is likely to reoccur within 3 years	7 (Medium)	12 (Medium)	17 (Significant)	21 (High)	24 (High)
3 – possible 10 years	The unwanted event has happened at some time or could happen within 10 years	4 (Low)	8 (Medium)	13 (Significant)	18 (Significant)	22 (High)
2 – unlikely 30 years	The unwanted event has happened at some time or could happen within 30 years	2 (Low)	5 (Low)	9 (Medium)	14 (Significant)	19 (Significant)
1 – rare >30 years	The unwanted event has never been known to occur or it is highly unlikely that it will occur within 30 years	1 (Low)	3 (Low)	6 (Medium)	10 (Medium)	15 (Significant)

Assessment continued

3.3

Deciding health risk acceptability

The control of occupational health hazards is guided by occupational exposure limits and standards, each of which represents a concentration of a particular stressor in the workplace exposure that, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers. If the standard is exceeded, then the risk is deemed to be unacceptable.

Exposure limits can be provided in one of three categories:

- time-weighted average (TWA)
- occupational exposure limit – short term exposure limit (OEL-STEL)
- occupational exposure limit – ceiling limit (OEL-C)

Occupational exposure limits are guidelines to be used in the control of occupational hazards by professional occupational hygienists. They should not be regarded as accurate levels dividing safe from dangerous concentrations or levels of health stressors. They are not a measure of relative risk and should not be applied in the control of community air pollution. They are largely based on the concept of threshold intoxication, but not all chemicals and physical agents are based on toxicity.

The majority of exposure standards for airborne contaminants are expressed as a TWA concentration over an entire eight-hour working shift and a 40 hour working week. During the averaging period, excursions above the TWA standard are allowed, provided these excursions are balanced by equivalent excursions below the standard during the shift. Because some substances can give rise to acute health effects even after brief exposure to high concentrations, it is prudent that excursions above TWA concentration are restricted.

Short-term exposure limits (OEL-STELs) are useful exposure standards to complement TWA exposure standards. OEL-STELs provide guidelines for the control of short-term exposures as opposed to the total intake over relative long periods of time. Application of OEL-STELs generally minimise the risk of:

- intolerable irritation
- chronic or irreversible tissue change
- narcosis to an extent that could cause or initiate industrial accidents.

OEL-STELs are expressed as airborne concentrations of substances, averaged over a period of 15 minutes. Concentrations greater than the OEL but below the OEL-STEL should not exceed 15 minutes in duration and should not occur greater than 4 times per day. A minimum of 60 minutes should elapse between successive exposures at OEL-STEL concentration. The TWA over the course of a day must still be respected.

OEL-C is the concentration that should not be exceeded during any part of the working exposure. For some rapidly acting substances and irritants, the TWA concentration is inappropriate as acute effects can be induced after relative brief exposures.

Therefore, exposure standards for these substances represent a maximum exposure to which workers may be exposed. It is recognised that there are analytical limitations to measurement of 'peak limitation' exposure standards but a single determination should not exceed 15 minutes.

Some substances cause acute effects upon brief exposure, even though the major toxic effects may be due to long-term exposure through accumulation of substance in the body or gradual health impairment with repeated exposures. Exposures should be controlled to avoid both acute and chronic health effects.

It should be understood that exposure standards are not finite values dividing safe and unsafe exposures and should be regarded as target concentrations. They are really guides for use in the control of potential health problems, and thus the true target should be zero. The ultimate aim is to eliminate or control exposure to all occupational health stressors likely to adversely affect health. The application to situations outside the norm, such as 12-hour shifts, for which they were not designed, could lead to illness, disability or death.

3.4

Identifying and managing effective controls

What is a control?

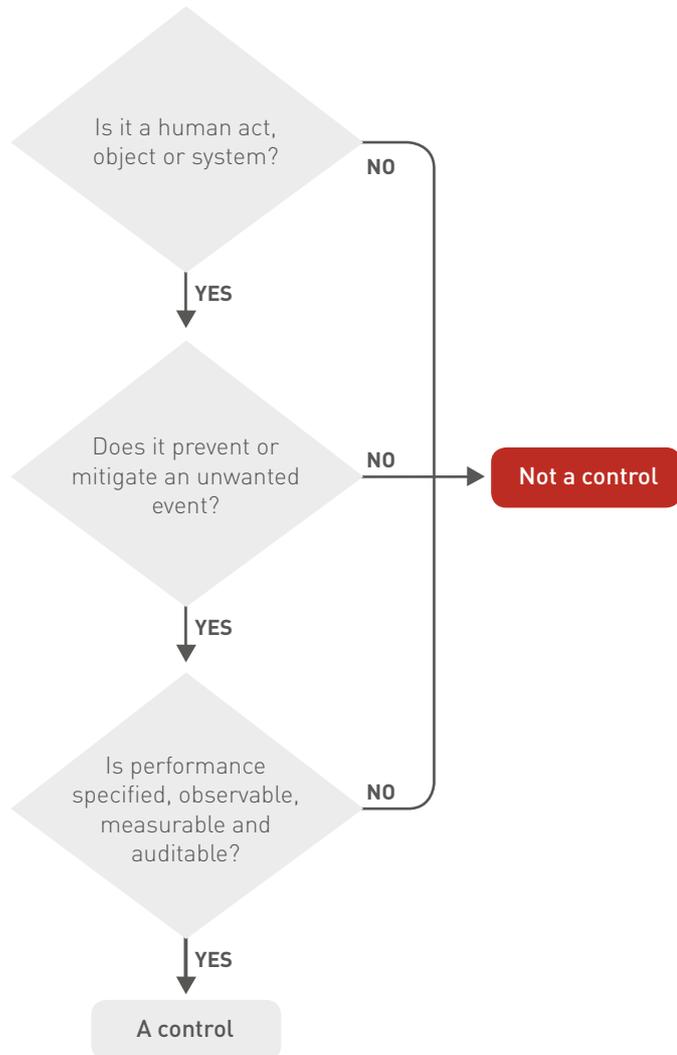
Once the exposures have been estimated by hazard, by SEG and by Control measures are the acts, objects or technological systems that help to eliminate or reduce the levels of hazardous exposure.

A control either prevents the release of the hazard or mitigates the consequences of its release. There are three 'zones' where control measures can be applied:

- at the source of the stressor
- along the transmission path
- at the worker.

This is graphically illustrated in Figure 5, which is taken from ICMM's *Health and safety critical control management: good practice guide* (2015).

Figure 5: Control identification decision tree



Source: adapted from Hassall, M, Joy, J, Doran, C and Punch, M (2015). *Selection and optimisation of risk controls*. ACARP report no C23007. Available at www.acarp.com.au/reports.aspx (accessed 31 October 2016).

‘It should be understood that exposure standards are not finite values dividing safe and unsafe exposures and should be regarded as target concentrations.’

Assessment continued

Hierarchy of control

There are several levels of control measures that can be put in place to deal with adverse exposures. These are generally termed the hierarchy of control. In order of reliability, effectiveness and likelihood of reducing exposures they are:

- elimination
- substitution
- source or process modification
- automation
- engineering (including isolation/containment/enclosure)
- administration (including education and training)
- personal protective equipment.

Ideally, all hazards would be eliminated from the workplace, but in practice, most controls fall into the engineering category and below, since elimination and substitution, by their nature, fundamentally alter the risk. A mixture of 'lower level' controls in the hierarchy of control will be applied. For example, while education and training approaches alone are unlikely to achieve adequate control, they are usually an essential element in ensuring that other measures are applied and used correctly. The hierarchy of control can be applied to all health hazards, and one or more control measures from the different levels usually need to be put in place (ie multilevel controls). However, not all the levels of control are applicable to every potential health hazard. An iterative process of reviewing hazards and controls should be implemented to ensure that a continuous drive 'up' the hierarchy of control is embedded in the operational culture.

Though personal protective equipment should only be used as a last resort, it can be a valuable addition to any hazard control programme and, in some instances, may be the only effective option. When it is used, it should be associated with a well-planned programme of training, routine maintenance and replacement.

The following are examples of how the hierarchy of control might work in a specific instance.

Elimination

Remove a major emission source of particulates and various gases by replacing diesel-powered equipment with electrically powered equipment. This completely prevents the release of the hazard since the hazard no longer exists.

Substitution

Electrically powered tools such as rock drills can emit lower levels of noise and vibration than pneumatically powered ones. Automation options could also be considered under substitution controls.

Engineering (including isolation)

Engineering controls fall into two categories: those that prevent release of the hazard and those that reduce exposure. Prevention of release acts on the source of the hazard whereas reduction of exposure acts on the hazard itself. For example, prevention of dust creation acts on the source whereas wetting of dust acts on the dust. In some areas such as ore processing plants, enclosures around screens and other noisy equipment can reduce noise levels in the remainder of the plant. Vibration-reducing mountings and damping can reduce both vibration and noise levels. The cabin design on

mobile equipment plays a large role in improving operator comfort, reducing exposure to noise, dust, muscular stresses and extreme temperatures and reducing fatigue. Work refuge stations or cabins can be used in a variety of locations to isolate workers from hazards such as dust, noise, chemicals and heat.

Administration (including training and education)

Making changes to work procedures, for example restricting when work is carried out or the number of hours worked, more frequent rotation of tasks and work permits to allow workers into designated areas, can reduce exposure to hazards. Education and training to understand hazards and the measures taken to combat them are also important, especially where health hazards are linked to the proper use of equipment or a particular task, for example manual handling.

Personal protective equipment

The use of personal protective equipment, for example hearing protection devices, face masks, body suits, etc, can also protect workers from noise, dust and chemical exposures. However, this can never be regarded as an effective control as its effectiveness is very dependent on the user.

3

Key questions to consider when assessing control measures

Existing control measures can be either assessed directly on their ability to eliminate or reduce the levels of exposure through the measurement of exposures with and without control measures, or they can be inferred indirectly from existing information, for example previous exposure measurements, the walk-through survey and any available health records.

- What are the current standards used to determine the level and nature of the control measures?
- Are there existing control measures for processes, tasks and areas with high levels of exposure to hazards? Have these control measures been set up, operated and maintained appropriately?
- Are there high levels of exposure despite the control measures in place functioning effectively?
- Are working practices and the use of control measures different from that prescribed by workplace protocols and guidance?
- Are control measures part of an ongoing maintenance programme?
- Is there a regular assessment of the effectiveness of controls?

Rating control measures

Control measures can be rated in a similar way to exposures with a scale that classifies the level of inadequacy of the control measures currently in place and the potential need for action to remedy this.

Managing the effectiveness of controls

No matter how good the controls applied to solve a particular problem, they can only be effective if they are used, and used properly. They also need to be properly maintained and managed effectively.

There are many examples where expensive control measures are installed only for them to remain unused, used infrequently, used incorrectly or poorly maintained, thereby rendering them ineffective. Management measures therefore need to be put into place to ensure that the controls continue to work effectively. Such measures are likely to include:

- Supervision to ensure that the procedures are followed.
- Maintenance to ensure that engineering controls continue to operate effectively.
- Testing of controls which should apply to organisational measures as well as engineering controls. In the case of engineering controls, such as local exhaust ventilation, this will require regular visual checks and a thorough examination and testing at least annually.
- Air monitoring and health surveillance, which are, effectively, additional checks on the effectiveness of controls.
- Information, instruction and training to ensure workers know why the controls are needed, how to use them correctly, procedures for reporting faults, etc. For example, workers should be trained in the hazards of the materials, the procedures and control measures necessary and how to use them effectively. In the case of respiratory protective equipment, for example, this will include careful selection of

the equipment to provide appropriate protection and to suit the individual's facial characteristics. It will also include fit checking and quantitative fit testing to ensure appropriate protection as well as information, instruction and training on the wearing, cleaning and maintenance.

- Emergency procedures for dealing with leaks, spills, failure of controls, etc.
- Good housekeeping practices, to minimise accumulation of contaminants.

Finally, the effectiveness of the control strategy as a whole should be checked by periodic reassessment and exposure monitoring if appropriate – closing the loop on the management cycle.

‘No matter how good the controls applied to solve a particular problem, they can only be effective if they are used, and used properly.’

Assessment continued

3.5 The bow-tie analysis – putting it all together

Introduction

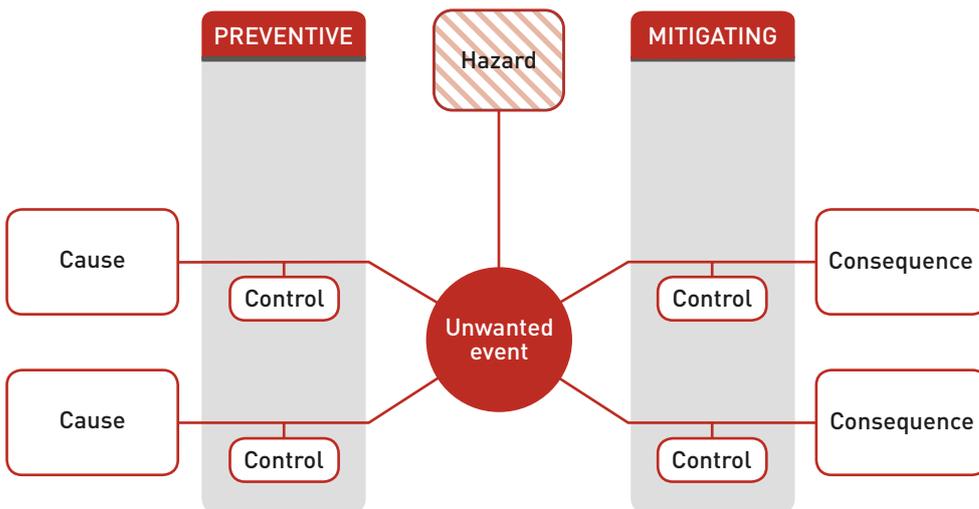
The bow-tie analysis is a method for identifying and reviewing controls intended to prevent or mitigate a specific unwanted event. It combines fault tree analysis with event tree analysis in one easy-to-use diagram. The name bow tie comes from the shape of the diagram, which arranges the hazards to the left of an unwanted event and the consequences of that event on the right with the unwanted event becoming the knot of the tie. There are numerous references to the use of the bow-tie method in health and safety but these almost all only deal with safety-related outcomes.

The bow tie is a useful way of organising controls, the threats to them and the consequences of failure in a graphical format that shows which controls are preventive and which are used for mitigation of the consequence. The process of formulating a bow tie also helps to identify the pivot point at which prevention is most effective, and this becomes the MUE (usually release of the hazard rather than an outcome of release).

Bow ties are useful especially in aiding the development of a critical control regime for an MUE. Below is a brief description on how to conduct a bow-tie analysis. However, additional guidance can be found in ICMM’s *Health and safety critical control management: good practice guide* (2015).

‘The process of formulating a bow tie also helps to identify the pivot point at which prevention is most effective’

Figure 6: Bow-tie diagram indicating preventive and mitigating controls



3

How to conduct the bow-tie analysis

1. Identify the hazard, the sources and its consequences (this comes from the baseline and issues-based HRA), for example silica dust and pneumoconiosis. The hazard sits on the far left of the diagram and the consequences on the far right.
2. Decide on the MUE, for example release of the hazard/critical control failure. This is at the centre of the diagram and is the point at the end of the fault tree and beginning of the event tree. All controls beyond this point are mitigation or recovery from the event.
3. Assess the threats. The threats are factors on the left of the MUE that potentially result in the event (release of the hazard), for example crushing process and transfer points on a conveyor (those factors that result in generation of dust).
4. Identify the controls. Controls are measures that are put in place to manage a threat. Controls can be found on both sides of the MUE with those on the left being preventive and those on the right being recovery or mitigation, that is they reduce or limit the severity of the consequences.
5. Identify the critical controls. In HRA a critical control can be defined as a control that prevents significant release of the hazard.
6. Identify threats to the controls. These are conditions that lead to failure of the controls. These may be mechanical, abnormal operating conditions, behavioural (switching off or overriding), operating outside design parameters, etc.
7. Identify the controls for the threats to the controls. The principle is one of building multiple layers of control and redundancy in the system.
8. Identify the indicators for failure of the controls. These may be regarded as incidents for the purposes of investigation and can vary from direct measurements of the hazardous agent and health effects seen at medical surveillance to proxies such as pipeline pressures and voltage draw on motors.

Creating the bow tie is an iterative process that may involve changing the MUE as the process unfolds. Controls initially thought to be preventive may actually be recovery (mitigation) as understanding of the management process develops.

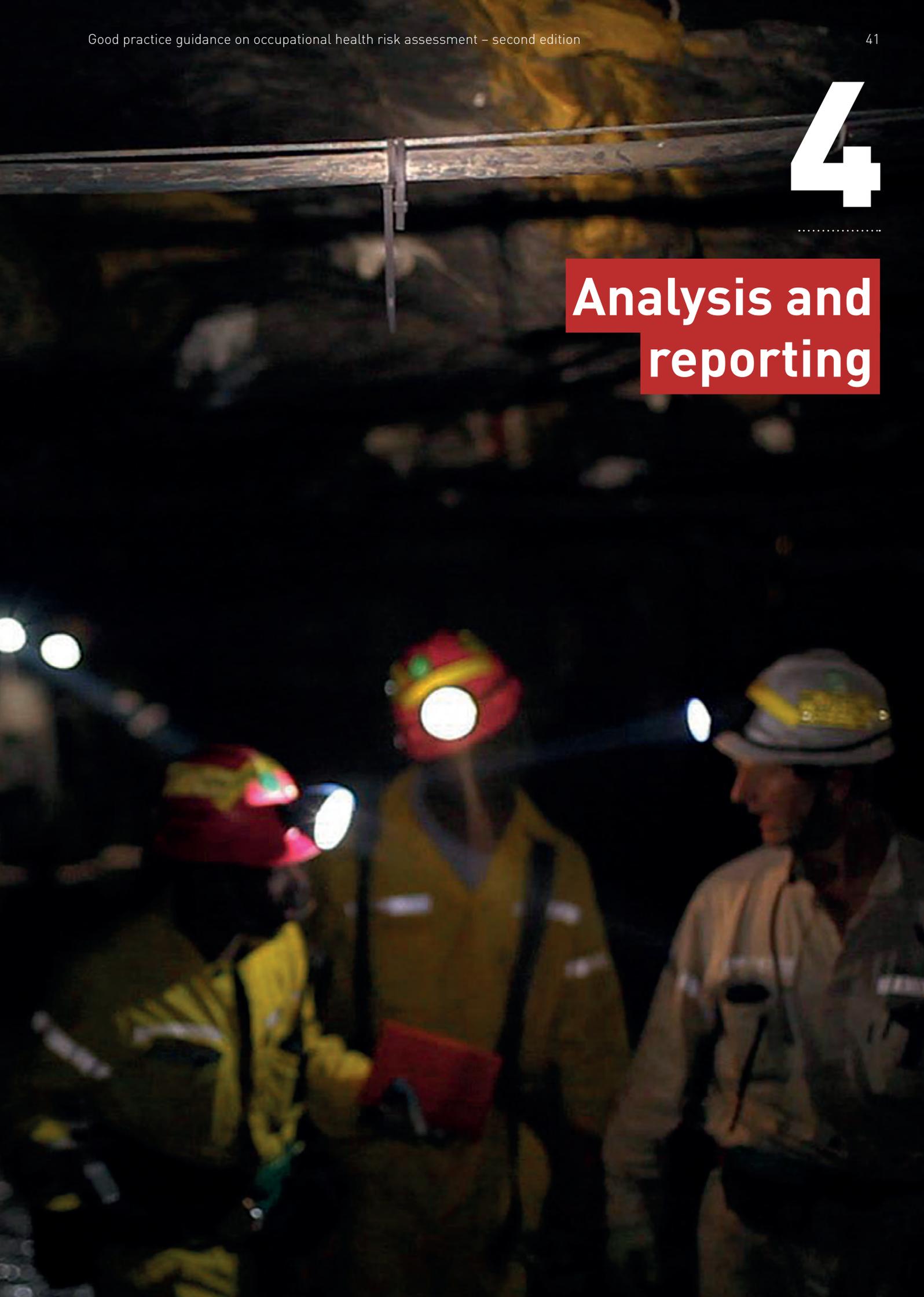
‘The bow tie is a useful way of organising controls, the threats to them and the consequences of failure in a graphical format that shows which controls are preventive and which are used for mitigation of the consequence.’



You are entering a workplace where noise levels exceed 85 dB(A). Exposure to noise levels equal to or above 85 dB(A) could result in noise induced hearing loss. This area is a demarcated noise zone. You may not enter this area without wearing hearing protection devices.

4

Analysis and reporting



Analysis and reporting

4.1

Documenting and communicating HRA

Introduction

Maintaining systematic and accurate records of the HRA and the priorities for action – as well as communicating the findings – are vital for ensuring that progress is made in reducing exposures and developing a zero harm culture in the workplace. Maintaining an auditable trail of information also facilitates future evaluations and assessments of the workplace risks to health.

Maintaining systematic and accurate HRA records

A written record of an HRA should be kept in a format that is decided on by the organisation based on legal requirements, especially when significant risks have been identified. The record serves as a point of reference to indicate the information and criteria used in the decision-making process. Regardless of the outcome of the assessment, reliable information should be available to defend judgments. These records should:

- contain sufficient information to ensure an audit trail on how the HRA was undertaken, the rationale for the approach used and how conclusions were arrived at
- include the findings of any exposure monitoring and health surveillance
- include the findings and action taken regarding the reporting and investigation of incidents
- meet legal and organisational requirements
- be readily retrievable when needed, for example for internal/external audits, review by local or national authorities or periodic internal review

- be kept for at least 30 years or as long as required by national laws as these records will enable the evaluation of individual health effects and the accurate assessment of future insurance or liability claims for chronic health risks.

Communicating the HRA

The findings of the HRA should be communicated to all staff as part of a hazard and risk communication programme so that the risks, uncertainties and the need for further measures, including additional resources, are understood and agreed. This could be through email, company intranet, company newsletter, bulletin on a notice board and worker health and safety meetings.

It is also imperative that training materials are updated when there is new information from an HRA. When new control measures are identified, they should become part of the existing monitoring programme.

‘The findings of the HRA should be communicated to all staff as part of a hazard and risk communication programme so that the risks, uncertainties and the need for further measures, including additional resources, are understood and agreed.’

4

4.2

Review and quality assurance of the HRA

Introduction

It is important to quality assure and progressively improve the quality of the HRA process and the documentation of the HRA process over time. This can be done at the level of the individual HRA as well as a business unit and organisational level through the health management system.

Review of HRAs

Individual HRAs should be fully reviewed and revised every three to five years at a minimum. Where, for instance, the UK Health and Safety Executive (HSE) annual reports are published, these require updates on the progress of HSE and HRA action plans. Any significant change that may have an impact on health risks, including changes in the work processes and activities or in the understanding of specific hazards and risks, should trigger a review of the HRA. Subsequently, there should be a review of any new control measures put in place.

Quality assurance of HRAs

Individual HRAs should be fully Within their quality assurance plans, companies and business units should have procedures in place to ensure that the requirements of current best practice in relation to assessing health risks are being met. The HRA process and individual HRAs should be regularly audited and appraised through a process of internal and independent external auditing. The scope of such an audit could include:

- the management system for conducting and implementing HRAs
- the resources available to carry out and implement HRAs
- the quantity and quality of HRA records
- remedial actions taken following HRAs
- the effectiveness and maintenance of controls
- learning from incidents
- areas of non-compliance with occupational exposure limits
- the documentation of work and health histories
- evaluation of the quality of the HRA by experienced and independent occupational health and hygiene professionals.

The ICMM Sustainable Development Framework requires third party assurance in a number of areas, and a specific procedure has been established to assist ICMM company members in meeting their commitments. It is recommended that any external assurance for HRAs should be developed with consideration of the overall corporate assurance procedure.

‘Any significant change that may have an impact on health risks, including changes in the work processes and activities or in the understanding of specific hazards and risks, should trigger a review of the HRA’

Analysis and reporting continued

4.3

Links between HRA and health impact assessment

Introduction

When carrying out an initial assessment of health-related risks at a site associated with a new project or a major modification, prior to closure of an existing project or prior to mine or operation closure, it is important to consider the health impacts on the local community and wider society. An assessment that assesses these types of risks or impacts is referred to as a health impact assessment (HIA). This is a separate assessment to an HRA though there can often be important overlaps in the health risks faced by workers of a mining or metals operation and surrounding communities. Occupational HRAs assess the potential health risks or impacts 'within the fence' of a mining and metals operation. HIAs assess the potential health risks or impacts 'outside the fence' that are linked to the operation.

Please also see the companion ICMM report *Good practice guidance on health impact assessment* (2010).

Definition of HIA

The Gothenburg definition of HIA is 'a combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population'.¹⁰

HIA is the systematic analysis of the differential health and well-being impacts of proposed plans, programmes and projects so that positive health impacts are maximised and negative health impacts minimised within an affected community. It works within an explicit value framework that promotes an assessment process that maximises the health of a population and is democratic, equitable, sustainable and ethical in its use of evidence.

HIA is, therefore, about health protection, health improvement and health equity/inequality.

When are HIAs conducted?

HIAs are generally conducted where a project or operation has the potential to impact on the health of the local communities living nearby and before the project or operation is started. This can be a separate assessment but is now more usually undertaken as part of an integrated environmental, social and health impact assessment.

The potential impacts on human health of industrial development are numerous and cut across many specialist concerns. Most industrial development projects are expected to have an indirect beneficial effect on health by increasing the resources available for food, education, employment, water supplies, sanitation and health services.

Sometimes the indirect impacts include unexpected negative effects on health, although many of these can be avoided by careful planning. Adverse health impacts are most likely to affect the most vulnerable social groups, and this may serve to amplify the overall adverse effects. Such impacts can reduce the social and economic benefits expected from industrial development.

Experience shows that the environmental and social impact assessment (ESIA) often does not pay due attention to the health component. HIA offers an opportunity to identify health hazards in advance, and to coordinate with ESIA activities. The analysis of community health risks provides an opportunity both to implement risk controls and to incorporate health-promoting measures.

10. The Gothenburg consensus paper on health impact assessment (1999) was the product of a joint effort between the World Health Organization Regional Office for Europe and the European Centre for Health Policy and has been adopted worldwide (WHO European Centre for Health Policy (1999). 'Health impact assessment: main concepts and suggested approach', Gothenburg consensus paper, December 1999. Brussels: WHO Regional Office for Europe. Available at www.apho.org.uk/resource/item.aspx?RID=44163 [accessed 31 October 2016]).

4

HIA methodology

HIA follows a similar methodology to ESIA. The HIA process is generally made up of eight overlapping stages:

- screening
- scoping
- baseline and community profiling, evidence gathering
- stakeholder involvement
- analysis of impacts
- developing mitigation and enhancement measures and/or making recommendations
- writing the HIA statement and presenting to decision-makers
- follow-up (monitoring of the health impacts and evaluation of the HIA process).

Though the steps above are presented as linear, HIA tends to be an iterative process where findings and issues that emerge in later steps mean that earlier steps are revisited and the scope and analysis amended accordingly.

Benefits of the HIA

Just as HRA demonstrates the value and care an organisation has for its workers, so HIA demonstrates an organisation's care and concern for the welfare of the local communities. HIA can help to structure the thinking about how best to support, alongside local and national governments, the health and well-being of local people.

'HIA is the systematic analysis of the differential health and well-being impacts of proposed plans, programmes and projects so that positive health impacts are maximised and negative health impacts minimised within an affected community.'

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Abbreviations

ALARP	as low as reasonably practicable
BTA	bow-tie analysis
ESIA	environmental and social impact assessment
HIA	health impact assessment
HRM	health risk management
HRA	health risk assessment
HSE	Health and Safety Executive
ICMM	International Council on Mining and Metals
MFL	maximum foreseeable loss
MUE	material unwanted event
OEL	occupational exposure limit
SEG	similar exposure group
STEL	short-term exposure limit
TWA	time-weighted average

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