Health Exposure Assessment: A ‘step change’ in occupational hygiene management.

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ABSTRACT
In the latter part of 2006 BHP Billiton Mitsubishi Alliance (BMA) developed a Hygiene Management Plan for its Central Queensland coal mining operations. The foundation of the BMA Hygiene Management Plan was a health exposure assessment process which used qualitative and quantitative risk assessment methodologies. The process involved conducting walk-through occupational hygiene surveys, grouping workers with similar potential exposures, devising and conducting exposure sampling programs and statistically analysing the exposure data. The end result of the health exposure assessment was an understanding of the potential exposure risks faced by workers when performing various jobs and tasks. This information was then used to develop the BMA Hygiene Management Plan. Using the management plan, BMA sites are now in the process of mapping the controls currently used to manage hygiene risks. Ultimately these Hygiene Risk Control Plans will be used by BMA operations to identify areas for improvement and provide BMA with a ‘step change’ in occupational hygiene management.

INTRODUCTION
In 2002 BHP Billiton introduced the HSEC Guideline for Health Exposure Assessment. The antecedent to this document was work conducted by the BHP Billiton Iron Ore Occupational Hygiene Technical Committee (OHTC), in 2001, under the mentorship of Dr Brian Davies. At the time, the OHTC came to the conclusion that after 30 years of hygiene monitoring activities, at both the mining and port operations, there was little data that could be salvaged from previous work that could be used to create a legally robust, statistical depiction of occupational exposures for the various iron ore businesses. The reasons for this were threefold. Firstly, the data had been collected by assessing individual exposures and most often in a reactive fashion meaning that most sampling was done as the result of a complaint about noise or dust conditions. This meant that meaningful statistical analysis was next to impossible. Secondly, the data that had been collected was incomplete. Over the decades it had been lost either because it was paper based and had been discarded or it had resided on an individual’s computer hard drive usually in a spreadsheet (or a simple database - if the hygienist was computer literate) and had been deleted when the person had left the business. Thirdly, each new occupational hygienist in the business had attempted to ‘re-create the wheel’ by commencing a new hygiene monitoring campaign.

The OHTC decided that the way forward was to document a process to ensure that:
1. potential occupational hygiene exposures were identified and assessed in a systematic way;
2. any new data collected could be validated and added to previously collected data; and
3. new hygienists coming into the business would understand and be able to follow the work done by previous incumbents.

The result of the work by the OHTC and Brian Davies culminated in the BHP Billiton Health Exposure Assessment Guideline.

On review, the experiences in BMA are almost identical to that of BHP Billiton's iron ore businesses. Sampling programmes conducted prior to the health exposure assessments in 2004 had been ad hoc and was usually driven by legitimate worker complaints about noise or dusty conditions. The data generated by these activities was reviewed and determined to be incomplete or biased and generally meant that statistically valid assertions about exposures was impossible.

The following paper discusses the improvements made to hygiene exposure assessment and management in BMA over the last 5 years.

HEALTH EXPOSURE ASSESSMENT PROCESS

The purpose of the BHP Billiton Health Exposure Assessment Guideline is to outline the approach to health exposure assessment as the foundation of preventative and protective health practice for its businesses [1].

The process relies on a competent occupational hygienist to conduct walk-through occupational hygiene surveys, group workers with similar potential exposures, devise and conduct exposure sampling programs and then to statistically analyse the exposure data.

Essentially the hygienist is required to conduct and evaluate two types of exposure assessment:

- Qualitative Assessment - which is the basic characterisation of exposure based on interview, observation and simple measurement; and
- Quantitative Assessment - which is conducted in accordance with recognised exposure monitoring strategies.

Regardless of the type of assessment conducted, the hygienist must analyse the data obtained and produce a scientifically sound report and provide guidance, clearly indicating any requirements for further exposure assessment and interim risk mitigating measures [1].

Both types of exposure assessment processes are discussed in greater detail in the following sections.

QUALITATIVE ASSESSMENT

The first part of the health exposure assessment process is to conduct an initial assessment of occupational hygiene risks at a site (Figure 1). This broad survey should be conducted by a competent occupational hygienist.

The purpose of the survey should be to:

1. establish the types of chemical, physical and biological hazards that are, or are likely to be present at the site,
2. establish which persons or groups of persons are potentially exposed to the hazards; and
3. produce qualitative risk assessments that estimate the extent of exposure [1].

The type of information that needs to be collected and considered during the initial survey includes:

- the nature of the hazard and route of entry into the body;
- whether the hazard produces acute or chronic health effects;
- whether exposure is continuous, intermittent or seasonal;
- the numbers of persons engaged in tasks where there is potential exposure;
- the nature of tasks and variations in procedures between individuals or groups; and
- shiftwork patterns [1].

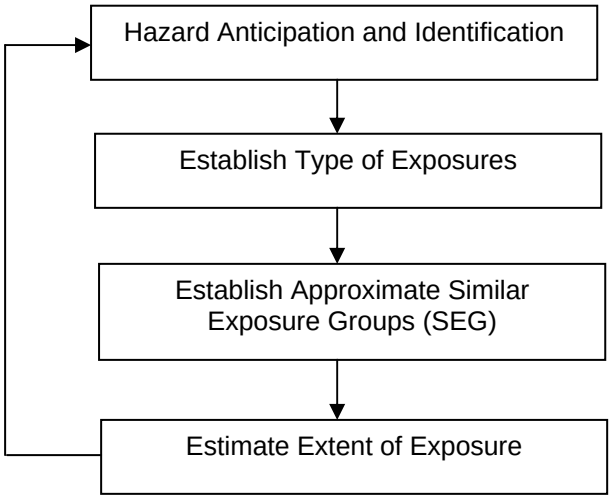

Figure 1 - Qualitative Occupational Hygiene Assessment Process

If at the conclusion of the initial survey, risks cannot be eliminated immediately an occupational hygiene monitoring programme will need to be implemented [1].

To comply with the BHP Billiton Health Exposure Assessment Guideline BMA conducted its first walk-through qualitative surveys towards the end of 2002 and early 2003. BMA has planned to conduct reviews of the initial site surveys every 5 years. An example of the Qualitative Occupational Hygiene Assessment form recommended by BHP Billiton is attached in Appendix 1.

QUANTITATIVE ASSESSMENT

The second part of health exposure assessment process is to quantitatively assess exposures and to commence the processes to investigate, control and review exposures. Again, this part of the process should be conducted by a competent occupational hygienist. A Flowchart of the process is outlined in Figure 2.

Essentially the quantitative assessment is a statistical sampling strategy conducted to determine exposures for comparison with the BHP Billiton Occupational Exposure Limits (OEL) and to provide statistical confidence that the likelihood of known health effects occurring is acceptable from both a regulatory compliance and epidemiological perspective [1].

Baseline Exposure Sampling

The information collected during the qualitative survey can be used to define Similar Exposure Groups (SEGs). A SEG is a group of workers, generally performing the same task for the same period of time, such that exposure measured on any one person within the group will be representative of the exposure of the whole group [1]. The term Homogeneous Exposure Group is also frequently used and is interchangeable with SEG. Once the SEGs are defined a statistical sampling strategy can be developed so the exposure estimates can be quantified.

The number of samples needed to be taken for each SEG is dependent on the population of the group. The BHP Billiton guideline uses samples sizes recommended by the American Industrial Hygiene Association (AIHA) [1]. The AIHA strategy is to determine that at least one

worker from an exposure group will be in the top 10% of exposures, to a confidence limit of 95 percent [1].

The information that must be collected, considered and recorded during this process includes:

- the information collected during the initial qualitative survey;
- the reason the survey is being conducted;
- the time period for the survey;
- the rationale for sampling the SEGs;
- the measurement methods to be used ;
- the accuracy of the sampling and analysis methods; and
- the acceptable confidence limits for predicting the exposure of the workforce [1].

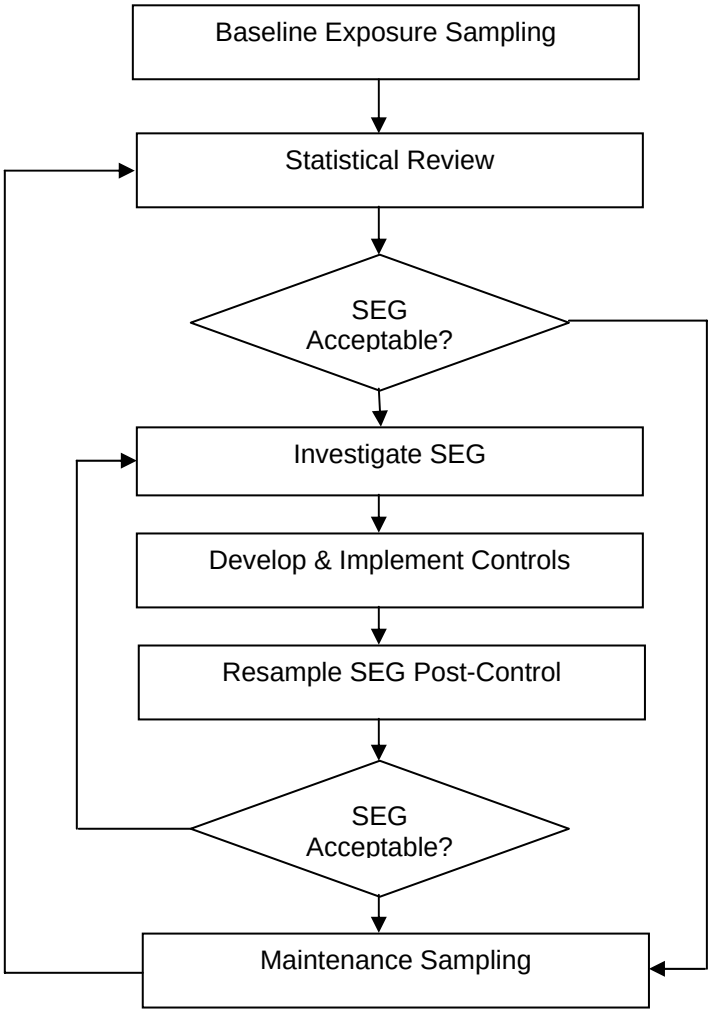

Figure 2 – Quantitative Occupational Hygiene Assessment Process [1]

Statistical Review

In order to assess whether an exposure estimate complies with BHP Billiton Occupational Exposure Limits, statistical techniques must be applied along with some professional judgement. Exposure data is generally lognormally distributed although some data such as noise exposure measurements may be normally distributed [1].

When assessing the tolerability of exposure the statistical techniques used must be consistent with the distribution of the sampling data [1]. BHP Billiton has a corporate licence to use a statistical software package called LogNorm2 ® which was specifically developed for use by occupational hygienists by the Intech Software Corporation. This software statistically assesses the 'best fit' distribution for the data and calculates the appropriate statistics.

For data which is lognormally distributed the 'best estimate' of mean exposure is the Minimum Variance Unbiased Estimate (MVUE) together with the Land's Exact 95% Upper Confidence Limit (UCL) [1]. For normally distributed data the arithmetic mean and 95% UCL are used [1]. Land's Exact 95% UCL indicates the probable range of the mean exposure of that population of workers. However, there remains a 2.5% probability that the mean exposure will be higher [1].

For hazards with chronic effects BHP Billiton considers exposures acceptable where:

- for lognormally distributed data, the Land's Exact 95% UCL is less than 50 percent of the OEL; or
- for normally distributed data, the 95% UCL is less than 50 percent of the OEL [1].

Exposure is considered unacceptable where:

- for lognormally distributed data, Land's Exact 95% UCL is greater than the OEL; or
- for normally distributed data, the 95% UCL is greater than the OEL [1].

BHP Billiton requires that exposure to all hazards must be reduced to As Low As Reasonably Practicable (ALARP). Because BHP Billiton's goal is Zero Harm, even where exposures are considered to acceptable using the companies own risk assessment criteria the ALARP principle is still required to be applied. The ALARP principle applies where:

- for lognormally distributed data, Land's Exact 95% UCL is greater than 50% of the OEL and less than the OEL; or
- for normally distributed data, the 95% UCL is greater than 50% of the OEL and less than the OEL [1].

Investigation of Unacceptable Exposures

Where a SEG indicates that exposures are unacceptable an investigation is required to determine the root causes of exposure and to assist with corrective action and control. The process includes:

1. Reviewing the data for outliers that may be causing statistical bias
2. Assessing the data distribution to determine if SEG definition is correct
3. Reviewing the worksheets and other relevant workplace information to determine if conditions were unusual at the time of sampling
4. Observing tasks performed by SEG members
5. Measuring specific contaminant sources
6. Implement control measures based on investigation outcomes
7. Resample and statistically analyse the SEG data to assess control effectiveness [1].

Maintenance Sampling

The monitoring of workplace hygiene risks should not become the primary focus of a programme. The emphasis of any hygiene sampling programme should be to reduce exposures to ALARP. Re-assessing the quantitative assessment should be based on risk, the nature of the risk and the health effects of over-exposure coupled with the need to maintain an up-to-date knowledge of exposures. A hygienist should be used to determine the need and frequency of any further sampling.

Cases where frequent re-assessment is not justified include:

- SEGs where the mean exposure is greater than the OEL, unless changes have been made to reduce exposures;
- SEGs where the mean estimate of exposure is less than 25% of the OEL; or
- SEGs where the mean estimate of exposure is greater than 50% of the OEL but a comprehensive PPE program is in place to manage exposure [1].

In the cases mentioned above annual re-assessment maybe sufficient to maintain the integrity and validity of the sampling data set [1].

David Grantham also provides practical guidance on how to determine the number of repeat samples based on the ratio of measured exposure to the exposure standard. Where the ratio is greater than 1 – one sample per month is recommended. If the ratio is between 0.1 - 0.5 - only one sample per year is recommended [2].

BMA HYGIENE MANAGEMENT PLAN

The BMA Hygiene Management Plan was identified as a business need at a workshop to review site occupational hygiene practices in May 2006.

The high turn-over of health and safety professionals at the time and a lack of occupational hygiene expertise at sites necessitated the development of a document to identify both strategic and site-based approaches to managing occupational hygiene risks. After consultation with site health and safety professionals, the management plan was released for use in July 2006.

The management plan documented the occupational hygiene hazards identified by the qualitative risk assessment process. The following generic information was provided for each hazard:

- Hazard Overview
- Hazards Source
- Exposure Limit
- Health Consequences
- Risk Assessment
- Management Obligations
- Strategic Approach
- Site Approach
- Control Methods
- Other Resources [3]

Appendix B provides an example of the type of information contained within the management plan.

The management plan remains dynamic so information regarding hygiene risks is able to be updated on a regular basis to reflect changes to legislation, exposure limits, new control technologies or the research literature.

SITE HYGIENE RISK CONTROL PLANS

Because the BMA management plan contains generic information, each site is required to use the information contained within the plan and from the site health exposure assessment data to develop a Hygiene Risk Control Plan [1]. BMA sites are now at various stages of mapping the controls currently used to manage site-specific hygiene risks. Sites as a minimum are required to document hygiene exposures considered to be moderate to high

risks by qualitative assessment and between 50 percent and 100 percent of the OEL or greater than 100 percent of the OEL by quantitative assessment.

The Site Hygiene Risk Control Plan documents information about the:

- Hazard
- Source of Exposure
- Affected SEGs
- Control Description
- Hierarchy of Control (Elimination, Substitution, Redesign, Isolation, Administration, PPE)
- Status of Control (Fully Implemented, Partially Implemented, Proposed/Pending)
- Management System (Maintenance; Safety & Health Management System)
- Control Effectiveness Monitoring (Task Observation, Inspection, Audit, Sampling, Review)
- Monitoring Frequency (Opportunistic, Daily, Weekly, Monthly, Quarterly, Annually) [4].

Essentially, the Hygiene Risk Control Plans provide a record of what controls currently exist and how they are managed as well as what controls are proposed to be implemented. This provides an auditable document that may assist with regulatory compliance and internal governance auditing.

Ultimately these Hygiene Risk Control Plans will be used by BMA operations to identify areas for sustained continuous improvement in management of occupational hygiene risk.

CONCLUSION

The last five years have seen iterative improvements in BMA's management of occupational hygiene. The introduction of the BHP Billiton Health Exposure Assessment Guideline in 2002 has resulted in both qualitative and quantitative assessment of BMA's occupational hygiene risks. This has benefited the business in that it no longer needs to continually focus on complaint or compliance driven exposure assessments. Completing health exposure assessments has meant that more resources can be focussed on controlling and managing the more highly ranked hygiene risks. To manage these risks BMA has developed a Hygiene Management Plan. The plan combines an educational and strategic approach with practical approaches for sites to adopt. Using a Hygiene Risk Control Plan BMA sites are now documenting how occupational hygiene risks are managed at a site. The whole process has put occupational hygiene on a more sustainable footing and will provide BMA with a 'step change' in preventative and protective occupational hygiene management.

REFERENCES

1. BHP Billiton (2006), *HSEC Guideline 14 - Health Exposure Assessment (Issue No. 2)*. BHP Billiton, VIC.
2. Grantham, D (2001), *Simplified Monitoring Strategies*. AIOH, VIC
3. BMA (2006), *BMA Hygiene Management Plan*. BMA, QLD.
4. BMA (2006), *BMA Site Hygiene Risk Control Plan*. BMA, QLD.

APPENDIX A - Qualitative Occupational Hygiene Assessment Form with Examples [1]

QUALITATIVE OCCUPATIONAL HYGIENE ASSESSMENT									
Site			Conducted by			Date		Revision	
AREA / SIMILAR EXPOSURE GROUP	EXPOSURE TYPE								
	Respirable Dust [1]	*Inhalable Dust*	*Noise*	*Whole Body Vibration*	*Hand Arm Vibration*				
Draglines [2]	*Medium* [3]	*Low*	*High*	*High*	*Low*				
Coal Mining	*Medium*	*Low*	*High*	*High*	*Low*				
Truck & Shovel	*Medium*	*Low*	*High*	*High*	*Low*				
Field Maintenance	*High*	*Low*	*High*	*Low*	*High*				
Mobile Equipment Maintenance	*Low*	*Low*	*High*	*Low*	*High*				

[1] Identify exposure types in each area for each workgroup
[2] Identify work areas within the site and the workgroups in each area, - this assessment is to be completed for each workgroup on site
[3] Estimate exposure of each group as : HIGH (possibly exceeding half the OEL); MEDIUM (possibly exceeding 10% of OEL); or LOW (less than 10% of OEL or not applicable for that exposure type)

APPENDIX B – Extract from the BMA Hygiene Management Plan [3]

Airborne Dust – Respirable & Inhalable

Hazard Overview	Dusts are airborne solid particles. Dust is generated during grinding, crushing or chipping of hard materials or from the mechanical dispersion of fine powders. If particles are sufficiently small that they may be breathed in and reach the narrowest airways of the lung, they are termed *respirable*. Respirable particles are generally smaller than 10 micrometres. (One micrometre is one millionth of a metre). Larger particles, up to 100 micrometres, are termed *inhalable*. When breathed in, inhalable particles are generally trapped in the upper respiratory passages.
Hazard Source	• Opencut & underground mining operations • Earth works • Traffic movements on unsealed roads • Wind blowing across de-nuded ground and product stockpiles • ROM's, breaker stations and conveyor transfers • Shiploading • Stacker/reclaimer • Equipment 'blow downs' • Abrasive blasting • Grinding • Maintenance activities where dust deposited on machine surfaces is disturbed
Exposure Limits	• Respirable Coal Dust (< 5% Quartz):TWA - 3 mg/m^3 • Respirable Quartz or Crystalline Silica: TWA - 0.1 mg/m^3 • Respirable (PNOC): TWA - 3 mg/m^3 • Inhalable (PNOC): TWA – 10 mg/m^3 PNOC – Particle Not Otherwise Classified
Health Consequences	• Respiratory Irritation (Dust) • Occupational Asthma • Coal Miner's Pneumoconiosis (Coal Dust and Quartz) • Silicosis (Quartz) • Progressive Massive Fibrosis (Dust) • Chronic Obstructive Airways Disease (Dust) • Lung Cancer (Quartz)
Risk Assessment	Moderate – High
Management Obligations	**Legislative Provisions:** • S&H Management System Element – Dust (s89 CMSHR) • S&H Management System Element - Air-conditioning units (s86 CMSHR) • SOP - Abrasive Blasting (s96(c)(i) CMSHR) • SOP - Watering & Maintaining Mine Roads (s129 CMSHR) • SOP – Using PPE (s65 CMSHR). **Company Provisions:** • BHP Billiton – Occupational Exposure Limits (P09) • BHP Billiton – Health Surveillance (G13) • BHP Billiton – Health Exposure Assessment (G14) • BHP Billiton – PPE Compliance Auditing (G23) • BHP Billiton - Respiratory Protection Program (G29)

Strategic Approach	Historically dust exposure monitoring at BMA sites has indicated that airborne dust generally presents a low risk in our open cut mines and an increased risk in our underground mines. With the advent of air-conditioned cabs in mobile equipment, better respiratory protection and a lowering of the regulatory occupational exposure limits in the 1990's the rates of dust related disease such as Coal Workers Pneumoconiosis and Silicosis have declined significantly over recent decades. With only a small number of mining and maintenance activities contributing to potentially significant dust exposures the focus should be on reducing dust at the source where practicable and preventing it entering the worker's breathing zone. Health surveillance should be adopted where potential exposure to dust remains unacceptable with controls in place and/or where PPE is being used as a long-term control.
Site Approach	The following management activities could form part of the Site Safety & Health Management System: 1. Qualitatively assess dust exposure and identify Similar Exposure Groups (SEG's). 2. Quantitatively assess dust exposure for all medium to high dust exposures identified in the qualitative assessment. 3. From the quantitative assessment investigate exposures that are unacceptable and develop short-term and long-term control plans using the hierarchy of control. This should also include assessing the suitability of PPE. 4. Continue to perform maintenance sampling of SEG's to validate data and identify deterioration in controls. 5. Develop/implement/audit a SOP for Abrasive Blasting. 6. Develop/implement/audit a SOP for Road Watering & Maintenance. 7. Develop/implement/audit a system to manage cleaning and maintaining air-conditioning units. 8. Develop/implement/audit a Respiratory Protection Program. 9. Ensure dust exposure risk is included in Task Risk Assessments and the Coal Mine Workers Health Surveillance Scheme.
Control Methods	**Substitution/Elimination** • Risk based and opportunistic. **Engineering** • Local Exhaust Ventilation • General Dilution Ventilation • Enclosure and segregation • Air-Conditioned Cabs • Road watering and other dust suppression techniques • Process automation • Dust suppression (with water sprays/bars) **Administration** • Work rotation • Housekeeping • Change Management **PPE** • Respiratory Protection Program
Other Resources	• NIOSH – Handbook for Dust Control in Mining [2003-147].