Assessment of Vibration Exposure in the Mining Industry

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ABSTRACT

The EU Vibration Directive in 2002 established exposure limits for hand-arm and whole-body vibration in the workplace and this has led have led to legislation and regulations in the EU countries and to an increasing awareness of the hazard and the mitigation measures for whole-body (WBV) and hand-arm vibration (HAV). Currently in Australia there are no limits for vibration exposure and this hazard has not received sufficient attention. A survey sponsored by Safe Work Australia highlighted that approximately 24% of the overall workforce self reported exposure to vibration and a recommendation from the survey was for a study of the application of the EU exposure limits in Australia with a view to considering adoption in Australian regulations. In view of the nature of the work, a high proportion of workforce in the mining industry is exposed to vibration, in particular WBV, which may exceed these action and exposure limits. This paper will discuss findings from a range of assessments in the Australian mining industry and the implications of adoption of exposure limits in legislation.

INTRODUCTION

Vibration in mining related workplaces is created by the operation of tools, plant and machinery. Much of the plant used on site, such as rock breakers, create vibrations in order to achieve their role. A little vibration transmission back to the operator can be beneficial in that it indicates that the item is working. However, like other workplace exposures, as the level of vibration transmission to the operator increases it can cause annoyance, disturbance, fatigue and at higher exposures there is a risk of injury.

Human vibration in the workplace is categorised in two ways:

- Whole-body vibration (WBV) where the where the transmission is from the item via the feet or the buttock and into the body.

- Hand-arm vibration (HAV) where the transmission is from the tool via the hand, into the arm and then the body.

Similar to noise in the workplace, there is both the effect of continuous vibration and of sudden impulsive shock; often referred to in mobile plant as ‘jolts and jars’.

There are currently no exposure limits for vibration in the workplace in Australia. The Model Work Health and Safety Regulations [Safe Work Australia, 2011a] define the exposure standards for noise (Regulation 56) and a Model Code of Practice deals with noise in the workplace [Safe Work Australia, 2011b]. The model regulations make reference to taking care with exposure to human vibration under a number of sections including manual handling, electrical installations etc and it is similarly mentioned in some codes of practice, such as for construction. But there is currently no regulation limiting HAV or WBV exposure in Australian workplaces or a code of practice providing guidance on limiting such exposure .

To date there has been no comprehensive quantitative study of exposure to vibration across workplaces in Australia. The study undertaken for Safe Work Australia on “National Hazard Exposure Worker Surveillance (NHEWS) – Exposure to vibration and the provision of vibration control measures in Australian workplaces” [Safe Work Australia, 2010] was undertaken via computer assisted telephone interviews from 4500 workers across 17 Australian Industries. While keeping in mind that this was only a self reporting study the findings do lead to concern about the broad extent of vibration exposure in Australia. The overall findings were that 43% reported exposure to HAV, 38% to WBV and 17% to both HAV and WBV.

The NHEWS survey did not include responses from the mining industry; a growth industry in Australia where it is known there is a high risk of excessive vibration exposure. There has been an awareness and concern about excessive exposure to vibration for those working in mining for some decades. In many respects the industry has been at the forefront by seeking information on exposure levels and seeking advice on how to minimise those exposures. In part this has been driven by the large international companies which are aware of the importance of managing vibration exposure in the workplace.

In the mid 1990’s, Worksafe Australia (which has since become Safe Work Australia) began to investigate the extent of exposure to vibration in mining. At that time, obtaining data on vibration exposure on mining sites was particularly challenging due to the type of measuring instrumentation and data acquisition equipment available as well as the need for it to be intrinsically safe.

In 2002, following a research grant from the Joint Coal Board, the first version of the Handbook for mining entitled “Bad Vibrations” [McPhee, Foster & Longl] which focussed WBV was published. This has since been revised and republished in 2009 and this continues to provide guidance on the range of exposures and the strategies that can be adopted to reduce WBV exposures.

EXPOSURE LIMITS FOR VIBRATION IN THE WORKPLACE

The importance of establishing exposure limits for human vibration in the workplace was recognised by the European Union and in 2002 a directive was issued by the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) [EC 2002]. The agreement on this directive meant that the European countries were obliged to introduce legislation and regulations defining vibration exposure limits in the workplace. The UK adopted regulations with exposure limits in 2005 [UK 2005].

Exposure limit values in the EU vibration directive are shown in Table 1 where m/s^2 A(8) is the daily exposure value normalised to an eight-hour reference period A(8), expressed as the square root of the sum of the squares (r.m.s.) (total value) of the frequency-weighted acceleration values and VDV is the vibration dose value based on 4th power of the acceleration signal and the units are $m/s^{1.75}$. The option for the metric for the WBV as VDV is based on research that showed a 4th power relationship between vibration magnitude and discomfort. The VDV has an important role by providing a better indication of those rides with a high proportion of shock or "jolts and jars". However the UK regulations [2005] have adopted only the r.m.s. metric for WBV exposure limits and have not included VDV limits in their regulations.

Employers are obliged to minimise the risks of exposure to vibration but once the "action level" is exceeded they must minimise the exposure and introduce health surveillance. Exceedance of the "limit value" requires immediate action to reduce the exposure below the limit value.

Table 1 Exposure limit values and action values from EU Vibration Directive.

Vibration	Exposure Action Value	Exposure Limit Value
Hand-arm vibration	2.5 m/s^2(A8)	5 m/s^2(A8)
Whole-body vibration	0.5 m/s^2(A8)	1.15 m/s^2(A8)
	9.1 $m/s^{1.75}$ VDV	21 $m/s^{1.75}$ VDV

Although there are no regulated exposure limits for vibration in Australia there is some guidance from the health guidance zones for WBV from Annex B of AS 2670.1 [Standards Australia, 2001] and similar guidance for HAV from the outdated Appendix A of AS 2763 [Standards Australia, 1988]. Like Australia, the United

States of America’s Occupational Safety and Health Administration (OSHA) has not developed exposure standards for vibration although there are some guideline Threshold Limit Values (TLV) (ACGIH 2012).

EFFECTS OF EXPOSURE TO VIBRATION

Hand-arm vibration

The most commonly reported effects of exposure to excessive HAV are vascular and the obvious signs are known as ‘vibration white finger’. The first link with occupational vibration exposure of this effect was made by Alice Hamilton in 1918 following her study on the hands of stone cutters. In a follow up study by Taylor et al [1984] on stonecutters in the same quarries. Non-vascular effects of HAV include disorders to bone and joints, peripheral neurological, muscles as well as the whole body and central nervous system. The symptoms of injury include tingling and numbness in the fingers; not being able to feel things properly; loss of strength in the hands; and the fingers going white (blanching) and becoming red and painful on recovery (particularly in the cold and wet, and probably only in the tips at first). The effects include: pain, distress and sleep disturbance; inability to do fine movements (e.g. fastening buttons); reduced ability to work in cold or damp conditions which can trigger painful finger blanching attacks; and reduced grip strength which might affect the ability to do work safely. [HSE, 2011a]

Whole-body vibration

Back pain is the most commonly reported effect of excess WBV. Therein lies the problem for definitely attributing an injury to the WBV and a robust dose-response relationship. There is also the concern that in many cases, posture or manual handling may be more important than the vibration exposure. The risk factors in the workplace that may contribute to WBV include: poor design of controls, making it difficult for the driver to operate the machine or vehicle easily or to see properly without twisting or stretching; incorrect adjustment by the driver of the seat position and hand and foot controls, so that it is necessary to continually twist, bend, lean and stretch to operate the machine; sitting for long periods without being able to change position; poor driver posture; repeated manual handling and lifting of loads by the driver; excessive exposure to whole-body vibration, particularly to shocks and jolts; and repeatedly climbing into or jumping down from a high cab or one which is difficult to access [HSE,2011b].

While it may be difficult to directly attribute back pain to WBV exposure there is some clear evidence of spinal damage caused by severe shocks encountered by crew in a fast vessel going across the waves in a high sea state [Price, 2010]. Repeated shocks on the body can also be experienced by those in vehicles travelling at speed over rough terrain, for example on construction and mining sites, referred to as ‘jolts and jars’.

WBV VIBRATION EXPOSURE IN MINING

From European data it is clear that the risks for excessive WBV vibration exposure is high in mining and construction. As summarised in “Bad Vibrations” [McPhee et al, 2009] and the key components to WHV are rough roads, vehicle activity and engine vibration. Foster has undertaken a number of exposure measurements across mining sites since the 1990s.

The design of the mobile plant has improved considerably so that more modern well designed plant has reduced the transmission of vibration from the engine to the cabin. Similarly a well designed and properly adjusted seat can reduce the vibration transmission to the driver. The main remaining variables that unfortunately still lead to excessive WBV exposure form jolts and jars are the surface of the road and the speed which the driver uses.

Figure 1 shows the exposures for a range of dozers, loaders, dump trucks etc that could be moving around a mine site. Both the caution zones from the Australian Standard and the limits from the EU Directive are superimposed and it is clear that the exposures for many are well above the caution or action levels. The items are ordered in Figure 2a terms of the r.m.s. value and Figure 2b presents the data for the same items but in terms of the VDV measured data. It can be seen that not only has the rank ordering been changed but more items are above the action level for this metric, which has a greater sensitivity to jolts and jars. As well as the high levels experienced by these workers, their long work shifts and long work weeks mean that their body has less time to recover – thus increasing the risk of long term injury.

The great variability in the vibration exposure during the day on a mining site can be seen from Figure 2 which identifies the different activities over an hour and compares the peak vibration with the r.m.s vibration. This detailed analysis can assist with developing appropriate site specific mitigation measures.

The mitigation measures for WBV include keeping the vehicles well maintained, keeping the road ways as smooth as possible, keeping the seat suspension system properly adjusted, training the drivers not to use high speed that will increase the incidence of jolts and jars.

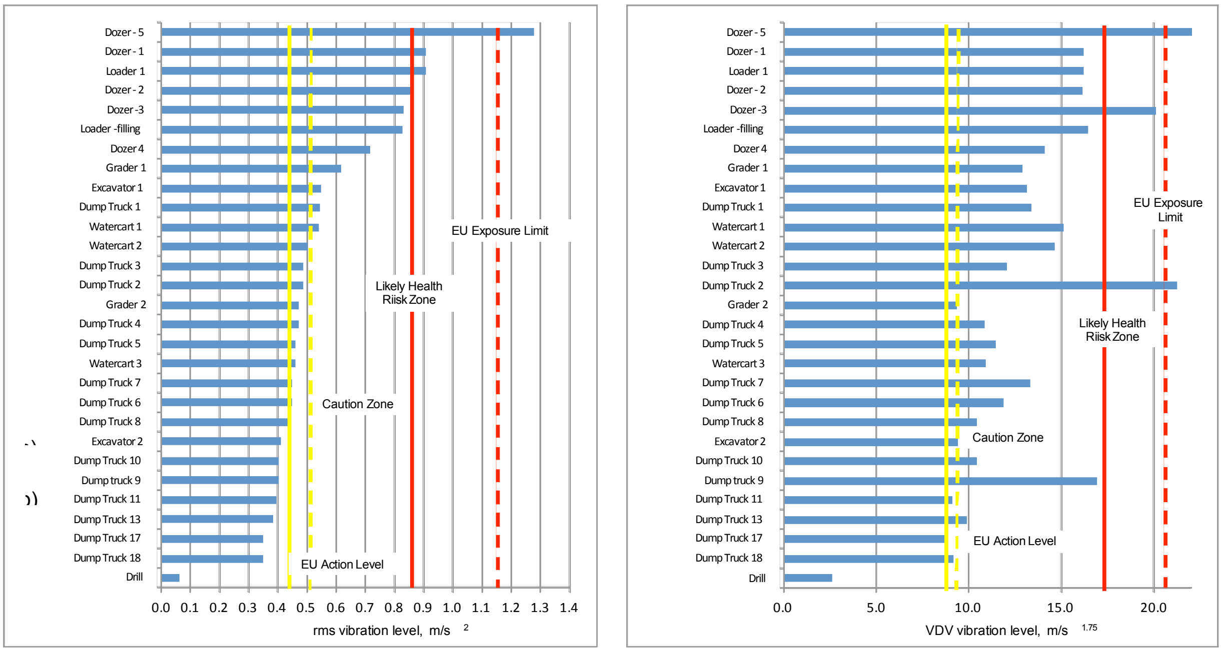

Figure 1 Whole body vibration levels, in terms of r.m.s. (a) and VDV (b), for a range of mobile plant used on mining and construction sites.

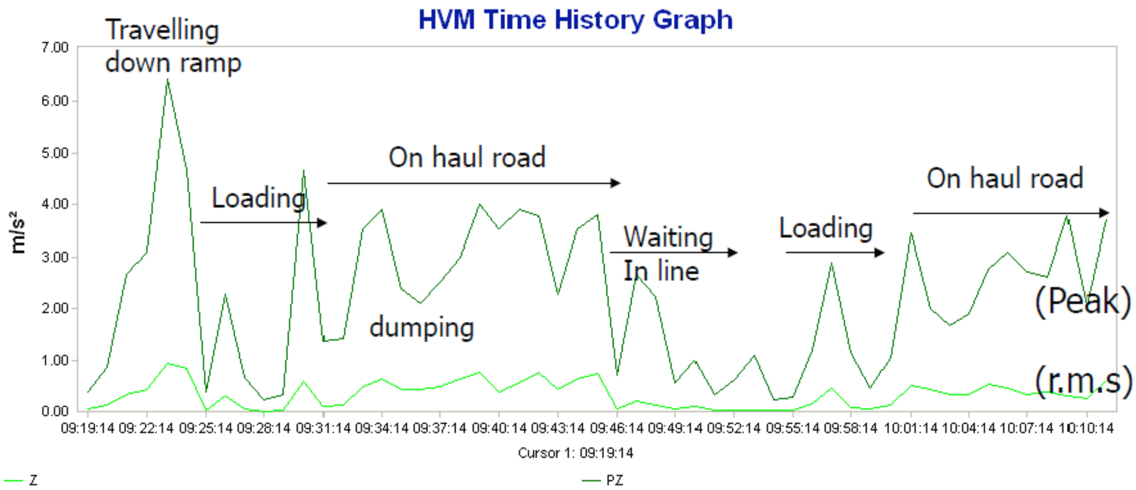

Figure 2 Vibration levels over 1 hour for a dump truck on a mining site in terms of r.m.s. and peak in the vertical (z axis).

HAV EXPOSURE IN MINING

From European data it is clear that the risks for excessive HAV exposure is high in mining and construction. For example Table 2 gives a sample of some exposures measured in Australian mining workplaces by one of the authors (Foster).

Table 2 Examples of some HAV exposures in mining workplaces [Foster].

Tool	Vibration level (m/s^2)	Time to Action Level	Time to Exposure Limit	Estimated Daily Exposure Time	Average Daily Exposure Level (m/s^2)
Angle grinder metal plate	2.5	8.5 hr	>24 hr	4 hr	1.7
Jack hammer on asphalt	9.9	30 min	2 hr	1 hr	3.5
Rattle Gun	13.7	16 min	1 hr	1 hr	4.8
Rattle Gun on Dozer Track	19.9	8 min	30 min	1 hr	7
Needle gun on dozer track	17.9	9 min	37 min	1 hr	6.3
Engraver	6.2	1.5 hr	5 hr	30 min	1.6

These values highlight that the personal exposure is not just the vibration level from the tool but the combination of the tool and the workpiece and the length of time of use. The exposure for the individual also depends on how effectively the vibration is transmitted from the tool handle into the body. Some workers always have a firm tight grip which encourages effective transmission while other may hold the same tool only as tightly as is necessary to control the action. The design of some tools/tasks may necessitate a firm grip – an engraver is an example and the data in Table 2 shows that it is not just the big powerful tools that can produce the high HAV exposure for the operator.

The most effective mitigation measure for HAV is to reduce the source of the vibration either by changing the operation of the tool or incorporating vibration damping in the design of the tool. Since the introduction of the EU Machinery Directive, in 1998 and updated in 2006 [EC, 2006], there is a requirement for tools manufactured and sold within the EU to declare the levels of vibration. These ‘declaration values’ are measured under specified test conditions and so the declared values cannot be directly applied in all workplaces. Some studies have shown that the declared values do not even provide an accurate rank ordering of the items when used in the workplace [Heaton and Hewitt, 2011]. However the implementation of the directive, coupled with the advice to industry on the benefits of choosing low vibration output tools, has led to greater emphasis by the manufacturers on the engineering design of tools to minimise vibration and maintain their market advantage. One example, is that Atlas Copco [2006] has been awarded a UK award for its Cobra jack hammers, which incorporate isolation and "meeting the requirements of increasingly stringent health and safety legislation".

Changing the operation of the tool is another mitigation measure and can range from reducing the time use through to reviewing the entire process. Changes such as removing the operator from direct contact with the tool or introducing a rig to provide support can reduce the transmission into the hand-arm. Other means for minimising HAV exposure include keeping the hands warm to limit the vascular damage and minimising grip force while maintaining control of the tool. While there is usually greater concern about HAV in cold climates, recent a comparative study showed that while the prevalence of HAVS was lower for those working in the tropical rather than a cold environment, all workers had a higher vibrotactile perception threshold value [Tamrin et al 2012].

Gloves are commonly provided as a mitigation measure but there are widespread concerns about their actual effectiveness. Research studies are in progress to evaluate the role of gloves as a mitigation measure. Their use does however keep the hands warm and may also encourage a reduced the grip force.

CONCLUSION

There are no regulations for vibration exposure in Australia and there have been no comprehensive quantitative studies of exposure to vibration across mining in Australia. However, for the last decade, Foster has been increasingly involved with exposure assessments over a range of over and underground mines. In most cases these assessments are for multinational companies which are aware of the potential for injury and the exposure limits for overseas operations. These companies are seeking the data to ensure that the Australian operation is adopting best practices and meeting company policies.

Australia currently has no regulations for exposure limits for either HAV or WBV in the workplace. Even from the limited information available there is demonstrated risk of injury from excessive exposure to vibration across Australian workplaces. The implementation of the EU machinery and vibration directives in European countries has led to manufacturers and suppliers paying greater attention to the vibration levels of their tools and plant. Instead of being ignored, design of plant and tools with low vibration exposure has been shown to be achievable and has become a marketing advantage. Adoption of similar codes of practice and regulatory limits in Australia would lead to greater demand for low vibration plant and tools, better training for workers on how to minimise their vibration exposure and ultimately greater protection of the Australia workforce from injury.

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