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A Quantitative Evaluation of Occupational Noise Exposure in Marine and Mining

Vasos ALEXANDROU[1]; Peter TEAGUE

[1] Vipac Engineers & Scientists Ltd, Australia

ABSTRACT

Occupational noise is one of the most prominent health risks that many workforces are exposed to, and regular noise monitoring forms part of the prudent processes conducted by industry to determine noise exposure for personnel.

Vipac Engineers & Scientists Ltd has conducted noise dosimetry of over 790 samples spanning a 4 year period, across two key industries – Marine and Mining. Noise Dosimetry was conducted over typical shift lengths, including extended shift lengths greater than 8 hours, which is common amongst these industries. A quantitative review from a representative sample of Marine Vessels and Mines has provided an evidence-based dataset on which a statistical analysis has been conducted. This review assesses 8 hour and extended shift adjusted average noise levels for Similar Exposure Groups against the Noise Exposure Limits set in the WHS Legislation and internationally recognised standards and guidelines.

A qualitative review of industry specific improvements, deficiencies and recommendations across both industries is discussed. Practical noise control measures have also been derived to improve noise control practices across both industries and provide a quieter future for Marine and Mining personnel.

Keywords: Occupational Noise Exposure, Marine, Mining, Extended Work Shift, Ototoxic Substances
I-INCE Classification of Subjects Number(s): 13.5, 14.3.1, 53.2, 62.5, 71.4, 77, 78, 81, 82

1. INTRODUCTION

Exposure to hazardous work areas is not a new phenomenon, and workers in certain industries have long been exposed to workplace hazards, occupational noise is just one of these hazards. Noise Induced Hearing Loss (NIHL) is a consequence that occurs when the human ear is subjected to long term exposure to high noise levels, and exposure to very high peak noise. As part of the ever-growing focus on Work Health and Safety (WHS), both within Australia and internationally, assessing and understanding the health risks to a workers' health have become a key responsibility for employers. National legislation states that employers must ensure employees are not exposed to noise levels within the workplace that exceed the national exposure standard (NES) for noise; i.e. $L_{Aeq,8hr}$ of 85 dB(A) or L_{Cpeak} of 140 dB(C). One common method used by industry to understand and assess occupational noise exposure is that of personal noise dosimetry sampling.

Two prominent industries that have been the cornerstone of the modern world's growth into the 21st century are Mining and Marine. High noise exposure is both common and sometimes unavoidable for worker groups within these industries. Vipac Engineers and Scientists Ltd (Vipac) is a medium sized engineering consultancy that specialises in the measurement, assessment and control of occupational noise within the Marine and Mining industries. Based on a significant dataset conducted over 4 years, a detailed assessment, statistical analysis and risk ranking of personal noise dosimetry measurements provides a greater understanding of occupational noise exposure for Similar Exposure Groups (SEGs) within these industries, with a greater understanding of the noise exposure impact of extended work shift.

[1] vasosa@vipac.com.au

2. BACKGROUND

The fiscal value of compensation claims paid to employees who suffer from some form of hearing loss is estimated to be well into the hundreds of millions globally. One such example is the estimated US$137 million in compensation paid in 2005 to more than 18,000 United States Department of Navy veterans with hearing loss (1). The Australian Worker's Compensation Statistics state that the median compensation claim made for sound related injury or disease was $8,700 in 2013/14, with a median lost time due to injury at four weeks per year (2). Occupations with the highest rates of workers' compensation claims for noise-induced hearing loss over the three-year period 2008 to 2011 include: engine & boiler operators, tradespersons and miners (3).

Permanent NIHL can be one of the most prevalent and serious occupational health conditions within industry, it is irreversible and can be minimized or eliminated through an understanding of ongoing measurement data and effective noise management. Marine and mining operations typically involve extended periods of exposure to major noise sources such as engines, generators, hand-tools, welding, exhausts, pumps, ventilation and flow noise.

It has become industry standard practice to conduct regular personal noise dosimetry monitoring of personnel. The objectives of personal noise dosimetry allows for:

- An assessment of existing noise exposure to personnel during the course of a typical work shift
- Establishment of baseline levels for comparison against future noise levels
- Identification of noise sources and activities that contribute to excessive noise exposure
- A statistical analysis of SEGs including:
  - mean, lower confidence limit, upper confidence limit, and percentage of employees above the NES
- A risk ranking for each SEG
- A greater understanding on the effects of extended work shifts.

Given the high number of employees at some mines and vessels, it is neither feasible nor practical to measure every employee over an extended work shift. As such, representative samples are conducted using a variety of methods. A key performance indicator of personal noise dosimetry sampling is to assess the number and percentage of individuals in a SEG who have a daily exposure above the NES.

3. HEALTH EFFECTS OF HIGH NOISE EXPOSURE

The health effects of occupational noise exposure vary from person to person, however physiological and psychological responses are known effects. Excessive noise can cause ringing in the ears, which is a temporary effect but can become permanent (e.g. tinnitus). This ringing can be very distracting and cause difficulties in concentration or sleep. Irritating background noise and high noise levels can also lead to stress resulting in:

- An increased metabolic rate which can also lower an individual's resistance to noise
- Tiredness, irritability and aggression
- Increased blood pressure and headaches which can place the heart under strain
- A lack of balance and dizziness

All of these symptoms can lead to temporary and permanent hearing loss.

4. CRITERIA AND APPLICABLE REFERENCES

There are several standard references that detail the level of acceptable noise exposure and methods to measure noise levels at a workplace, they include:

- Commonwealth Work Health and Safety Legislation 2011 (4)
- Australian Standard AS/NZS 1269.1:2005 Occupational Noise Management – Measurement and Assessment of Noise Immission and Exposure (5)
- Australian Standard AS 2254-1988 Recommended noise levels for various areas of occupancy in vessels and offshore mobile platforms (6)
- International Maritime Organization (IMO) Code on Noise Levels on Board Ships 2014 Edition (4).

It is widely accepted that the acceptable noise exposure for individuals is assessed using two metrics:

- eight hour equivalent continuous A-weighted sound pressure level $L_{Aeq,8hr}$ of 85 dB(A)
- a peak noise, C-weighted sound pressure level not exceeding L_{Cpeak} 140 dB(C).

The marine industry applies noise level limits pertaining to a 24 hour period equivalent continuous A-weighted sound pressure level of $L_{Aeq,24hr}$ of 80 dB(A) (7). As a seafarer is on-board a vessel for 24 hours a day, noise exposure whilst confined to a ship is greater than 8 hours. In order to compare the effect of noise exposure during a workday other than 8 hours, it is necessary to normalize this exposure to an equivalent 8 hour exposure $L_{Aeq,8hr}$ using equation (1):

$$LAeq,8hr = LAeq,T + 10\log(T/8) \quad (1)$$

Where T is the exposure in hours, (i.e. 24 hours).

Substituting T for 24 hours, the $L_{Aeq24hr}$ criteria of 80 dB(A) is derived from equation 1. However it must be noted that this level does not take into account an additional penalty adjustment for extended work shifts, as stipulated in AS/NZS 1269 (see section 6.4).

4.1 WHS Legislation

The WHS Regulations 2011 mandates that the person or organisation conducting a business or undertaking (PCBU) must ensure that the noise that a worker is exposed to at the workplace does not exceed the exposure standard for noise and that they must manage risks to health and safety relating to hearing loss associated with noise. The WHS Act 2011 states that where noise hazards are identified in the workplace, they are to be eliminated or at least minimized 'so far as is reasonably practicable (SFARP)'.

Noise surveys and associated measurements must be done in accordance with the methodology in the WHS Regulations 56–57, the Approved WHS Code of Practice – *Managing Noise and Preventing Hearing Loss at Work* and Australian/New Zealand standard AS/NZS 1269.1 (or an equivalent or higher standard method). Noise measurement surveys should be done by a competent person in accordance with AS/NZS 1269.1 and the WHS Code of Practice.

Other WHS Regulations also apply, including in the areas of: identifying, assessing and managing WHS risks (Regulations 33 to 35), hierarchy, maintenance and review of control measures (Regulations 36 to 38), provision of information and training (Regulation 39) and provision of personal protective equipment (Regulations 44 to 47).

Audiometric testing must be provided for workers who are frequently required to use personal protective equipment (PPE) as a control measure, such as hearing protection, within 3 months of the worker commencing work, and in any event, at least every 2 years (Regulation 58).

4.2 AS/NZS 1269 Standard

Requirements for, and guidance on, the types of noise assessments, details on suitable noise measuring instruments and procedures for the measurement of noise levels are detailed within AS/NZS 1269. A personal sound exposure meter (PSEM), also known as a noise dosimeter is considered a common instrument for the measurement of noise exposure over a work period. The standard highlights the inherent shortcomings through the use of PSEMs which include, shouting and tapping across the microphone, taking the meter off for short periods, not directing the microphone at the noise source, and a reliance on personnel who are untrained and unskilled at carrying out noise measurements, often in uncontrolled areas. Despite these limitations, when used properly PSEMs provide a good foundation for the identification and assessment of personal noise exposure for workers.

4.3 Ototoxic Substances

Exposure to ototoxic substances such as Volatile Organic Compounds (VOCs) from paints and fuel can lead to hearing loss. Hearing loss can be exacerbated through combined exposure to both noise and VOCs. There are three major classes of ototoxic substances: solvents, heavy metals and asphyxiates. Activities where these substances may become an issue include painting, construction, fuelling, degreasing, weapons firing and fire-fighting. Ototoxic substances are often present in marine and mining SEGs, specifically fuels and carbon monoxide within engineering spaces (engines and generators) and maintenance personnel who are often exposed to fuels, metals and solvents.

The WHS Code of Practice; *Managing Noise and Preventing Hearing Loss at Work* (5) states that where

workers are exposed to ototoxic substances, unprotected exposure to noise levels should not exceed an $L_{Aeq,8hr}$ of 80 dB(A) or an L_{Cpeak} greater than 135 dB(C). Vipac's assessment method has allowed for a 5 dB(A) penalty adjustment for personnel exposed to a combination of high noise and ototoxic substances.

5. SIMILAR EXPOSURE GROUPS

All personnel exposed to occupational noise are categorized into Similar Exposure Groups. This allows for a greater understanding and determination of a risk profile of employees based on noise dosimetry measurements. All mines and vessels at which Vipac have conducted noise monitoring have established SEGs. The common SEGs used for assessment and comparison purposes are outlined in Table 1.

Table 1 – Key Similar Exposure Groups

SEG	SEG Description
Marine – Executive	Officers and senior members on-board a vessel who typically work on upper decks.
Marine – Supply	Crew who are responsible for the stowage and supply of material and food, including food preparation in the Galley. (e.g. stewards, chefs)
Marine – Engineering	Typically work on lower decks, electronic and machinery technicians that conduct regular inspections and repair machinery, electrical and other services
Mining – Production	Operation of vehicles, excavators, dozers for the removal and relocation of dirt and coal.
Mining – Maintenance	The repair and maintenance of field equipment, vehicles and plant maintenance, including boilermaker activities
Mining – CHPP	Coal sampling, processing, handling and washing. Plant inspections and stockpile dozer operations.

6. METHODOLOGY

Vipac always maintains a consistent a best-practice measurement and assessment methodology to limit variables as much as practically possible when conducting noise dosimetry measurements. The occupational noise exposure of an individual comprised all the noise to which they are exposed at work. In the mining industry, this is typically vehicle generated noise (in-cabin and external), hand tools, plant and machinery noise. Within the marine industry typical sources include exhaust noise, pumps, flow noise from various piping systems, ventilation noise and machinery noise from engineering spaces. Contribution to cumulative noise exposure also occurs from the use of various alarms and communication via speaker broadcast. Common sources of noise shared between both industries are the presence of entertainment radio, communication systems (two-way radios, ship speakers) and engines/exhaust noise. All measurements used for this quantitative review are considered representative of a typical noise exposure within the workplace at a mine or ship.

6.1 Instrumentation

Personal noise dosimetry was always measured using the same model and type, a Class 2 Quest Edge 5 Dosimeter. Field calibration (reference level) of 114 dB at 1 kHz was always conducted with a Quest QC-10 Calibrator both prior to and at the end of each measurement period. Any variations were noted on the site datasheet. All instrumentation was in current laboratory calibration as per the requirements of IEC 61672 (9) and IEC 60942 (10) standards All noise dosimeters are fitted with a custom made windscreen for added protection against knocks and wind/air-flow noise. Where measurements had a discrepancy of greater than plus or minus 0.5 dB to the reference level, the measurement was considered invalid.

6.2 Noise Dosimetry Methodology

Noise dosimeters were typically fitted to personnel at the commencement of their working shift and retrieved at the end or very close to the end of their shift. Microphones were always positioned (when practicable) approximately 0.1 to 0.2 metres from the entrance to the ear canal. The L_{Aeq}, L_{Ceq} and L_{Cpeak} noise metrics were always measured in 1-minute sampling resolution. The measurement period typically varied between 8 and 12 hours depending on the working shift length, specific to both marine and mining.

6.3 Hearing Protection Devices

Two methods were used for determining hearing protection requirements. The Classification

method (5) was used for $L_{Aeq,8hr}$ noise levels up to 110 dB(A), and the octave-band method (5) was used for exposure greater than 110 dB(A). Based on these two methods and the measured data, appropriate hearing protection was selected for use and application by exposed workers. This typically ranged between Class 4 and Class 5 hearing protection devices (HPDs), in the form of ear plugs or ear muffs. It is noted that quite often throughout a measurement survey workers either do not wear the correct HPD (or properly fitted), do not wear any HPD and/or are not aware of HPD requirements. This is a general problem that occurs within industry and it is the responsibility of the employer to train its employees, but also a responsibility of the worker to understand noise and its effects on health.

6.4 Extended Work Shifts

Shift durations greater than 8 hours impose a higher health risk to exposed workers. The increased health risk occurs from the additional damaging effect that continued exposure to noise has, once the maximum temporary threshold shift is reached. Risk may be further increased if there is a reduced recovery time between successive working shifts. Consequently, AS/NZS 1269 provides a penalty adjustment to the normalized $L_{Aeq,8hr}$ noise exposure level. The adjustments according to shift length are provided in Table 2.

Table 2 – Extended Work Shift Adjustment

Shift Length, hours	Adjustment to $L_{Aeq,8hr}$, dB(A)
<10	+0
≥10 to <14	+1
≥14 to <20	+2
≥20 to 24	+3

7. MEASUREMENT RESULTS

Noise measurement data spanning four (4) years from 2012 to 2016, from eight (8) Australian coal mines and 16 ships were used for this quantitative review. Personal noise dosimetry samples were performed over a representative work shift. Noise dosimetry data was normalized, adjusted for an extended working shift and adjusted for exposure to ototoxic substances (where necessary). The final calculated noise exposure was then assessed against the regulatory NES; namely, $L_{Aeq,8h}$ 85 dB(A) and L_{Cpeak} 140 dB(C).

7.1 Sample Size

In order to determine the number of samples required to ensure a statistically relevant dataset for each site and ship, the NIOSH Occupational Exposure Sampling Strategy Manual (11) was adopted. In accordance with (11), the recommended sample numbers to ensure at least one worker from the sampled group will be in the top 10 percent of the exposures occurring in the population group to a confidence limit of 95%, is presented in Table 3.

Table 3 – Adopted NIOSH Sample Size Recommendations per Group Size

For Groups of Size (N)	12	13-14	15-16	17-18	19-21	22-25	26-27	28-31	32-35	36-41	42-50	>50
Samples Required (n)	11	12	13	14	15	16	17	18	19	20	21	29

Note: Where the Group Size (N) <12, then the Number of samples, n = N. However, the minimum value of n = 6.

A total of 513 and 277 noise dosimetry samples from mining and marine projects respectively were used for this quantitative review. A breakdown of noise dosimetry samples measured per SEG and the average SEG distribution found in the industry shown as a percentage is produced in Table 4.

Table 4 – Breakdown of Noise Dosimetry Samples per SEG and Industry SEG Distribution

	Marine Executive	Marine Supply	Marine Engineering	Mining Production	Mining Maintenance	Mining CHPP
# Noise Dosimetry Samples	138	45	94	298	157	58
% Noise Dosimetry Samples	50%	16%	34%	51%	35%	14%
% SEG Distribution (Industry avg.)	55%	10%	35%	60%	30%	10%

Table 4 shows that the number of noise dosimetry samples measured was close to the percentage distribution of employees per SEG when compared against industry average levels.

7.2 Average Noise Level Summary ($L_{Aeq,8hr}$)

Each of the 790 noise dosimetry samples for each SEG were normalized and adjusted, as required, specific to their respective shift lengths and exposures, with the following $L_{Aeq,8hr}$ summary data presented in Table 5.

- Minimum
- Maximum
- Mean
- Samples above the NES
- Percentage above the NES
- Lower Confidence Limit (LCL)
- Upper Confidence Limit (UCL)

Table 5 – Summary Table of $L_{Aeq,8hr}$ Noise Data

	Marine Executive	Marine Supply	Marine Engineering	Mining Production	Mining Maintenance	Mining CHPP
Minimum	64.6	76.7	76.2	64.4	67.5	79.8
Maximum	101.4	103	113.3	103.3	109.5	100.7
Mean	83.1	86.9	97.9	86.6	86.9	87.8
Samples above NES	45	28	92	204	104	48
% above NES	32.6%	62.2%	97.9%	68.5%	66.2%	82.8%
LCL	82.2	85.6	96.7	86.1	86.1	87.0
UCL	83.9	88.2	99.1	87.0	87.7	88.7

Figure 1 presents the statistical analysis of the noise dosimetry samples by plotting the mean $L_{Aeq,\ 8hour}$ noise level with the lower and upper confidence levels for each SEG.

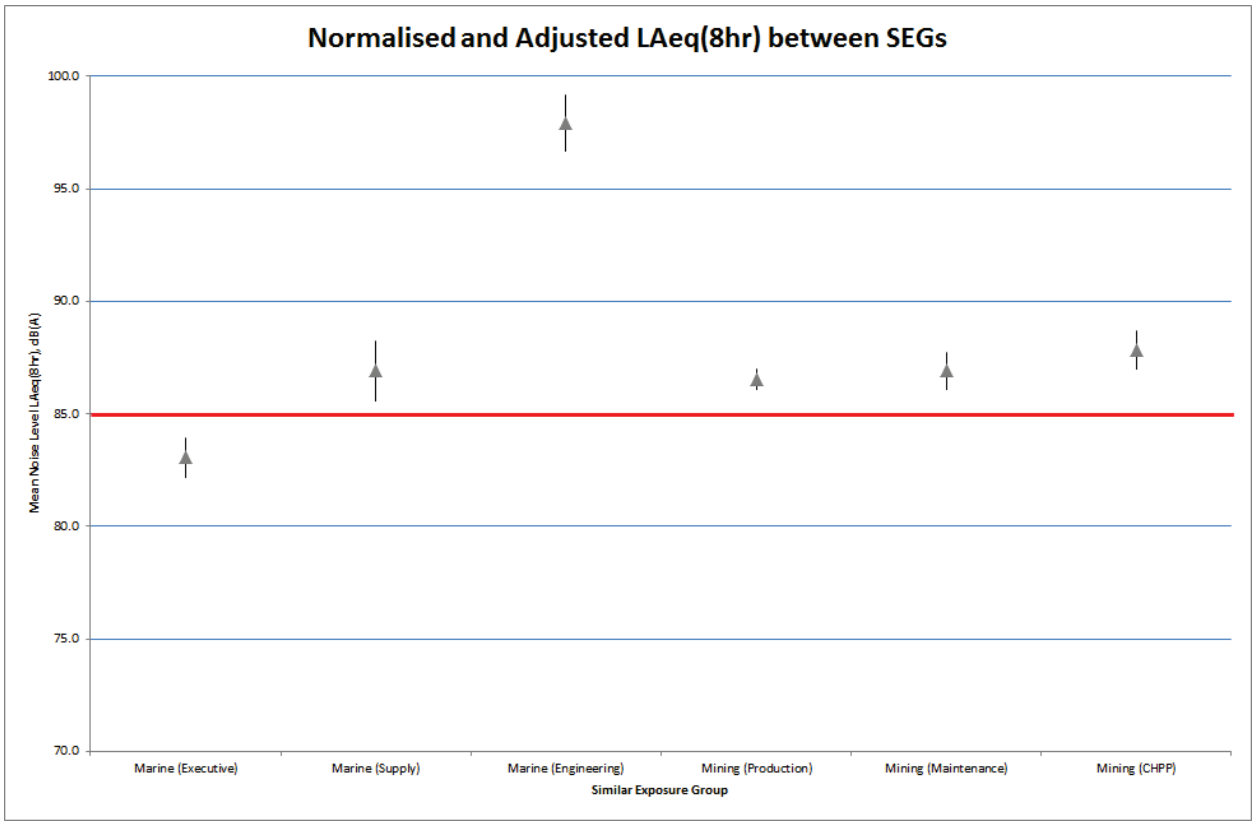

Figure 1 – Normalised and Adjusted $L_{Aeq,8hr}$ (mean, LCL, UCL)

A wide range of noise exposures were measured for each SEG. The mean 8-hour equivalent $L_{Aeq,8h}$ noise exposure level exceeded 85 dB(A) for each SEG, with the exception of the Marine – Executive SEG which was assessed to be an average of 2.8 dB(A) below the NES. The mean noise level for each SEG is expected given the job descriptions, roles, activities and exposure to fewer high noise sources than other SEGS. The following conclusions are derived from the dataset:

- The marine engineering SEG had the highest mean noise exposure level of 97.9 dB(A), almost 13 dB(A) higher than the NES and more than 10 dB(A) higher than the next highest SEG (i.e. mining CHPP SEG at 87.8 dB(A)).
- Mean noise exposure levels for four of the six SEGs were within 1.5 dB(A) of each other and about 2 to 3 dB(A) higher than the NES
- 98% of marine engineering personal noise dosimetry samples exceeded the NES
- 83% of mining CHPP samples exceeded the NES
- 33% of marine executive samples exceeded the NES
- The marine executive group was the only SEG with the mean, lower and upper confidence levels below the 85 dB(A) criterion.

It is common for marine engineers to spend 15 minutes every hour and up to 4 hours per shift inside engineering spaces, where near field noise levels commonly exceed 110 dB(A). The highest noise exposures for mining maintenance were related to boilermakers who can often be exposed to high noise levels of greater than 105 dB(A) for long periods throughout a work shift.

Given the high percentage of exceedances and high risk to workers within marine engineering and mining maintenance SEGs, noise control solutions must be considered and administered as part of the employer's responsibility. Engineering noise controls are not always practical, and as such PPE requirements and administrative controls, such as job rotation and limitation of exposure time, are usually implemented.

7.3 Impulse Noise Summary (L_{Cpeak})

Very high impulse noise levels can be experienced within all SEGs. The L_{Cpeak} noise dosimetry samples of each SEG were assessed and it is noted that the L_{Cpeak} data can be easily contaminated by extraneous events and may exceed the measurement range threshold of the dosimeter, and therefore

may not be a reliable indicator of the actual health risk. It is noted that during specific activities, such as maintenance tasks (impacts during hand tool use), exceeding the NES of 140 dB(C) can occur. These peak events do not typically affect the average noise level. Based on a summary of measured data, the mean, LCL and UCL L_{Cpeak} noise level did not exceed 140 dB(C) for any SEG.

7.4 Dosimetry Example

Example time history plots of a typical shift within the marine engineering and mining maintenance SEGs are shown in Figure 2. Note that the cumulative noise exposure (shown in pink) rises significantly during visits to the engine room for inspection and repair, and remains quite high, and in fact well above the exposure standard, until the end of the shift period. The cumulative noise level shown does not include adjustments for extended work shifts or exposure to ototoxic substances. The engineer from the example plot was exposed to carbon monoxide and fuel vapours for extended periods during repair work inside the engine room, as such, an adjustment for exposure to ototoxic substances should be applied. The $L_{Aeq,T}$ for the example plot was 91.3 dB(A). This level when normalized, adjusted for an extended work shift and adjusted for ototoxic substances becomes $L_{Aeq,8hr}$ of 100 dB(A). This is an exceedance of the NES by 15 dB(A).

This provides an indication to the employer that noise controls must be considered and further imparts responsibility to the employer to ensure that the marine engineering crew is subjected to minimum rest periods and also provided with suitable hearing protection (and also possibly respiratory protection).

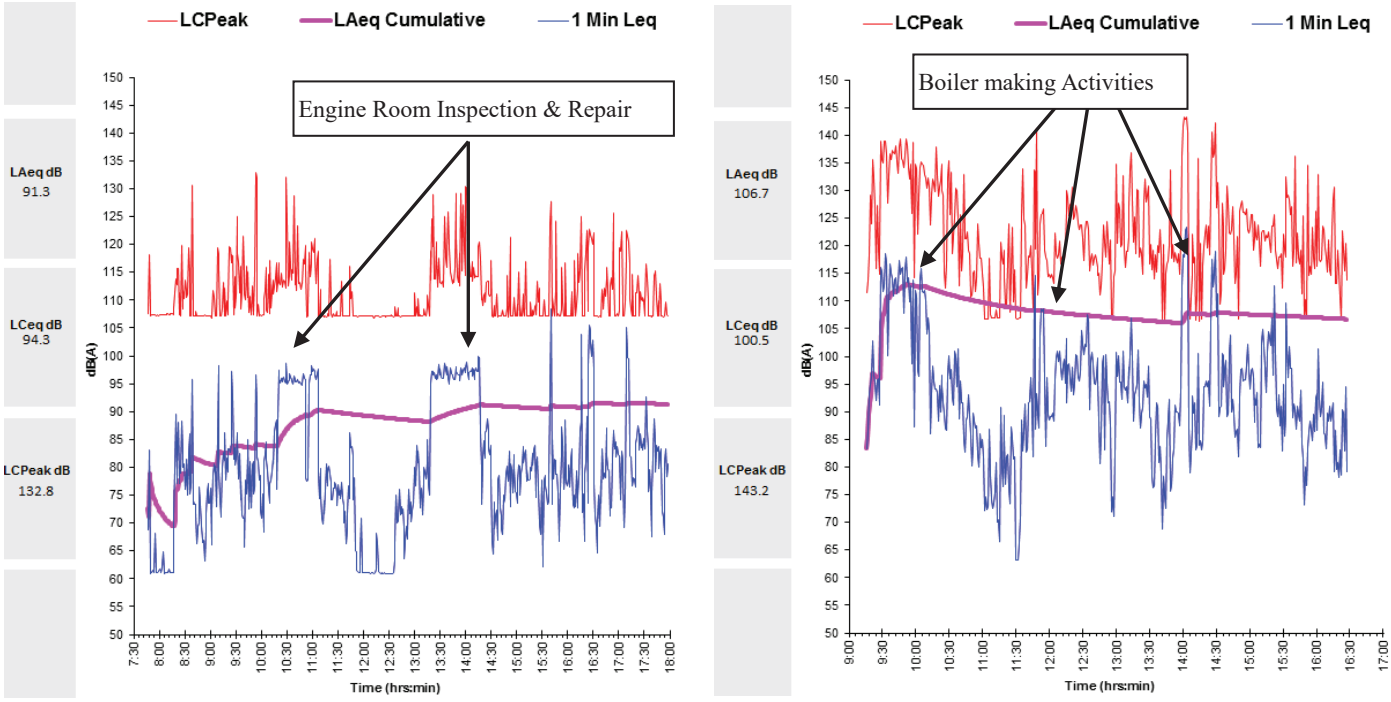

Figure 2 – Example Time History of Marine – Engineering SEG & Mining – Maintenance SEG

7.5 Risk Ranking

The sampling data was used to categorise the likely health risks associated with occupational noise exposure for each SEG. Table 6 shows the risk ranking determined for each SEG in accordance with a ranking system derived by Vipac, relative to the NES and based on a consequence and likelihood risk matrix procedure.

Table 6 – Risk Ranking per SEG

Risk Ranking	Marine Executive	Marine Supply	Marine Engineering	Mining Production	Mining Maintenance	Mining CHPP
% Very Low	19%	2%	1%	6%	6%	0%
% Low	31%	11%	1%	7%	13%	0%
% Medium	20%	24%	0%	22%	18%	19%
% High	30%	62%	98%	65%	64%	81%

Based on the measured noise dosimetry samples, the following conclusions are made regarding the risk ranking of each SEG:

- 81% and 98% of mining CHPP and marine engineering workers are rated a high risk of developing health risks if their hearing is not protected during their work shift
- Greater than 60% of workers in the marine supply, mining production and mining maintenance are rated a high risk of developing health risks if their hearing is not protected during their work shift
- Compared with other SEGs, 30% of marine executive workers are rated a high health risk, 20% medium risk and 31% low risk.

The SEG risk ranking and significant percentages of workers rated high risk, allows employers to:

- Target and prioritise work areas for noise control
- Determine correct and suitable HPDs for use in high noise areas
- Establish a schedule and determine workers who require audiometric testing

7.6 Effects of Adjustments

The dataset used for this quantitative review was also assessed not taking into account the adjustments for extended work shifts or exposure to ototoxic substances. The following conclusions were made from the analysis:

- The mean noise exposure level drops significantly between SEGs, with only the marine engineering and mining CHPP SEGs exceeding the NES
- All other SEGs are rated a low to medium health risk (from medium to high)
- 97% and 64% of workers within the marine engineering and mining CHPP SEGs respectively, are rated a high health risk (reduced from 98% and 81%). The percentage of high risk rated workers for all other SEGs dropped to below 50% (a reduction of between 7 and 18%).

8. SUMMARY OF DATA

When considering mean exposure levels, all SEGs with the exception of the marine executive SEG do not demonstrate legislative compliance with the NES.

In general, the noise dosimetry samples confirmed that:

1) High noise exposure areas exist throughout marine and mining
2) There is widespread exceedance of the noise exposure standard throughout all SEGs
3) A significant number of workers are exposed to a high risk of health effects for unprotected noise exposure in their respective workplaces
4) Adjustments to normalised noise levels for extended work shifts and ototoxic substances have a significant combined effect on measured noise exposure levels

The SEGs that experience the highest exposure levels include engineers, technicians, maintainers and workshop personnel. Notably, many of these trades work extended work shifts and are also exposed to a range of ototoxic substances (e.g. solvents and fuels).

9. NOISE CONTROLS

One of the objectives of conducting noise dosimetry sampling is to identify work areas and SEGs exposed to high noise. Where noise controls are required from the measurement dataset and subsequent risk assessment, the hierarchy of noise control should be considered. Engineering noise control is the preferred method of noise reduction, however this is not always practicable. As such, the implementation of mandatory personal protective equipment (PPE) usage and administrative controls are normally applied and used widely within industry.

Administrative control measures recommended and applied throughout industry include job rotation, work scheduling, changing work processes, limiting exposure times for high noise tasks, minimum rest periods, limiting distances from noise hazards, limiting exposure to ototoxic substances and hand-arm vibration and equipment maintenance. Observations made throughout most site surveys were the improper fitting of HPDs. Improper fitting can mean that the HPD will not achieve the attenuation it is designed to provide, and that wearers could be under-attenuating noise levels by up to 10 to 15 dB. Therefore incorrect fitting of HPDs has the potential for workers to be exposed unknowingly to unacceptably high noise levels and subsequent health risks.

As such, a recommended action is for training for the use of, and fitting of HPDs for all workers. Personal hearing protectors should be selected and maintained in accordance with WHS Regulation 44, the Code of Practice and AS/NZS 1269.3 (12). Employers should involve workers in the selection process and offer a reasonable choice of hearing protector types. Ensuring that workers are comfortable with the HPD of choice is important, as an uncomfortable HPD is likely to lead to improper use or no use at all.

It is noted that SEGs exposed to ototoxic substances (such as marine engineering crew) may require additional PPE in the form of respiratory protection in addition to suitable hearing protection. This would depend on the number of ototoxic agents exposed to, the exposure levels to ototoxic agents (relative to standard exposure criteria for each chemical agent) and the combination with the level of noise exposure.

As part of the WHS legislation, workers exposed to high noise levels also require regular audiometric testing. Basic noise controls observed within industry for some of the work processes includes; buying quiet equipment, installing acoustic screens in high noise areas (e.g. boilermaker area, workshops etc.), applying silencers and low noise fittings to applicable applications/tools. All of these solutions have proven effective in reducing occupational noise exposure for high noise SEGs within both marine and mining work processes.

10. CONCLUSIONS

Based on the quantitative review conducted, 66% of employees within the mining and marine industries are exposed to noise levels greater than the allowable noise exposure standard of $L_{Aeq,8hr}$ 85 dB(A), when adjustments for extended work shifts and ototoxic substances are considered (where applicable). Consequently these workers are rated a high risk of developing health risks based on long term exposure to their workplace. The SEGs that experience the highest exposure levels include engineers, technicians, maintainers and workshop personnel.

When the measured noise exposure levels from this dataset are assessed for an 8 hour working period (instead of the assessed extended periods), 43% of samples were exposed to noise levels greater than the allowable NES. This demonstrates a significantly increased impact of extended work shifts greater than 8 hours and highlights the increased likelihood of developing health risks related to hearing loss.

Based on these results, it is clear that regular noise monitoring of workers and the implementation of targeted noise control are a significant priority for the marine and mining industries to effectively reduce the widespread high levels of noise exposure across these industries.

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