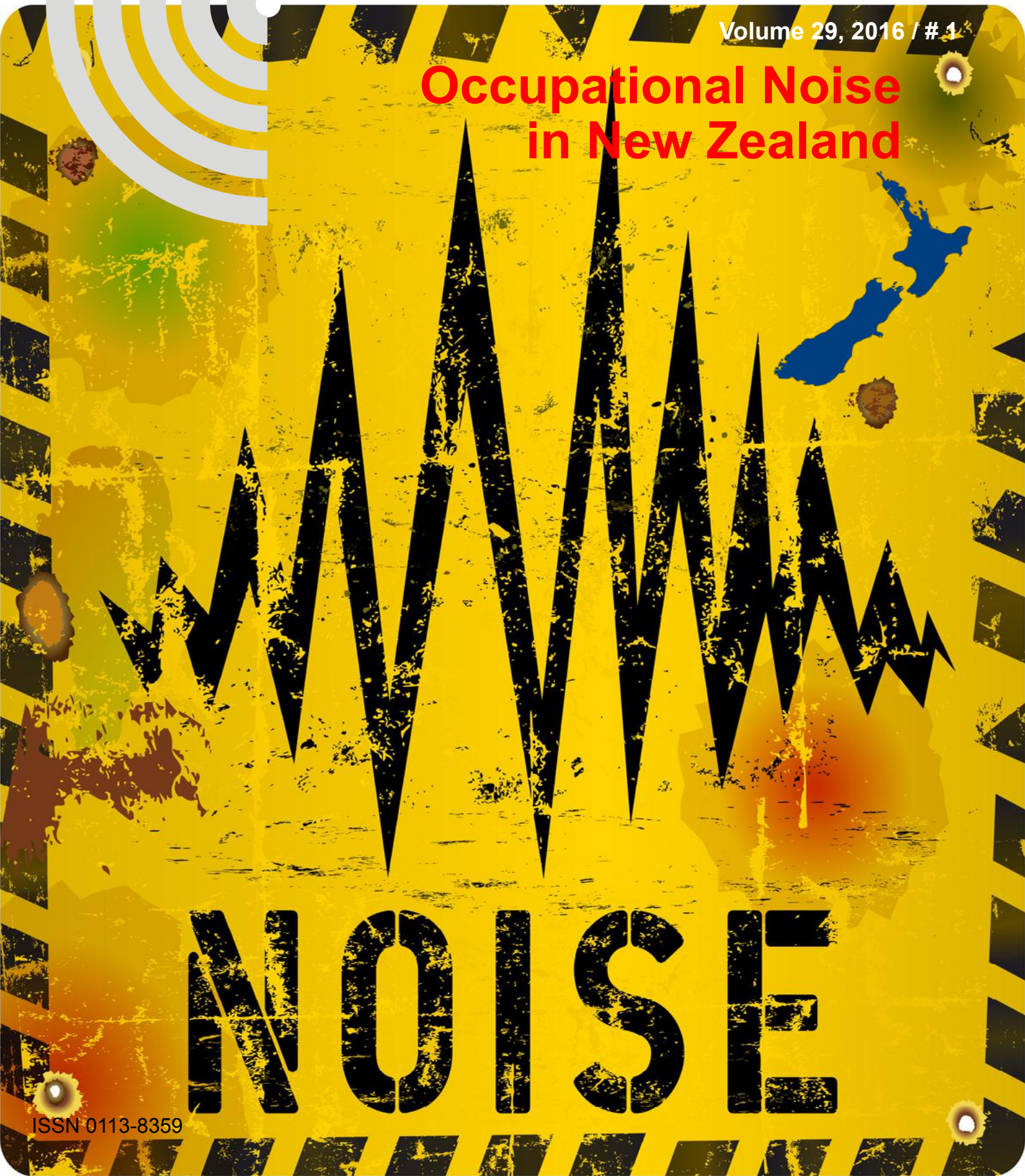
New Zealand Acoustics

Special Topic

Volume 29, 2016 / # 1

Occupational Noise in New Zealand



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Features

Regulars

Cover Image: Workplace Safety - Occupational noise exposure

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From the President and the Editor's

President's Column

Dear Members,

It has been a seriously busy start to 2016. Everyone I talk to, no matter what sector they are in, has been flat tack since January. This is great for lots of reasons, but it can take a bit of a toll. That whole work-life balance thing is a hazy nirvana that may never be truly achieved, but at least we can make good use of the many public holidays we get at this time of year. Plus, Game of Thrones Season 6 starts up again very soon, so how bad can life be really..?

Talking of stuff that I like to watch (and bear with me here... this one does have an acoustic angle), you may recall that in my column two years ago (Vol. 27, 2014 #1) I had a bit of a rant about Formula 1, and the complaints that had surfaced about the sound of the (then) new V6 turbo engines. Well, it's been two years now... and over the Xmas break the FIA went to some pains to make the engines louder. It didn't work. Maybe they should have hired an acoustic consultant. I actually wrote an email to the local chapter of the FIA explaining that it it's the frequency content of the sound that needs to change not the loudness. They don't appear to have listened. Ah well, there are (a few) more important things in life.

One of the most important things in my life (and yours too, even if you hadn't realised it...) is the upcoming Acoustical Society Conference in November. More and more details are being locked into place every day. The abstract deadline has been extended to **22 April** so there's still time to get up the front and contribute (and earn a heap of CPD points!). Registrations will open later this month and we will email members when it does. Please visit **www.acoustics2016.com.au** for details, but here are some appetisers:

- The conference will be held at the Brisbane Convention and Exhibition Centre, 9-11 November 2016.
- Three Plenary Speakers: Associate Professor Christine Erbe (Curtin University), specialist in underwater sound and noise effects on marine animals; Associate Professor Tapio Lokki (Aalto University), concert hall specialist (with a very interestingly titled paper!); and Mark Batasch (CH2M), windfarm specialist.
- 8-10 invited and keynote speakers from NZ and Australia.
- Two technical tours to choose from: South Bank Parklands leisure, education and cultural precinct; and the Centre for Hypersonics at University of Queensland.
- Three short courses to choose from which will be held the day before the Conference.

I will be spearheading a Classroom Acoustics short course, with a focus on Innovative Learning Environments, but you could also choose a course on Noise Control or Physiological and Psychological Aspects of Acoustics.

This is a hugely significant event for our Society and I warmly invite as many Affiliates and Members as possible to attend. The Aussies have the population advantage but I'll be very proud when we turn up there and put up a great showing of quality papers and good solid attendance! Scholarships and grants will be up for grabs, to help with the added cost of getting across the ditch, so stay tuned for those to be announced.

Lastly, our biennial AGM will be held at the conference too, which is of course a very important event in the ASNZ calendar. And (last thing)... AND we will be inducting a brand new Fellow of the Acoustical Society of New Zealand, an honour preserved for the most significant contributors to New Zealand Acoustics. Please do join me in Brisbane, and feel free to email me directly if you have any questions about the conference.

Yours faithfully,

James Whitlock

Editor's Column

Welcome to the first Journal of 2016 (Vol. 29 #1). This is a special topic journal focusing on occupational noise. The feature article is a review of occupational noise in New Zealand prepared especially for this edition by the editorial team. The second paper looks at noise sources, exposures and controls in small New Zealand enterprises. The final paper, prepared by Wyatt, is an opinion piece on occupation noise law and where it may be heading in the future in New Zealand. The key connection between all three papers is a New Zealand focus, so we recommend you read them all - many hours of research has been undertaken to prepare and present this work especially for this journal issue.

Finally we also want to encourage you all to consider preparing a paper for this year's Joint Australian and New Zealand Acoustical Societies 2nd Australasian Conference to be held in Brisbane in November of this year. The first joint conference held in Christchurch was a great success and the 2nd Australasian Conference will no doubt be better. Registration is now open and with the paper abstract deadline being extended what's stopping you? We hope to see you there.

Lindsay & Wyatt journal@acoustics.org

Acoustics 2016
9-11 November
Brisbane, Australia
Innovate for the Future

The Second Australasian Acoustical Societies' Conference

Join us at our biennial ASNZ conference to be held in Brisbane this year, together with the Australian Acoustical Society!

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Journal Feedback and Comments

If you have any feedback on what you would like to see in future issues or even things you don't like to see, please share with us via email to journal@acoustics.org; we would like to hear from you! All comments and feedback is treated as confidential by the Editors.

The Acoustical Society of New Zealand

www.acoustics.org.nz

The ASNZ webpage contains a host of information including information on Membership, Journal Articles, Continuing Professional Development (CPD), Cafe and Restaurant Acoustic Index, Standards Committees and Standards, the Latest News and Discussion and Contact details of the Society. *Why not visit for yourself?*

Cafe and Restaurant Acoustic Index (C.R.A.I.)

The Cafe and Restaurant Acoustic Index, C.R.A.I., is now online with all results and forms are able to be viewed and download from the acoustics.org.nz website under the C.R.A.I tab. See page 39 for ratings focusing on Christchurch.

What's the Quietest Place in the World?

What is the quietest place in the world'? The response may shock you. Microsoft's Ultimate Ears' anechoic chamber located just outside

...Continued on Page 27

A Review of Occupational Noise in New Zealand

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Original peer-reviewed article

1. Introduction

This paper started life as an adaptation of the occupational noise chapter from the Massey University course notes for the 300-level paper '214.316 Bio-Physical Effects of Noise and Vibration'. But with the new Health and Safety at Work Act 2015 due to come into force 4 April 2016, it was decided to produce a heavily condensed version of the chapter that integrates the new legislation and then follow it up with a discussion paper on where occupational noise regulations and practice in New Zealand should go.

The International Labour Organization (ILO) defines occupational health and safety as "*the outcome of adequate protection for a worker from sickness, injury and disease arising from work*". In this context the term occupational noise includes "*all sound in the workplace, whether wanted or unwanted*".

1.1 New Zealand workforce by industry sector

In terms of sector employment by occupation, figure 1 illustrates a breakdown of the New Zealand workforce by industry sector (data sourced from the New Zealand Labour market tables [1]).

Approximately a quarter of the total workforce is in potential '*noisy*' industries, with agriculture, forestry, fishing, mining, manufacturing, electrical and construction. In terms of people in these industries, this equates to approximately 25% of the total workforce and includes both the primary and manufacturing sectors.

Occupational noise is associated with every work place, from low-levels in open-plan offices, through to very high noise levels associated with industry based activities such as manufacturing, processing or construction. Various types of workplaces are associated with a high risk of occupation noise exposure. Such workplaces include (but are not limited to) employment in various production based industries, the defence or military and musicians. High levels of unmanaged occupational noise remain a problem in all regions of the world including throughout New Zealand.

Figure 2 shows the range of sound pressure levels (L_{Aeq}) across industrial construction and music/entertainment industries. This data is sourced from OSHwiki a website developed by European Agency for Safety and Health at Work [2]. In terms of the peak sound levels (L_{peak}) for these industries, they typically range from 101 to in excess of 140 dB L_{peak}. In some sectors, like armed forces and other

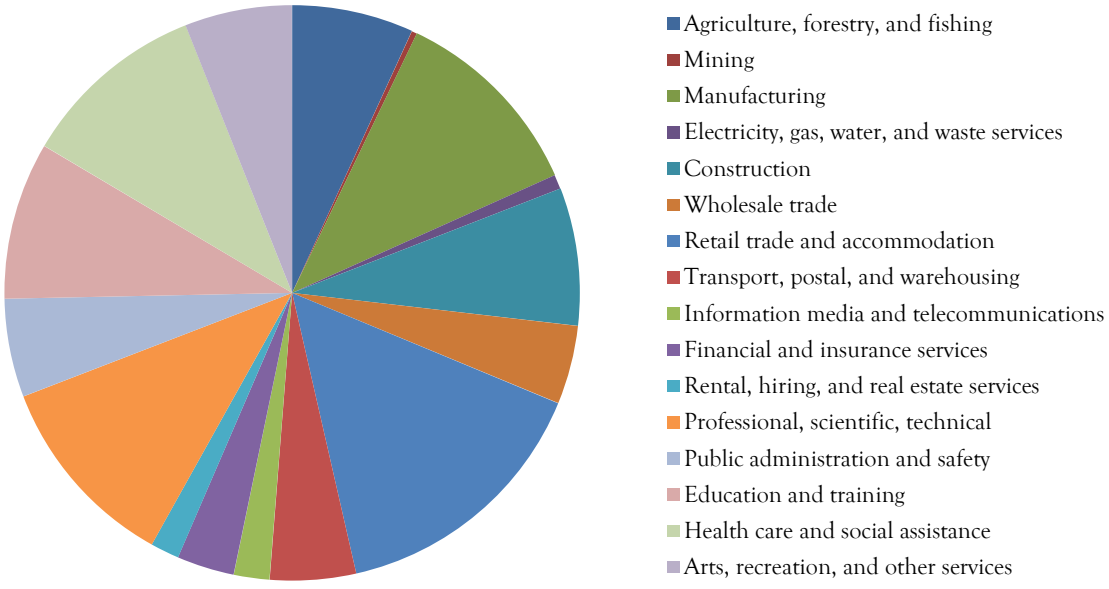

Figure 1: Occupation breakdown (of '*noisy*' Industry) by percentage of employed population

explosives work, peak sound pressure levels may be as high 170 dB.

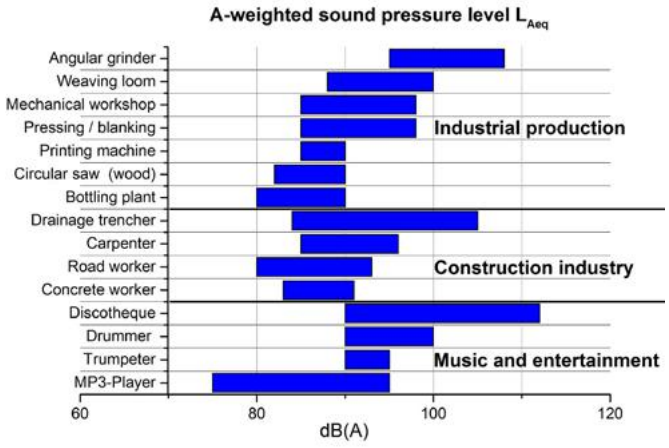

Figure 2: Measured sound pressure level L_{Aeq} (dB) range, across entertainment, construction & production industries

1.2 Occupational Noise - Health Effects

It is generally accepted by experts that at noise exposure levels of less than 70 dB L_{Aeq}, even for extended periods, there is little or no likelihood of any effect on long term hearing acuity (sensitivity). This is supported by the World Health Organization (WHO) which states that hearing impairment is not expected to occur at levels as high as 75 dB $L_{Aeq,8h}$, even for prolonged periods of noise exposure [3].

It is estimated that currently around a quarter of the total New Zealand workforce of approximately 1.47 million workers, are affected to some degree by harmful noise at work [4]. Based on current trends, this is a major cost and burden to New Zealand which will only become worse in the future. It is further estimated that somewhere in the region of 180 million persons worldwide could currently be affected to at least some degree, by noise-induced hearing loss (NIHL) from occupational noise exposure. There are several motivators to assess the burden of disease related to occupational noise. Occupational noise is a widespread risk factor with a strong evidence base linking it to an important health outcome which includes hearing loss.

Occupational noise is distinct from environmental noise, as it is defined as being associated with employees in the workplace and hence the responsibility of employers as well as individual employees. An assessment of the burden of disease associated with occupational noise can help guide policy and focus research on this problem. This is particularly important in light of the fact that policy and practical measures can be used to reduce exposure to occupational noise [5].

1.2.1 Noise Induced Hearing Loss (NIHL)

Noise induced hearing loss (NIHL) stems from long term exposure to loud sound. The effects of NIHL include permanent reduced hearing acuity through to tinnitus. Males and females are believed to be equally at risk of NIHL for the same sound exposure. The hearing impairment occurs predominantly in the higher frequency range from 3 to 6 kHz, with the largest effect typically at 4 kHz. But with increasing sound pressure levels and exposure time, NIHL occurs even at lower frequencies [3].

NIHL is one of the major causes of disability in the world. The Accident Compensation Corporation (ACC) webpage [6] defines NIHL in lay terms as:

> "*permanent deafness that happens when your ears are exposed to sounds over a period of time which are generally too loud for them to handle. It doesn't hurt and it doesn't happen straight away, so you don't know it's happening. In fact it can take ten or twenty years before you know you've got a problem, and by then there's nothing you can do except prevent further damage*".

1.2.2 Non-Auditory and second tier health effects of noise

It is well documented that there are additional health risks related to noise exposure. These 'non-auditory effects' may be defined as all those effects on health and well-being which is caused by exposure to noise, excluding NIHL. There are a host non-auditory effects that may occur in an occupational noise setting. These may include annoyance, increased accidents and reduced productivity due to interference with performance tasks such as reading, writing or speech interference resulting in communications difficulties.

These non-auditory effects can themselves have a host of second tier health effects including sleep disturbance and physiological and psychological stress. In all cases the level of effect depends on a host of factors including the sound pressure level, the type of sound and the exposure time. However, the level of annoyance and stress do not necessarily relate directly to the actual sound pressure levels, such that even at low-levels of noise, some individual may be significantly affected. The potential effects can be made worse by a host of other factors including the age of the person, whether or not they already have hearing disabilities and/or other health issues.

The main social consequence of hearing impairment is an inability to understand speech in daily lives, which is considered a severe social handicap. Even small levels of hearing impairment (10-15 dBHL (dB hearing loss) averaged over 2 to 4 kHz, and over both ears) may have an effect on the understanding of speech. When the hearing impairment exceeds 30 dB, a social hearing handicap is noticeable [7]. The masking effect of interfering noise in speech discrimination is more pronounced for hearing-impaired persons than for persons with normal hearing. This is particularly true if the interfering noise is composed of speech or sound in a similar frequency range to speech. As the sound pressure level of an interfering noise increases, people automatically raise their voice to overcome the masking effect of the interference and

this imposes an additional strain on the speaker. For someone with normal hearing, even if the interfering sound is moderately loud, most of the sentences during ordinary conversation can still be understood fairly well. Nevertheless, the interpretation required for compensating the masking effect of the interfering sounds, and for comprehending what was said, imposes an additional cognitive strain on the listener.

2. Responsibility for workplace health and safety in New Zealand

The Crown (government) Agency responsible for workplace health and safety in New Zealand is 'WorkSafe New Zealand'. They are a standalone Crown Agency, formed in 2013 and who focuses only on workplace health and safety issues, including workplace noise. Historically the 'Department of Labour' (DoL) was responsible for workplace health and safety, however they were dissolved in 2012 and its duties integrated into the then new Ministry of Business, Innovation and Employment (MBIE) formed in July 2012. The MBIE was a merger of the Department of Building and Housing (DBH), the Department of Labour (DoL), the Ministry of Economic Development (MED), and the Ministry of Science and Innovation (MSI). WorkSafe New Zealand has since undertaken MBIE's responsibilities for workplace health and safety. The key catalyst for the creation of the standalone WorkSafe New Zealand agency was a key recommendation of the Royal Commission on the Pike River Coal Mine Tragedy. Worksafe is responsible for administering health and safety legislation in all workplaces, except on ships where Maritime New Zealand is responsible and on operating aircraft where the Civil Aviation Authority (CAA) is responsible.

3. New Zealand's health and safety legislative framework and structure

3.1 The Health & Safety in Employment Act 1992

Before 4 April 2016, the Health and Safety in Employment Act 1992 (HSE Act 1992) was the principal health and safety statute. It follows other western legislative models in moving from a prescriptive approach to a general duty approach. The HSE Act came into force on 1st April 1993. Figure 3 shows the general hierarchy for the health and safety documentation with an emphasis on occupational noise. The HSE Act 1992 is at the top, followed by the Health and Safety in Employment Regulations 1995 (HSE Regulations 1995). Which in turn are supported by the Approved Codes of Practice (ACoP), followed by Standards and Technical Guidelines.

The overall aim of the HSE Act 1992 was to prevent harm occurring in the workplace, including potential harm from noise. Under each the Act, "Duty Holders" are required to take 'all practicable steps' to remove, control, or otherwise manage hazards in the workplace including noise. In general terms a '*Duty Holder*' is a person upon whom a duty is imposed. In regards to the Act, this can be employers, employees, principals, persons who control places of work, self-employed, persons in charge, or persons selling or supplying plant for use on a place of work.

To ensure compliance, the Act also gives specific duties to Inspectorates. Detail on how to achieve required performance is provided through approved codes of practice, standards, industry codes of practice and guidelines.

There are a number of additional Acts which also impact on workplace health and safety such as the Health Act 1956. The Health Act 1956 lists noise and vibration as a nuisance under Section 29 Ka. This was added to the list of (statutory) nuisances in 1978 and further amended in 1993. Section 29 Ka states where any noise or vibration occurs in or is emitted from any building premises, or land to a degree that it is likely to be injurious to health. The burden of proof is high in being able to prove that noise/vibration is of such a level and nature that it is likely to be injurious to health. Medical practitioners are required to notify the medial officer of health and local authority any cases of notifiable infectious diseases. There are also other non-person to person infectious conditions that are notifiable to the medical officer of health which include parasitic tapeworms, decompression sickness, lead absorption to a prescribed level, and poisoning arising from chemical contamination. Injury caused by noise is

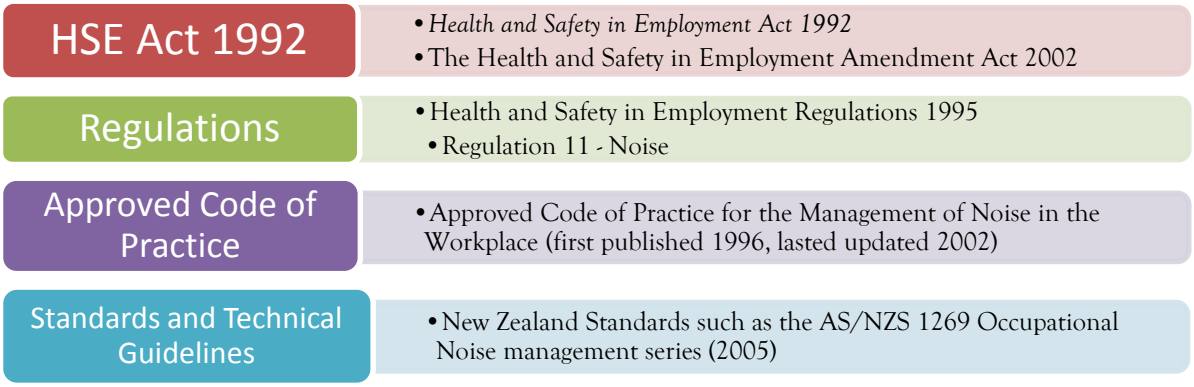

Figure 3: The current Health and Safety hierarchy in New Zealand for Occupational Noise

not a notifiable condition under the Act.

Core sections of this HSE Act 1992 include Section 6 (s.6) which requires employers to take '*all practicable steps*' to ensure the safety of employees at work, and to provide a safe working environment. Under the HSE Act 1992, all employers are required:

> "*to ensure the safety of employees, thus every employer shall take 'all practicable steps' to ensure the safety of employees while at work; and in particular shall take all practicable steps to provide and maintain for employees a safe working environment; as well as provide and maintain for employees while they are at work facilities for their safety and health; and ensure that plant used by any employee at work is so arranged, designed, made, and maintained that it is safe for the employee to use; and ensure that while at work employees are not exposed to hazards in their place of work; or near their place of work*".

Under Section 2A of the HSE Act 1992, it states that all practicable steps in relation to achieving the requirements of the Act and any result in any circumstances, means all steps to achieve the result that it is reasonably practicable to take in the circumstances having regard to:

(a) the nature and severity of the harm that may be suffered if the result is not achieved; and
(b) the current state of knowledge about the likelihood that harm of that nature and severity will be suffered if the result is not achieved; and
(c) the current state of knowledge about harm of that nature; and
(d) the current state of knowledge about the means available to achieve the result, and about the likely efficacy of each of those means; and
(e) the availability and cost of each of those means.

Section 2 (s.2) 'Interpretation', of the HSE Act 1992, does not define noise and the Act does not incorporate vibration. However, other legislation such as the Resource Management Act 1991 does include vibration under the definition of noise which states "*noise includes vibration*" (refer to Part 1 'Interpretation and application' [9]).

3.2 The Health and Safety in Amendment Bill 2001 and Employment Amendments Act 2002

The Health and Safety in Employment Amendment Bill 2001 was introduced in October 2001 and enacted as 'The Health and Safety in Employment Amendment Act 2002' (HSEA Act 2002) which came into force on 5th May 2003. Amendments included (but not limited to) extending coverage of the Act so to now include the crew of aircraft in certain circumstances, and the crew of ships governed by New Zealand law. Mobile workers were also specifically covered. Additional amendments implied new duties being imposed on persons regarding the sale or supply of plant for use in a workplace as well as providing increased protection to volunteers, persons on work experience and employees 'on loan' i.e. secondment to another employee. The definitions of "harm" and "hazard" were amended to explicitly include stress and fatigue (s.2(1)) while the definition of "all practicable steps" was expanded. The amendments also prohibited persons from being "*indemnified or from indemnifying others against the cost of fines and infringement fees for failing to comply with the Act*".

3.3 The Health and Safety at Work Reform Bill and the Health and Safety at Work Act 2015

In August 2013 the National Government introduced a reform package called '*Working Safer: a blueprint for health and safety at work*'. This blue print became part of the introduction of the *Health and Safety Reform Bill*, introduced in June 2014. The Health and Safety Reform Bill represents a significant part of the Government's health and safety reform package designed to help achieve

a significant reduction in unwanted statistics relating to workplace accidents and deaths.

The Health and Safety Reform Bill was passed into legislation to create the new 'Health and Safety at Work Act 2015' (HSW Act 2015). This replaces the HSE Act 1992 and comes into force on 4th April 2016. The Acts structure and content closely follows the Australian Work Health and Safety Act and regulations. The HSW Act 2015 states the purpose of the new legislation in positive terms, through identifying that workers are to receive the '*highest level of protection*'. This ensures that the safety of workers is to take primacy in interpreting and applying the Act.

A core concept in the HSW Act 2015 is that of '*a person conducting a business or undertaking*' (PCBU). The PCBU will be the primary Duty Holder, whose duties will replace those of employers, principals and persons in control and the like under the Act. It is understood that the definition of PCBU is intentionally wide in order to reflect the wide array of modern working arrangements. The concept of 'employee' in the HSE Act 1992 is replaced by 'worker' in the new HSW Act 2015, with a wide definition that includes; contractors, subcontractor, outworkers and volunteers. The Act expressly provides that a PCBU will not include workers.

The 'all practicable steps' language of the HSE Act 1992 has been replaced with 'reasonably practical' in the new HSW Act 2015. This extends the previous concept, in particular it now includes what the person concerned knows, or ought to reasonably to know, about the hazard or risk and ways of eliminating or minimising the risk. Throughout the new Act the concept of '*reasonable care*' is applied in different ways; 'reasonable efforts', 'reasonable policy', 'reasonable steps', 'reasonable opportunities' and so forth.

Although some commentators are stating that the HSW Act 2015 is a welcome modernisation of health and safety law in New Zealand, with simple plain language, some commentators have also stated that it has on face value significantly weakened occupational noise as a hazard. For example, while Schedule 1 (s2(4)) 'Serious harm' of the HSE Act 1992 specifically included "*...noise-induced hearing loss...*" the new HSW Act 2015 does not mention noise in anyway. The closest characterisation under notifiable injury or illness would be the "*loss of a bodily function*" category.

Figure 4 shows the general hierarchy for the health and safety documentation under the new HSW Act 2015 with an emphasis on occupational noise. The HSW Act 2015 is at the top, followed by regulations, in particular Regulations 11 of the transitional Health and Safety in Employment Regulations 1995. This is then followed by a new tool called 'Safe work instruments'. These have legal effects to the extent that regulations refer to them, are developed by regulators (such as Worksafe NZ) and have limited purposes. These are in turn supported by the ACoP and other documentation, such as standards and guidelines.

3.4 Health and Safety in Employment Regulations 1995

The Health and Safety in Employment Regulations 1995 (HSE Regulations 1995) were made pursuant to Section 21 (s.21) of the HSE Act 1992 and apply to all workplaces. The regulations cover:

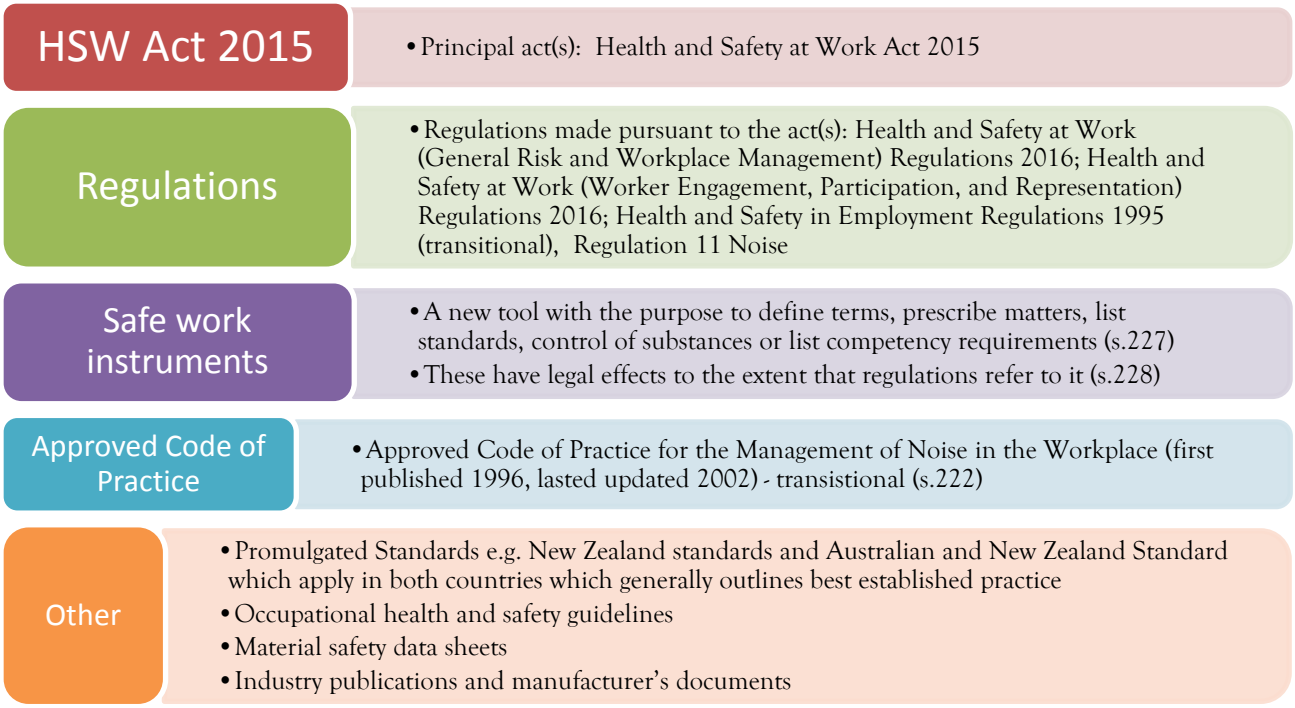

Figure 4: The new health and safety hierarchy in New Zealand for occupational noise

- Facilities required for the safety and health of employees;
- Precautions to be taken with some particular hazards;
- Notification of hazardous construction and forestry work;
- Certificates of competence for some kinds of work; and
- Young people in hazardous places of work; and
- Agricultural workers' accommodation.

Part 2 of the HSE Regulations 1995 covers 'Duties in relation to management of particular hazards' and the first named hazard concerns 'Duties of all employers in relation to noise at any workplace'. This duties section begins by stating what the terms 'employer' and 'employee' includes in relation to Regulation 11.

3.4.1 Regulation 11 – Noise (Transitional)

As part of the 'Transitional and savings provisions' of the HSW Act 2015, existing regulations remain inforce, but could be subject to amendment and revocation at a later date. The amended Regulation 11 of the Health and Safety in Employment Regulations 1995 still remains the key regulation relating to noise in the workplace and is as follows:

11 Noise

(1) Every employer must, so far as reasonably practicable, ensure in relation to every workplace under the control of that employer, that no employee is exposed to noise above the following levels:

(a) A noise exposure level, $L_{Aeq,8h}$, of 85 dB(A); and

(b) A peak noise level, L_{peak}, of 140 dB, —

whether or not the employee is wearing a personal hearing protection device.

(2) For the purposes of subclause (1) of this regulation,—

(a) The noise exposure level, $L_{Aeq,8h}$, is the level of the daily noise exposure normalised to a nominal 8 hour day, in dB(A) referenced to 20 micropascals; that is to say, it is the steady noise level that would, in the course of an eight hour period, cause the same A frequency weighted sound energy as that due to the actual noise over the actual working day; and

(b) The peak noise level, Lpeak, is the highest frequency unweighted peak sound pressure level in the workplace, decibels referenced to 20 micropascals, measured using sound measuring equipment with P time weighting, as specified in the Australian Standard numbered AS 1259.1 1990 and entitled "Sound level meters Part 1: Nonintegrating"; and

(c) The levels of noise referred to in subclause (1) of this regulation shall be measured and assessed in accordance with the Australian Standard numbered AS 1269 1989 and entitled "Acoustics—Hearing conservation".

(3) Where an employer has, so far as reasonably practicable, taken steps to ensure that no employee at any workplace under the control of that employer is exposed to noise above the levels specified in subclause (1) of this regulation but has not eliminated the risk that any employee may be exposed to noise above those levels, the employer shall communicate clearly, by way of signs, labelling of machinery, or other appropriate means—

(a) The fact that noise levels at the workplace are or are likely to be hazardous; and

(b) The sort of personal hearing protection device that is suitable to protect against the noise levels; and

(c) Where such a device may be obtained.

Note 1: Subclause (2)(b) above relating to peak sound pressure level measurement states that the frequency weighting is 'unweighted' and to use 'P time-weighting'. At the time of this regulation 'unweighted' meant the most flat or linear frequency response that the instrument could measure and was not defined. With modern instruments this would more-or-less be equivalent to 'Z (frequency) weighting', which has defined characteristic. The 'P time-weighting' was specific to the Australian standard (that New Zealand adopted) at the time for sound level meters and was equivalent to the peak measurement specification of the IEC standard for sound level meters.

Note 2: Notation has undergone some transformation since the enactment of Regulation 11. The nomenclature for the units of noise exposure level in subclause (1) (a), "$L_{Aeq,8h}$, of 85 dB(A)", meaning a dB value using A (frequency) weighting, is now outdated, but still widely used. Modern notation is not to put any suffix onto the dB, for example, 85 dB $L_{Aeq, 8h}$.

There are no adjustments or penalties stated in Regulation 11 for various factors such as working for more than 8-hours per day, 5-days a week. However, guidance on this does appear in later editions of the AS 1269 when it became a joint standard with New Zealand in 1998 (see Section 3.6 below).

3.4.2 Regulation 11 – A Statistical analysis of risk for exposure to noise

As explained in "AS/NZS 1269.0:2005 Occupational noise management- Overview", the 85 dB $L_{Aeq,8h}$ exposure level is based upon statistical analysis of risk. For example, over an 8-hour day exposed to 85 dB LAeq, Part 4 of AS/NZS 1269 predicts 95% of the exposed population would not be expected to have a hearing loss that exceeded 10 dB (mild loss) over a working lifetime, while 5% would have greater than 10 dB hearing loss [10]. Other literature predicts that up to 35% of the population exposed to 85 dB $L_{Aeq,8h}$ every working day for 40 years would have a significant hearing loss (>30 dBHL) [11].

The risk analysis assumes an 85 dB $L_{Aeq,8h}$ daily exposure limit for 5-days a week and hence the remaining time they are assumed to be exposed to 'insignificant' or low-levels of noise. These assumptions may not be valid, for example, work patterns are often far more varied and may include multiple jobs and assumes no high-level noise exposure outside of work time. Without quiet periods outside of work hours, the hearing will not have time to 'recovery' from the occupational noise exposure.

Unlike the 85 dB $L_{Aeq,8h}$ continuous exposure limit, the peak sound pressure limit of 140 dB L_{peak} means a single exceedance event and hence no employee may be exposed to any single sound pressure level in excess of 140 dB L_{peak} at any time regardless of their sound exposure. It is important to note that unlike the 85 dB $L_{Aeq, 8h}$ exposure limit, the L_{peak} in not based on the daily noise exposure normalised to an 8-hour day but rather an absolute limit at any time throughout the working day. The reasoning behind the 140 dB L_{peak} exposure limit is that any sound intensities up to and in excess of 140 dB L_{peak} can cause permanent hearing loss with a single exposure. However, this limit is also based on the statistical analysis of risk and levels less than of 140 dB L_{peak} could cause hearing damage or loss to some persons. It should be noted that a sound intensity level of 140 dB L_{peak} or more would be uncommon in most industries but are commonly found defence applications such as on a firing range or munitions work.

One issue that is not covered by the statistical analysis of risk in assessing occupational noise on hearing impairment is the susceptibility of an individual to NIHL. There is increasing evidence that some individuals are far more susceptible to NIHL at significantly lower noise levels than 85 dB $L_{Aeq,8h}$ or the equivalent.

3.5 Approved Code of Practice: Noise in the workplace

Section 20 (s.20) of the HSE Act 1992 enabled the Minister of Labour to direct the Department of Labour to prepare, and submit for the Minister's approval, a statement of preferred practices, aims, arrangements, principles, characteristics, components, configurations, elements or states relating to work, plant, protective clothing or protective equipment, substances or practices relating to a particular health and safety issue. Such statements are approved by the Minister and become an '*Approved Code of Practice*' (ACoP).

Approved codes of practice are not legislation themselves but statements of preferred practice or best practice which may be produced in courts as evidence of suitable means of compliance with the Act. They do not necessarily provide the only way of complying with the Act, but they do offer acceptable solutions. There are currently thirty health and safety ACoPs. In regards to occupational noise management in the workplace, there is only one, the 'Approved Code of Practice for the Management of Noise in the Workplace'. This ACoP was originally issued in 1996 and reviewed again in 2002 but has not since been updated and over 13 years have passed. As part of Schedule 1, 'Transitional and savings provisions' of the new HSW Act 2015, an ACoP issued under Section 20 of the HSE Act 1992 continues in force as if it had been made under this Act subject to any necessary modifications. Currently no amendments or modifications to this ACoP, has been published by Worksafe.

The ACoP for the 'Management of Noise in the Work Place' requires a preliminary assessment to identify the areas in a place of work where noise levels are likely to, or actually, exceed the exposure limits. The ACoP states the results of the preliminary assessment should determine which tasks, processes or areas in the workplace require detailed assessment. The approved codes states that preliminary assessments should be carried out when there has been no previous assessment, or when previous assessments are greater than 5 years old. Practically this means they should be carried out at least once every 5 years. Once the preliminary assessment is conducted a detailed assessment is required, this detailed assessment will among other things quantify the amount of noise to which employees are exposed, identify sources of noise and assist in developing noise control strategies and including if required, prescription of appropriate hearing protectors. The ACoP also stressed that follow up assessment should be required to monitor any change.

An important issue raised by the ACoP is that assessment work shall be carried out by 'Competent Persons'. The ACoP acknowledges that employers are not expected to become experts in noise or related areas however employers are expected to obtain the assistance of 'competent persons' with expertise in noise control and noise measurement and assessment. The ACoP states that examples of persons who possess competency through a combination of education, formal qualifications and experience are acoustic engineers. Further details on assessments and 'The competent person', can be found in Sections 6.2 and 6.3 of this paper.

3.6 New Zealand Standards for occupational noise

A 'New Zealand Standard' means a standard promulgated by the 'Standards Council' as a New Zealand Standard under the Standards Act. In essence, Standards are documents that provide requirements, specifications, and guidelines or benchmarks that, when applied correctly; promote consistency to ensure an agreed way of doing something, i.e. "standardisation". For example, standardised methods of measuring and assessing sound, if applied correctly, should produce consistent results.

The Australian Standard AS 1269 started out in 1989 with a single part titled 'Acoustics - Hearing conservation' as referenced in Regulation 11 of HSE Regulations 1995. It was withdrawn in 1998 and replaced by a far more comprehensive five part (0 to 4) standard on occupational noise management that was jointly adopted by both Australia and New Zealand as AS/NZS 1269:1998. All parts of the standard were updated in 2005 and part 4 on 'Auditory assessment' was updated in 2014.

AS/NZS 1269.0:2005 'Occupational noise management-

Overview', provides an overview and general requirements for the occupational noise management series AS/NZS 1269:2005. This standard sets out requirements for, and provides guidance on, the types of noise assessments which may be necessary and suitable noise measuring instruments to carry them out. The procedures for noise measurement are also included.

AS/NZS 1269.1:2005 'Occupational noise management-Measurement and assessment of noise immission and exposure', provides detailed information pertaining to the noise survey types and triggers. Section 6 of this Standard sets out the types of noise surveys: preliminary; detailed; follow up; or supplementary. The standard states that a preliminary assessment should be carried out if previous assessments are more than 5 years old as well as if any changes to the noise environment are made; generally the preliminary assessment is a walk through audit. It also states that detailed surveys are required if any employee is likely to be exposed to excessive noise (levels that exceed 85 dB $L_{Aeq,8h}$ or 140 dB L_{peak}). This is the 'trigger' for a detailed survey, the fact that after conducting a preliminary assessment that any employee is exposed to limits over that permitted in the legislation. AS/NZS 1269.1:2005 also notes that follow up or supplementary assessments should be taken at least every five years, or if for example there are changes for various factors such as new plant, layout changes or new production processes.

Overall the key objective of noise surveys are to guide and determine if employees are being exposure to excessive noise and if so, to obtain further detailed and specific survey information that will help reduce noise and ensure suitable engineering methods are adopted as well as assisting with planning and hearing conservation.

3.6.1 Instrumentation and calibration

Section 7 of AS/NZS 1269.1:2005 'Instrumentation and calibration', provides a guide for the instruments that may be used when performing occupational noise surveys and references the international standard for sound level meters, IEC 61672. Section 7.2 implies that an integrating averaging sound level meter should be used, the sound level meter should be at least Class 2/Type 2[1] and preferably Class 1/Type 1 but allows for the use of Class 2/Type 2 noting that any person using this instrument must allow for the reduced accuracy of this instrument. AS/NZS 1269.1:2005 also states that any acoustic testing should ensure, especially for Type 2/Class 2 that the instrument is capable of accurately measuring peak sound pressure levels. Overall the use of a Class 1/Type 1 with frequency analysis is recommended by the standard. Of importance, the standard also recommended observed measurement.

1 The 'Type' designation is not used in IEC 61672 but in earlier standards for sound level meters. Generally speaking the newer 'Class' designation provides stricter tolerance on performance of the instrument than the older historic 'Type' designation.

Section 7.3 of AS/NZS 1269.1:2005 covers the use of a personnel sound exposure meter (PSEM), also known as a dosimeter. The specification of PSEMs is defined in IEC 61252 (Electroacoustics - Specifications for personal sound exposure meters). Section 7.3 then goes on to state that the use of hand-held sound level meters by a competent person is preferred over PSEMs due to confounding issues. All the stated '*confounding issues*' relate to the unmonitored or uncontrolled use of these devices where the untrained wearer may shout across the microphone or tap the microphone or take it off for short periods. However, the use of PSEM in certain circumstances in preferred to hand-held meters and the stated 'confounding issues' can be suitably addressed by ensuing that the wearer of the PSEM is observed during the entire measurement period and sufficient detailed notes are recorded of the activities undertaken by the wearer. This would be consistent with best practice for making environmental noise measurements where observation is a key requirement. The last sentence in Section 7.3 confirms this by stating that if PSEMs are used, the wearer should be carefully monitored by a competent person to minimise any potential confounding issues.

Section 7.5 of AS/NZS 1269.1:2005 emphases the importance of the ability of the instrumentation to accurately measure peak sound pressure levels. While Class 2/Type 2 instruments can be used for preliminary assessment, Class 1/Type 1 should be used for detailed and follow-up assessments. The measurement of peak sound pressure levels are much more prone to confounding issues and by simply knocking or taping the microphone of an instrument can readily produce peak readings higher than 140 dB L_{peak}.

Section 7.6 of AS/NZS 1269.1:2005 specifies that the reference sound sources for field reference testing of the sound measuring instruments should be at least Class 2 and in accordance with IEC 60942. Section 7.10 covers the measuring system calibration and states that equipment should be calibrated in accordance with the relevant Standards at regular intervals not exceeding two years. In New Zealand the periodic testing of sound level meters and calibrators is undertaken in accordance with international standards, depending on the type of instrument being calibrated by laboratories that have quality assurance systems and calibration procedures independently accredited to the specific laboratory. All acoustic testing reports should include the calibration certificates.

3.6.2 Noise measurement procedures

Section 8 of AS/NZS 1269.1:2005, 'Noise measurement procedures', covers the type of instrumentation and measurement methodology and states that the analysis techniques used should be determined in accordance with the type of problem being assessed. It allows for

the use of two key measurement quantities for continuous noise exposure assessment. The traditional $L_{Aeq,T}$ or equivalent A-weighted sound pressure level (in dB) over the measurement period T and $E_{A,T}$, the A-weighted sound exposure (in Pascal-squared hours (Pa^2h)) over the measurement period T. This second measurement quantity (descriptor) E_A, is linear, so partial sound exposures can simply be added to produce the total sound exposure. Also, the $L_{Aeq,8h}$ sound level limit of 85 dB simply becomes 1.0 Pa^2h or 100% dose using this measurement quantity.

Section 8 also emphasises that there is always uncertainty in the measurements made but does not explicitly state how this should be handled. Section 8.2 on field reference level checking, says that if a discrepancy of more than +/- 0.5 dB (or +/-10% in the reference exposure reading) occurs between two successive checks, the measurements should be considered invalid. This is significantly tighter than normal practice for environmental noise assessment where a tolerance of +/-1.0 dB is used. There seems little scientific justification or benefit for such a tight tolerance, which if applied routinely, is likely to result in a significant number of measurements being treated as invalid, especially for dosimetry that is often occurs over many hours.

3.6.3 Noise evaluation and adjustments

Section 9 of AS/NZS 1269.1:2005, 'Noise Evaluation', covers the determination of key continuous noise quantities (descriptors) from the measurements. Section 9.1 emphasises that the preferred way to determine $E_{A,T}$ is to use a PSEM or integrating-averaging sound level meter and also shows the ease in which partial exposures can simply be added together to produce the total exposure and the average exposure over a 5-day working week. Sections 9.2-9.4 cover the determination of $L_{Aeq,T}$, converting it to an equivalent level over an 8-hour period and a normalised exposure level over a 5-day working week.

Section 9.4 provides detailed information on extended work-shifts and adjustments to normalised noise exposure level over an 8-hour work day. The standard states for work-shifts less than 10 hours, no adjustment is applied and for work shifts between 10 and 24 hours, up to +3 dB adjustment is applied. There is no equivalent adjustments stated when using sound exposure ($E_{A,T}$) as the descriptor but the dB values shown in Table 2 of the standard can be readily converted into a linear scalar. The +3 dB adjustment for work shifts between 20 and 24 hour would therefore become 2.0 multiplier for $E_{A,T}$.

3.6.4 Other Part of AS/NZS 1269

In addition to Parts 0 and 1 of AS/NZS 1269, there is Parts 2 to 4, summarised as follows:

- AS/NZS 1269.2:2005 'Occupational noise management-Noise control management'. This standard sets outs requirements and guidance on the management of noise control in occupational settings and applies to all types of workplaces and to all types of sounds.
- AS/NZS 1269.3:2005 'Occupational noise management-Hearing protector program'. This standard specifies administrative responsibilities associated with a hearing protector program; the selection, use and maintenance of various types of hearing protectors; and training and motivation in regard to hearing protector programs.
- AS/NZS 1269.4:2014 'Occupational noise management-Auditory assessment'. This standard supersedes AS/NZS 1269.4:2005 and is the most updated standard in the series which specifies procedures and requirements for air conduction pure tone audiometry (without masking) that are applicable to individuals whose hearing sensitivity might be adversely affected by occupational noise exposure and/or ototoxic agents (chemicals that can cause hearing impairment. It is understood that the relationship between these agents and exposure to hearing remain unclear and have not been altered to reduce hearing impairment risks. AS/NZS 1269.0:2005 'Occupational noise management- Overview' and related Appendix C provides further details on this topic.

3.6.5 Ultrasound and Infrasound in the workplace

Ultrasound is sound that is at a frequency above 20 kHz which humans cannot hear and Infrasound is at frequencies below 20 Hz that humans cannot hear but may feel as a vibration sensation. Exposure to ultrasound in the workplace would be limited to certain employment, such as medical practitioners and specialised fabrication. However infrasound exposure is likely to be more widespread, particularly for heavy goods vehicle drivers, workers at power plants or other heavy industries.

There are many international publications on both ultrasound and infrasound and guidelines exist internationally on safe exposure levels which it is believed adverse effects would not occur. Appendix H of the ACoP for the 'Management of Noise in the Workplace' provides comment on ultrasound and infrasound but the referenced technical reviews are now very outdated. Section 8.7 of AS/NZS 1269.1:2005 provides further guidance and comment on assessment of infrasound and ultrasound and recommend the use of one-third octave frequency measurements if there is a suspicion of exposure to infrasound or ultrasound. It also has a note to see 'AS/NZS 2243.5:2004 Safety in laboratories - Non-ionizing radiations - Electromagnetic, sound and ultrasound' for further guidance. This last Standard is of interest because Section '8.3.1 Effect of noise', states that these can include:

a) Temporary or permanent loss of hearing acuity;
b) Interference with speech and communication;
c) Disturbance of concentration tasks.

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And that "*...infrequent, single, extremely loud sounds can cause instantaneous, permanent hearing damage*". In Section '8.3.4 Disturbance of concentration tasks', it states that "*... various levels of background noise can disturb concentration... the more complex the task the greater the disturbance... keep levels below AS/NZS 2107, and these problems will not arise*". Then in the next Section '8.3.5 Low-frequency sound and infrasound non-auditory effects', it states that:

a) Low-frequency sound, up to 200 Hz can have non-auditory effects on the body;
b) At low levels, can lead to an individual feel unwell and can include feelings of nausea and headaches;
c) At high levels can result in physical damage;
d) Infra-sound is below 20 Hz...has similar non-auditory effects on the body to those of low-frequency sound.

This section concludes by saying see the guidelines for infra-sound exposure in the 'Approved code of practice for the management of noise in the workplace'.

3.7 Occupational noise mitigation and management hierarchy

The hierarchy of approaches explicit in the HSE Act 1992 are:

1. Significant hazards to employees are to be **eliminated** if practicable;
2. Significant hazards to employees are to be **isolated** where elimination impracticable;
3. Significant hazards to employees are to be **minimised**, and employees to be **protected**, only where elimination and isolation are impracticable (not before).

This hierarchy has been reinforced and extended under the 'Health and Safety at Work (General Risk and Workplace Management) Regulations 2016' (HSW-GRWM Regulations 2016), released 15 February 2016. These regulations introduce the detail to comply with the Health and safety duties - key principles of Section 30 of the HSW Act 2015 - Management of risk (s.30).

Duty to eliminate risks as far as reasonable practicable and if not possible:

- Risks are to be **minimised** as far as reasonably practicable ;
- Not transferable to another person;
- One person can have more than one duty;
- Must consult other persons with the same duty.

Clearly the elimination of any hazard must be the ultimate aim if at all reasonably practicable. The above regulations require a risk management process to be implemented in the minimisation of hazards.

- There is a duty to identify hazards (reg. 5)
- A hierarchy of control measures applies if not reasonably practicable to comply with (s.30) of HSW Act 2015, that is, eliminate risk, minimise risks to health and safety, implement control measures in accordance with this regulation by taking 1 or more of following (reg. 6):
  (a) substitution (wholly or partly) with something that gives rise to a lesser risk
  (b) isolating the hazard giving rise to the risk to prevent any person coming into contact
  (c) implementing engineering controls
  (d) if risk remains – implement administrative controls
  (e) if risk remains then personal protective clothing.
- There is a duty to maintain effective control measures fit for purpose and set up correctly (reg. 7) and duty to review control measures (reg. 8).
- There is a duty to provide information supervision training and instructions to workers (reg. 9).

Although the HSW Act 2105 does not mention noise as a hazard, the authors have assumed that under item (e) above 'personal protective clothing', that hearing protection devices would be part of *protective clothing*.

There are a host of methods that can be adopted in noise control at the design and planning stage. This includes design and specification of work spaces, areas and equipment ('buy quiet' [12]), through to location of plant, vents and so forth through the work areas. Once implemented, processes need to be put in place round maintenance of equipment and plant to ensure that sound pressure levels do not rise over time.

There are many cost effective administrative controls that may be effective in reducing the risk of NIHL and this includes signage in high noise areas where hearing protection is required and on-going staff training and education around noise hazards.

3.7.1 Selection of hearing protection devices

When controls measures cannot reduce noise exposure levels to comply with the lawful noise criteria, hearing protection will need to be used as part of the overview noise management programme. The primary criterion for selection of hearing protectors is that the continuous level of noise entering the ears is reduced to below 85 dB $L_{Aeq,8h}$. Appendices A and B of AS/NZS 1269.3:2005 cover methods for the selection of hearing protectors. It is important to correctly select hearing protectors that are not only effective in reducing the noise level, but are also compatible with the working environment, in particular use with any other protective equipment.

Section 6.2.2 of AS/NZS 1269.3:2005 covers the issue of over-protection and states that attention should be paid to the risk this presents where the wearer may feel isolated making it difficult to perceive useful sounds. In extreme cases over-protection has been one of several factors leading to death of employees who could not hear and thus were not aware of impending danger. Over-protecting

can lead to a number of secondary issues ,including employees not wearing or inconsistently wearing of the hearing protectors thus also potentially leading to hearing loss. The authors note from direct experience that over protection is common. Most employers in noisy environments simply provide protectors with the highest standard rating and are ignorant of the potential risks of over-protection. The guidance in AS/NZS 1269.3:2005 on how much is over protection is rather weak, with it simply stating that "*generally Leff of 70 dB(A) or less could lead to over-protection*". It would be better if the standard referenced some of the other international standards such as 'BS EN 458:2004 Hearing protectors', which specifies 75 dB L_{Aeq} as acceptable and 80 dB as a good target "*in-ear*" noise level.

Sections 7 to 9 of AS/NZS 1269.3:2005 cover the fitting of hearing protectors, cleaning and maintenance, and inspection for defects to ensure that once selected, the protectors continue to perform as expected.

The Appendix A of AS/NZS 1269.3:2005 covers the selection of hearing protectors based on their 'Class' rating. This method involves measuring and assessing workplace noise using the equivalent $L_{Aeq,8h}$ over the working shift and then selecting from a suitable protector by Class 1-5 (see table 1). An alternative selection method is detailed in AS/NZS 1270:2002 "Acoustics– Hearing Protectors", based on the SLC_{80} rating (see Section 3.7.2 below). This involves measuring and assessing workplace noise using the equivalent $L_{Ceq,8h}$ (**note** the use of C weighting here) over the working shift and subtracting off this the target "in-ear" noise level (e.g. 80 dB L_{Aeq}) to produce the required SLC_{80} value.

The following table shows the relationship between the calculated exposure level ($L_{Aeq,8h}$) and the 'Class' number and the corresponding SLC_{80} range.

Table 1: Hearing protector rating

Class	Calculated exposure $L_{Aeq,8h}$ (dB)	SLC_{80} range
1	< 90	10 to 13
2	90 to < 95	14 to 17
3	95 to < 100	18 to 21
4	100 to < 105	22 to 25
5	105 to < 110	26 or greater
	> 110	Seek expert advise

The Appendix B of AS/NZS 1269.3:2005 covers the selection of hearing protectors when the peak value, L_{peak} (note no frequency weighting specified) exceeds 140 dB. It states that "*there is no standard method for quantifying the attenuation of hearing protectors to impulse sound*". At the time of the writing of the standard that was true, however in 2010 the new standard 'ANSI/ASA S12.42-2010- *Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures*' was released. This enabled hearing protectors to be rated under impulse noise conditions. Measurements using this standard have shown that generally the attenuation of peak levels is higher than the attenuation of continuous levels for a given hearing protection device.

3.7.2 Rating of hearing protectors

Hearing protectors in New Zealand are tested in accordance with AS/NZS 1270:2002 "Acoustics– Hearing Protectors." Detailed test results are commonly found on the packaging of ear plugs and ear muffs and they will state if they are rated under this standard.

In New Zealand SLC_{80} is the method that is used to rate hearing protection devices and it is defined in the standard, AS/NZS 1270:2002 'Acoustics–Hearing protectors'. SLC stands for 'Sound Level Conversion' and the '80' in SLC_{80}, refers to the amount of protection attained by 80% of users when the protector is properly fitted and maintained. This is based upon laboratory testing involving multiple fittings of a batch of the same hearing protectors, producing an average and a standard-deviation

Figure 5: Sample of hearing protectors illustrating AS/NZS certified ratings

of the level of attenuation in octave frequency bands. These results are then combined to produce the single number SLC_{80} rating. It should be noted that the SLC_{80} rating is significantly lower than the *average* attenuation across all frequencies to ensure 80% protection for a population of wearers.

In addition to the SLC_{80} system, there are other rating systems used internationally. NRR is an American based value that stands for '*Noise Reduction Rating*'. It is determined in accordance with the standard ANSI 3.19:1974, and the calculation is very similar to SLC_{80}. The other common value is SNR, which stands for '*Single Number Rating*'. The SNR estimates attenuation performance according to the noise spectrum of the environment in which the protector is to be worn. This system rating number is used by the European Union and affiliated countries. The SNR rating descriptor is defined in ISO 4869-2 Acoustics – Hearing Protectors. It should be noted that both the NRR and SNR systems are not used in New Zealand and Australia but information accompanying hearing protector may include a rating under one or both of these systems as well as SLC_{80}.

4. HSW Act 2015 - Inspectors, Compliance and Enforcement

The HSE Act 1992 and the new HSW Act 2015, provide for accident investigations and set suitable powers for enforcement measures which range from notices, fines through to imprisonment. Section 163 (s.163) of the HSW Act 2015 defines an inspector as a person duly appointed by WorkSafe or any regulatory authority duly appointed by the Prime Minister (s.191). Criteria are detailed, but include an employee of the State (Government) Sector, statutory officer, or an employee of a regulator who is suitably qualified for the work involved. Like all inspectors/officers, they must have an ID card with appropriate details included, showing that they hold a certificate of appointment.

The powers of entry and inspection are set out in Section 168 (s.168) of the HSW Act 2015 and an inspector can enter any workplace at any reasonable time to carry out an inspection.

The Worksafe New Zealand webpage states:

"*...each year health and safety inspectors carry out 12,500 workplace assessments. These are proactive, planned visits and are not usually triggered by a report of serious harm or a health and safety complaint. At least 80% of workplace assessments are targeted to industries identified in the Health and Safety National Action Agenda 2010–2013 as high risk, which includes Agriculture, Forestry, Construction and Manufacturing*" [13].

The webpage then goes onto state:

"*...at least 1,000 Health and Safety and HSNO onsite investigations are undertaken by WorkSafe NZ each year. Investigations may be carried out to determine the causes of harm in the workplace, whether action has been taken or needs to be taken to prevent recurrence or where compliance or enforcement action [including prosecutions] may be required*" [13].

Of the fore mentioned workplace assessments, it is unclear from the data available how many of them were specifically for occupational noise.

Duties relating to exposure monitoring and health monitoring is covered under Part 3 of the HSW-GRWM Regulations 2016. Regulation 32 (reg. 32) states that "*exposure monitoring required by regulations, must be carried out*":

- At appropriate intervals or after significant change in work

- By or under the supervision of a competent person
- Must be kept for (asbestos) 40 years and 30 years others.
- Readily accessible to person who was exposed
- Must be kept confidential

5. Hearing conservation programmes compared to Noise management programmes

Hearing conservation programmes are designed primarily to protect individuals in noisy occupational settings from developing NIHL. Programmes normally including noise monitoring, the use of hearing protectors, audiometric testing, training and recording keeping.

The conservation programs usually begin with a noise survey of the workspace to establish exposure levels and identification of 'noise hazard areas', along with the use of personal hearing protectors and education and some form of engineering noise control. This is undertaken in conjunction with regular and standardised audiometry administered to all noise-exposed personnel, the results of which are monitored to identify any threshold shift to evaluate the effectiveness of the program [14].

Dobie [15] conducted a methodological analysis of the efficacy of programmes including hearing conservation programmes and found a number of shortcomings which led him to conclude that:

> "*Although noise reduction for individuals obviously can prevent noise-induced hearing loss, to my knowledge, no single study offers convincing evidence of the efficacy of occupational hearing conservation programs, primarily due to methodologic flaws.*"

In addition to Dobie's findings, other experts also acknowledge that while conservation programmes are effective at identifying, monitoring and lessening the severity of noise exposure, they cannot be considered a total and perfect solution. It should also be noted that such programs are only effective when implemented well and there is much scope for error, such as incorrect measurements and incorrect use of hearing protection.

Many experts, including the authors, view hearing conservation programmes based on assessment of hearing damage (audiometry or otherwise) as a remedial method to reduce the severity of potential NIHL, rather than as a proactive measure to prevent it from occurring in the first place.

Noise management programmes differ from hearing conservation programmes in that management programmes are based on the control of noise exposure across all levels with the primarily goal being to eliminate noise first, followed by exposure reductions via the use of hearing protection only when higher level elimination strategies are not yet implemented.

This is the exact approach in the duties of HSE Act 1992 and the new HSW Act 2015, which require identification of hazards, followed by elimination, isolation and then hearing protection if other measure are not reasonably practicable. Similarly this is the same approach suggested in the New Zealand Standards for 'Occupational Noise Management' series AS/NZS 1269. Waugh [16] reports that overall it would appear that there is a trend internationally to shift from a focus on 'hearing conservation' programmes to 'noise management' programmes in order to provide the conceptual change required to further develop the avoidance of dangerous noise exposure in the workplace.

We note of concern however that first-hand experience by the authors shows that some employers or Health and Safety Personnel believe that adopting hearing conservation programmes is the only requirement under the HSE Act 1992 (and now the HSW Act 2015). They often believe that going straight to hearing protection, satisfies there requirements as employers under the Act. General evidence suggests this is probably the case due to a misunderstanding of their responsibilities under the Act. While in other cases some employees do not wish to spend the time and funds on a hearing management programme, this being one of the reasons they choose to only adopt hearing protection and not other measures.

Legislation concerning occupational noise exposure as well the ACoP and other guidelines, are relatively easy to source. The exception here would be the AS/NZ 1269 series of standard that currently require them to be purchased at a total cost of about $630.

New Zealand legislation on occupational noise exposure is in line with international best practice however the author's first-hand experience is that the implementation and enforcement of this legislation may be insufficient due to a number of issues including (but not limited to):

- Education of both employers and employees regarding their requirements under the HSE Act 1992 and the HSE Regulations 1995.
- Education of both employers and employees regarding 'competent persons' to undertaken work in occupational noise assessment
- Attitudes and cultural behaviours (attitude issues can range from safe work place attitude through to various other things such as hearing protection being viewed as not being required)
- Resources and willingness to invest in occupational noise, noting that for small business, in particular those with less than ten employees; they are much more likely to bear greater costs per employee than larger businesses
- Resources for those responsible for enforcement and a willingness to ensure existing regulations.

6. Health and safety training

In regards to general health and safety training, there are a host of service providers ranging from industry training organisations (ITOs) delivering courses that achieve New Zealand Qualifications Authority (NZQA) Unit Standards in occupational health and safety practice, through to certificates, diplomas and degree levels courses at Universities.

Section 13 (s.13) duties under the HSE Act 1992 includes providing training, and in Section 19G, the '*Minister may approve occupational health and safety training*'. Part 1 of Section 19G states that the Minister may approve, by notice in the Gazette, courses of occupational health and safety training to be carried out at a place of work or elsewhere. Part 2 states that these courses may be approved only if the Minister is satisfied that the course is:

(a) consistent with the object of the Act; and
(b) relevant to the role of a health and safety representative.

The recently introduced Health and Safety at Work (Worker Engagement, Participation, and Representation) Regulations 2016 (HSW-WEPR Regulations 2016) covers "*training about work health and safety*". Part 1, 'Preliminary provisions', states that "*additional training*" means:

(a) that is within the occupational health and safety subfield of the New Zealand Qualifications Framework; or
(b) that the PCBU and the health and safety representative agree is relevant to the health and safety representative's role.

It also has provisions for an "*annual training entitlement*" and that "*initial training*" means training that covers content required to achieve the New Zealand Qualifications Authority (NZQA) Unit standard 29315 [17]. This is a new unit standard, entitled '*Describe the role and functions of the Health and Safety Representative in a New Zealand workplace*' dated 18th February 2016. It replaces unit standard 20198, titled '*Identify the roles and responsibilities of the health and safety representative in the workplace*'. The new unit standard is listed as Level 3 ('Some operational and theoretical knowledge in a field of work or study') and of 2 credits value whereas the previous unit standard was at Level 4 ('Broad operational and theoretical knowledge in a field of work or study') and of 8 credits. This means that initial training about work health and safety is at a lower level and less substantial than previously. However Section 21 (s.21) of HSW-WEPR Regulations 2016 states that "*a health and safety representative must complete initial training*", so it is compulsory for PCBUs that have a health and safety representative.

6.1 Current occupational noise, health and safety training

There are many reasons why in the context of health and safety that occupational noise is often a very low priority for many businesses. However, there is no lack of groups in New Zealand which require training in occupational noise. This includes various stakeholders such as employers and employees who are likely to be or are exposed to noise levels above permitted exposure limits on a day-to-day basis, delegated health and safety officers/representatives (the language under the HSW Act 2015) through to persons purchasing plant, to the simple acquisition of hearing protection. It is clear the requirements of each of these groups are diverse and hence any content and methods of training, including for occupational noise must be tailored to meet the specific needs of the groups, who in many cases will be lay persons.

It is the author's view that a pragmatic approach to education about occupational noise is required. It is also important that occupational noise courses should ensure that limitations of the training are made clear and that a person conducting a limited broad one or two day course is not going to have sufficient training compared to someone doing a detailed or specialist course.

There appears to be some large gaps relating to education and training in occupational noise. Occupational noise can be broadly defined as two branches; acoustic consultants/engineers and health professionals/specialists usually dealing with auditory assessment. It would be unusual for someone to be qualified in both these areas of expertise. However, direct evidence from experience by the authors shows that health professionals such as occupational health nurses or occupational hygienist conducting various occupational noise assessments are also conducting acoustic workplace reviews and providing advice on acoustic engineering. In such situations often very basic mistakes are being made, such as persons advising their clients of incorrect hearing protection (often leading to over-protection) through to inaccurate measurement or assessment or over engineering solutions for noise control. Ultimately poor or incorrect advice can cost employers significant time and money or place employees at risk.

A real concern is that currently there appears to be no standardised qualifications, competence standards or practicing certifications that must be achieved before practice in a subject area can be undertaken for occupational noise. This creates issues for employers wanting to engage professionals as generally they may not be aware of the level of competence or qualification held by someone practicing under a certain title.

One concern if the current system required formalised certification and registration, is that this would result in higher costs to employers. Compliance costs associated with a performance based framework generally do not fall equally on all businesses and small businesses (say < 10 employees) are likely to disproportionally bear greater costs per employee than larger businesses. However, small businesses can in principal contract suitably qualified

professionals on as-need-to basis as opposed to having in-house staff complete the work.

From direct observation of the authors, larger organisations (including both government and non-government organisations) are able to address occupational noise issues through the organisations structure, culture and health and safety processes. For smaller companies, often they cannot afford such health and safety 'infrastructure' and there may be little willingness to put it in place 'standard operating procedures' unless they are forced to.

6.2 The Competent Person

In regards to workplace noise, Section 8 of the ACoP for the 'Management of Noise in the Workplace' sets out requirements for training and education. *Appendix B* of the ACoP, titled "*The Competent Person*", clearly differentiates between persons conducing noise assessments and those performing audiometric testing.

The ACoP states under *Appendix B1* that people carrying out acoustic assessments shall be able to demonstrate a thorough understanding of a host of issues, this includes but is not limited to an understand of acoustics and the physics of sound, correct application and use of sound level meter, correct understanding and application of relevant statutory requirements, codes of practice and standards used in New Zealand through to principles of engineering noise control and noise management measures. The list set out in the ACoP is detailed.

Many experts acknowledge from the outset of an assessment and review of an employee's noise exposure that audiometry (that is, audiometric testing) should be given equal weight with any noise exposure assessment which requires accurate knowledge of both noise level assessment and assessment of noise exposure histories. The term '*audiometry*' comes from the latin term 'audre' meaning to "to hear" and 'metria', "to measure". Audiometry is itself a specialist branch of Audiology, the wider field concerned hearing disorders, including evaluation of hearing function and rehabilitation of patients with hearing impairments. Audiometric ('*hearing*') testing is very important as it is the only tool that can verify the success of hearing conservation programme.

In regards to audiometric testing, Section 7 and Appendix B.2 of the ACoP defines what a "Competent Person" is for both noise measurement and audiometric testing and states that "*most employers will need to employ or engage a competent person to do this work for them*". Appendix B.2 '*Audiometric Testing*' states that:

> "*Audiometric testing for the purposes of the Act may only be carried out by a person who has received proper training in basic pure tone audiometry. The level of training, education and experience required of the tester may be specified by the Occupational Safety and Health Service of the Department of Labour and may include a licence, approval or accreditation system with associated time frames*".

It is unclear however that if this actually occurs. Furthermore, it is unclear as to why the ACoP does not require the same level of competency and licensing requirements for noise assessment. It should be noted that where a detailed noise assessment shows noise levels to be above the exposure limits, or for any reason it is assumed the noise level exceeds the exposure limits, an employer must gain the informed consent of employees exposed to noise to carry out audiometric tests and the employer must then arrange for those audiometric tests to be carried out. This testing is required by Section 10 (s.10) of the HSE Act 1992. For the purposes of audiometric testing, an employee exposed to noise above the exposure limits means the direct measured noise and not the noise level with attenuation by hearing protection.

6.3 Towards a Competent Person for occupational noise

Both the ACoP for the 'Management of Noise in the Workplace' and AS/NZS 1269.1:2005 'Occupational noise management-Measurement and assessment of noise immission and exposure' (Appendix B) provide information and definitions around a competent persons training and what minimum skill set they should have. However, in both these documents, there is no clear definition of what constitutes a 'competent person'.

In the first round of regulations released supporting the HSW Act 2015, the HSW-GRWM Regulations 2016 implies that a competent person is one "*who has sufficient knowledge, skills, and experience in the appropriate techniques and procedures, including the interpretation of results*". But this is hardly a robust or comprehensive definition.

A possible definition for the competent person for occupational noise assessment is:

> '*A competent person in the context of occupational noise assessment means a person whom has acquired suitable knowledge and skills, through a combination of formal training, education and direct field practice and experience that enables that person to correctly perform a specified task required in providing occupational noise assessment*'.

The level of competence required will depend on the complexity of the situation and hence even a qualified competent person should ensure they exercise their technical skills and judgment to ensure that they are not misrepresenting their level of competence. They should disclose up-front the limits of their expertise and should not undertake work outside their actual area(s) of expertise. Members of the Acoustic Society of New Zealand are required under the 'Rules and Code of Conduct for Members' to ensure they exercise their professional and technical skill with careful judgement. Rule 5.0 of the '*Rules of Conduct and Disciplinary Measures for the Acoustical Society of New Zealand*' specifically notes that "*No member*

shall misrepresent their competence nor, without disclosing its limits, undertake work outside their area(s) of expertise".

It follows that in order for someone to be competent they must first be trained by competent and experienced persons. Acoustics and the science of sound is a technical field and hence poor training or limited training could be detrimental, especially if a person believes they are more of an expert that that actually are. Generally because the science of acoustics is a complex subject area, a longer duration course of training is required to ensure someone is competent.

6.3.1 Courses available in occupational noise

Industrial/Occupational hygienist's in New Zealand can obtain an internationally accredited intermediate level qualification that includes the core subject: W503 'Noise - Measurement and its Effects' [18]. The documentation states that "*these are designed as 5-day taught courses that provide practical, hands-on training. Students are taught in small groups by Approved Training Providers*". When delivered in New Zealand this subject is nationalised to the Standards and procedures of New Zealand. A recent review by the authors of the subject course book showed that it is somewhat outdated and in need of revision. Although the course coverage appears adequate, it is unlikely that sufficient competency, especially practical competency, would be achieved in such a short time frame.

Environmental noise assessment is a key competency required for Environmental Health Officer (EHO) roles. Currently only two tertiary providers in New Zealand provide degree level qualifications that are accepted under that 'Environmental Health Officers Qualifications Regulations 1993' [19]. Of these two providers, only Massey University includes a full course ('paper') on noise measurement and assessment. This course is at 300-level and covers: theory and practice; legislation and standards concerning noise and vibration in terms of the health effects; and involves significant practice field work. The course has evolved over many years to now include both environmental and occupational noise measurement and assessment in significant detail. In total, students spend about 150 hours doing this course and the compulsory assessments. However, the course coordinator does not consider this to be adequate to meet the competencies of Appendix B.1 of the ACoP for the 'Management of Noise in the Workplace'. Recently Massey University trialled a professional extension to the noise course with the aim of formally achieving Appendix B.1 'The Competent person' status. The main thrust of this extension course was to develop experience and practical competencies in carrying out noise assessment in a range of different real-world, complex workplace scenarios. The course participants were also required to develop and deliver an education and training course for at risk workers in their workplace.

7. National budget for health and safety

The National Occupational Health and Safety Advisory Council (NOHSAC) Technical Report 7 [8], Part V, advises that as of 2005, the national budget for occupational health and safety activities is approximately $47 million. This report states that approximately $37 million of this funding is provided through the Department of Labour for compliance and enforcement services with a further $10 million being provided to the Accident Compensation Corporation (ACC) for injury prevention activities. The report notes that the amount of funding provided to prevent workplace harm appears to be significantly less than what may actually be required to address these issues. For example, it is reported that the cost of injury amounts to approximately 3.4 % of New Zealand's Gross Domestic Product (GDP) while the expenditure to prevent such harm amounts to less than a hundredth of that (0.0033 %).

The predicted budget 2014-2015 for the occupational health and safety activities of Worksafe NZ for was $85 million [20]. However, there is currently no information available on what portion of this was used for activities involving occupational noise.

7.1 The cost of workplace noise

In New Zealand it is difficult to identify exactly how many people are affected by NIHL and how many are at potential risk of developing it. Between 1992 and 1998 in New Zealand there were around 2,400 validated cases (95 % male) of NIHL reported to the 'Notifiable Occupational Diseases System' (NODS), a voluntary register maintained by the Occupational Health and Safety Service [21]. From 1998 to 2000 Statistics New Zealand reported that there were a further 709 notifications. While these are voluntary reports and cannot be taken as a reliable indication of the actual prevalence of occupational NIHL, they do place NIHL as the second most *voluntarily* reported occupational disease in the country (after 'occupational overuse syndrome/osteoarthritis') and with more cases reported than all the remaining categories of occupational diseases combined [10]. In researching available data, one study [10] states that in 2004/05 around eleven New Zealanders were successfully in claiming ACC compensation for a new case of NIHL each day. This same study states that over the last decade ACC has met 28,805 claims for NIHL, at a total cost of about $218 million. Furthermore, over the last decade the cost of NIHL has increased by an average of 20 % each year.

There appears to be a crossover of data provided for workplace noise cost on both government agency webpages, for example the MBIE webpage has a link to a 'Department of Labour' document from 2007 [22] that states the following figures:

- Current ACC statistics indicate that total costs of noise induced hearing loss to New Zealand exceeds $40 million per year (double that of 5 years ago).
- About 4000 new serious injury claims are made to the ACC annually, which about eleven (11) new claims every day.
- Noise induced hearing damage appears in the top five (5) of all claims.

A publication titled 'Classified Hearing Protectors Booklet' dated March 2013 [23] prepared by MBIE, also states that:

"*Between July 2007 and June 2008, ACC received 4,865 new claims for noise induced hearing loss. The sectors with the highest claim rates were agriculture, forestry and fishing (1,145 claims) and manufacturing (1,109 claims), construction (851 claims)*".

Statistics New Zealand's webpage provides annual statistics of work-related injury claims which include NIHL but these statistics appear to be outdated and hard to find, as the statistics are included in larger groups such as 'cause of injury' including the entire '*workplace*'.

One of the most recent pieces of literature able to be sourced as part of this review was a paper titled "*Epidemiology of noise-induced hearing loss in New Zealand*" prepared by a panel of medical experts for the Journal of the New Zealand Medical Association [24]. This review paper states:

"*There is currently no reliable information regarding the overall incidence and prevalence of NIHL in New Zealand. ACC data reveals a substantial increase in the number of new NIHL claims annually, rising from 2823 in July 1995–June 1996, to 5580 in July 2005–June 2006. Together with ongoing claims the overall costs of NIHL claims increased by an average of 20% each year (a six-fold increase over the decade) resulting in a total cost to ACC of $194 million over the review period. Collectively, agriculture and fisheries workers, trades workers, machine operators, and assemblers accounted for 53% of new claims. Most claims were lodged in middle age or later, with the vast majority of claimants (95%) being men. The relationship of age with the probability of making a claim changed significantly over the study period with rates in older age groups increasing faster than in younger*".

The conclusion of the review paper states the "*substantial and increasing societal costs despite decades of NIHL control legislation suggests that current strategies addressing this problem are not effective, inadequately implemented, or both*".

Many employers may consider their obligations to undertake noise assessment surveys to be high without even starting to consider potential obligations of noise control or even the ongoing costs of exposing employees to excessive noise. The actual cost of NIHL is commonly referenced in monetary terms which do not include social costs or potential future costs, meaning that the actual real life cost of noise induced hearing loss goes well beyond the simple dollar amounts. Examples range from the low end where someone could sleep in as they have trouble hearing there alarm clock, through too more serious risks where an employee cannot hear a warning signal and this leads to a potential or even fatal accident. Interesting high pitch sound from such a warning device would also be hard to hear with the presence of NIHL such as on a moving crane would also likely directional and the directional 'cues' that help us locate danger the source of a sound. NIHL loss also has social costs the fact the "consonant" sounds of human speech, which help separate words into syllables and hence make communication frustrating. Further without the full function of hearing voices particularly those of women and children become muffled. The isolation people can also experience can lead to serious stress-related illnesses, withdrawal from the friends and family as well as a shying away from social activities. Noise Induced hearing loss is a potential accident risk and a serious quality of life issue. Fortunately it can be avoided; unfortunately it cannot be reversed or treated.

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AS/NZS 1269.0:2005 'Occupational noise management-Overview' states in Section 4.0 'occupational management' that "*for some workplaces reducing noise levels may require the application of noise management policies, planning and budging over a number of years.*"

The authors view from first-hand experience is that one of the many reasons occupational noise and its management is so hard to convince some employers and employees to take seriously is on a day to day basic (even after working in workplaces with excessive noise) a person's hearing seems to be same when they wake up as when they went to sleep that evening further more unless there is some sort of temporary threshold shift there seems to be no actual change in hearing, and unlike other workplace accidents where you may be exposed to discomfort or pain noise induced hearing loss takes years to manifest. The perverse outcome of this is that people who don't take it seriously will eventually notice a change but by the time this starts to manifest the damage is already permanent.

8. Qualification of this review

This review is intended as a guide only, it is not intended to be surrogate expert advice from a professional. The reader and users should further understand that the information within this review does not attempt to cover all areas and applications and therefore there are omissions.

While all care has been taken in the preparation of this work and the information which is included is believed to be correct at the time of preparation, users of this paper should apply discretion and rely on their own judgements regarding the use of the above information. It may be necessary to obtain independent professional advice from a suitably qualified and experienced acoustician or acoustic engineer.

It is not considered appropriate for the user to simply rely on the contents of this review without reading the contents of the relative legislation, New Zealand Standards, Approved Codes of Conduct or any related documents themselves.

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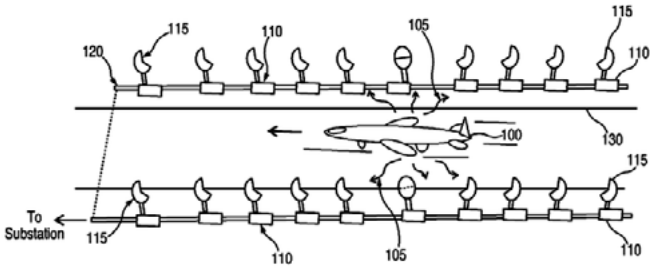
Portland, OR for short, was recently declared the quietest place on the face of the planet by the Guinness Book of World Records.

Independent tests carried out showed a background noise reading of -20.6 dB L_{Aeq}! Yes negative 20.6 dB! It may appear that it is impossible to measure below 0 dB but decibels are a ratio of two numbers and the value used to set the zero point in noise measurement is $20x10^{-6}$ Pascals thus if the change in pressure measured is less than this, you will get a negative dB value. For comparison the quietest point physically possible to be reached on our little blue planet, is set theoretically at -23 dB, which takes into account only the sound created by air molecules as they interact with one another. Find out more: http://news.microsoft.com/stories/building87/audio-lab.php

Will Boeing's Plan to Turn Jet Engine Noise Into Electricity Work?



Public health experts have always been concerned with mitigating the loud noise produced by aircraft. Boeing has an idea to do something useful with all that excess acoustic energy: Turn it into power for the people! For further information, see: www.inverse.com/article/6435-boeing-s-plan-to-turn-jet-engine-noise-into-electricity

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Foo Fighters frontman David Grohl takes on a local English council

The Foo Fighters frontman did just that by writing a letter of support addressed to the Cornwall City Council, and he also posted the missive on Twitter.

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Noise sources, exposures and controls in small enterprises in New Zealand

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Abstract

There is little published data on noise sources related to occupational exposures, particularly in relation to small enterprises (SE's). Most published sound level surveys focus more on exposures and controls and provide little detailed evaluation of noise sources and transmission paths. This paper describes a multiple case study designed to identify, describe and evaluate noise exposures, sources, paths and control strategies used by 30 SE's (employee count less than 20) in "high", "moderate" and "low" risk industry sectors in New Zealand.

Data collection involved workplace observations, noise assessments, semi-structured interviews, self-administered questionnaires, and reference to archival data. In addition to sound level measurements in work areas and personal dosimetry, assessments of each SE's conformance to current noise management standards were undertaken.

Area and personal sound level exposures were found to vary considerably within the "high risk" (agriculture, manufacturing and construction; range 80 - 90 dB $L_{Aeq,8h}$), "moderate risk" (cafes and restaurants; range 60 – 75 dB $L_{Aeq,8h}$) and "low risk" sectors (pre-schools; range 70 - 80 dB $L_{Aeq,8h}$). Generally noise sources and paths could be readily identified in the workplaces. The predominant noise control strategy in 90% of the industry sectors was minimisation, specifically the use of personal hearing protection. In most cases, noise management strategies aimed at the noise source and noise paths could have been investigated further by the management of the small business.

The findings suggest that there needs to be significant changes in expectations with respect to noise management practices and solutions for small enterprises in particular. In addition, national strategies on the prevention of noise-induced hearing loss (NIHL) need to be designed from a small business perspective and where noise management interventions are seen as a benefit to the enterprise rather than a cost.

Keywords: Noise exposure, sources, noise controls, compliance, small business

Original peer-reviewed article

1. Introduction

There is little published data on noise sources related to occupational exposures, particularly in relation to small enterprises (SE's). Most published sound level surveys focus more on exposures and controls and provide little detailed evaluation of noise sources and transmission paths. Sound level surveys that have identified noise sources are industry specific and include data from agriculture [1,2]; construction [3,4]; manufacturing [5,6], saw mills [7,8,]; mining [9] and energy [10].

In New Zealand it is difficult to identify exactly how many people are exposed to excessive noise, how many are at risk and how many are affected by noise-induced hearing loss (NIHL) [11]. It has been estimated that approximately one quarter of the New Zealand workforce of 1.47 million workers are affected to some degree by harmful noise at work [2]. Estimates of the prevalence of NIHL (≥ 25 $dBHL_{Ave\ 1,2,3,4\ kHz}$[1]) in the NZ workforce, in 2006, range from 29,242 (based on the WHO calculations) to 42,497 [12]. Extrapolation of the workforce data gives an estimate of the prevalence of NIHL (≥ 25 $dBHL_{Ave\ 1,2,3,4\ kHz}$) in the NZ population, in 2006, range from 62,169 (based on the WHO calculations) to 69,613 [12]. Based on these population data it is estimated that between 1.54 and 1.73% of the New Zealand population had a hearing loss that is solely due to occupational noise exposure. This gives an incidence in the workforce ranging from 1077 to 1537 new cases of NIHL in 2006.

It is also estimated that a large proportion of those exposed workers are employed in small enterprises [13]. The most recent data indicate that 97% of enterprises in agriculture, 92% in manufacturing, 98% in construction,

1 dBHL = decibels Hearing Loss; the dB level relative to the quietest sounds that a young healthy individual ought to be able to hear. In this case the value used was the average over the frequencies of 1,2,3,4 kHz.

92 % in hospitality and 75 % of enterprises in education employ less than 20 employees [14].

The international legislative requirements for control of exposure to noise tend to translate into a requirement to conduct preliminary noise surveys to identify possible hazards followed by detailed sound level surveys of identified noise hazards to assess if they are a significant risk. After this, employers are required to investigate, and if practicable, control the noise at the source and isolate noise sources away from employees. Where it is considered not practicable to eliminate or isolate the hazardous noise source, employers must provide approved hearing protection.

The primary objective of this study was to determine the nature and effectiveness of interventions currently used in small enterprises to control exposure to noise and the incidence of NIHL and identify the barriers to the implementation of noise management strategies and programmes. A secondary objective was to determine whether identified "high-risk" sectors and occupations conform to current industry recommendations and standards (e.g. Codes of Practice) to prevent NIHL.

2. Method

2.1. Study design

A multiple case study design was used to identify, describe and evaluate intervention/ control strategies used by 33 "high risk", "moderate risk" and "low risk" industries in relation to exposure to noise and the incidence and/ or severity of NIHL. Data collection included site visits to identify existing noise control strategies, barriers to adoption of controls, and critical factors that need to be considered when designing and implementing effective noise control interventions.

The industry sectors included in this study were: high risk – agriculture ([2]ANZSIC 0161 diary), manufacturing (ANZSIC 1211 beverages, 1340 knitted products, 1411 sawmilling, 1491 wood products, 2221 steel fabrication) and construction (ANZSIC 3019 residential construction); moderate risk - hospitality (ANZSIC 4511 café and restaurants), and low risk – education (ANZSIC 8010 preschool). These sectors were chosen with reference to the data provided by earlier studies [15] that identified specific industry sectors based on their ACC claims experience for noise induced hearing loss; ACC and Department of Labour target industry sectors for excessive exposure to noise and recommendations from the stakeholder group (comprising industry, enforcement agencies and research administration representatives).

2.2. Data collection and analysis

A combination of quantitative and qualitative techniques was used in the collection of primary and secondary data. The techniques used were workplace observations, noise exposure assessments, semi-structured interviews, self-administered questionnaires, and reference to archival data. Each organisation recruited to participate in the survey was visited and information collected about the organisations included details of work and work areas, existing noise sources and control strategies, and options for reducing noise. Data on exposure to noise were collected including area sound levels and personal sound exposures (noise dosimetry). Observational, interview and archival data were also collected on the extent to which organisations were complying with recommendations (e.g. Approved Code of Practice for the Management of Noise in the Workplace) [16] to prevent NIHL. A 10-point checklist was developed and coded 1 for each item where there was evidence that the requirement had been met, otherwise 0. Scores were summed giving each organisation a score from 0-10.

The sound level surveys used Rion type NA14 sound level meters and Cirrus Research noise doseBadges. A "walk through' survey identified the most noisy areas and activities and these area samples reflected a "worse case" scenario. Sound levels were undertaken in accordance with the standard methods detailed in the Approved Code

2 The Australian and New Zealand Standard Industrial Classification (ANZSIC) was developed by Statistics New Zealand and the Australian Bureau of Statistics to reflect the structure of Australian and New Zealand industries and improve the comparability with other countries' statistics.

of Practice for the Management of Noise (2002) and AS/NZS 1269, 1998: Part 1 Measurement and assessment of noise immission and exposure [17]. All sound level meters complied with the requirements of AS 1259.1 (IEC 60651) and/or AS 1259.2 (IEC 60804). Sound exposure meters and doseBadges complied with the requirements of IEC 601252. Reference sound sources (calibrators) complied with Class 2 specifications of IEC 60942. Where each workplace provided a range of sound levels, the median time average levels were included for analysis to account for outliers.

3.1. Noise sources, paths and controls

An analysis of noise sources and paths in the workplaces found that for the high risk industry sectors, the sources were primarily due to impact noise; rotational noise due to machinery, gears, conveyers and electric motors; engine noise; high frequency pneumatic noise due to hydraulic equipment and operations; pipe noise due to turbulent flow within pressurized steam lines; compressor noise and alarm noise due to operational alarm activation. For the medium and low risk sectors, noise sources tended to be related to the task, activity and equipment being used and the interaction of other, usually external sources of noise not directly related to the workplace such as traffic noise.

Identification of noise paths in relation to the noise sources was complex as it included indoor and outdoor environments. However, airborne paths were the primary route for noise, with some cases of structure-borne and duct-borne noise/vibration transmission. Agriculture, construction and saw milling sound sources and paths were similar in the fact that sound from many key activities, tasks and use of equipment and machinery were generated and transmitted in outdoor environments. This is opposed to the other traditional manufacturing sectors (bottling, textile, engineering) where key activities, tasks and machinery and equipment use were usually undertaken within a building structure (indoor), where structure borne sound transmission became more evident.

The predominant noise control strategy in the majority of organisations surveyed was that of protection specifically, the use of personal hearing protection. Of the 33 organisations assessed, twenty (20) had explored options for elimination and isolation of noise sources. Of those, only four businesses had undertaken modifications or replacement of equipment, which resulted in a self-reported reduction of noise exposure in the workplace. The remaining businesses (16) had not pursued these control options. Administrative controls were not used in any of the organisations surveyed.

3.2. Exposure to noise and personal sound exposure (dose) measurements

Table 1 summarises details of the workplaces' median $L_{Aeq,8h}$ and L_{Cpeak} levels, dose estimates and percentage of work areas equal to (=) or greater (>) than 85 dB. Of the "high" risk industry sectors, wood processing, sawmills, engineering manufacturing sites and construction operations experienced the highest time average levels with median $L_{Aeq,8h}$ values of 95 dB, 92 dB and 90 dB respectively. Median L_{Cpeak} levels were also high at 130 dB, 125 dB and 120 dB. Farms included in the agricultural sector surveys had median $L_{Aeq,8h}$ values of 85 dB, and median L_{Cpeak} level of 115 dB. The remaining high risk industry sectors surveyed (agriculture, bottling and textile industry) had median $L_{Aeq,8h}$ values of 85 dB, 83 dB and 80 dB, and median L_{Cpeak} level of 115 dB, 105 dB and 100 dB respectively.

Noise dose estimates for employees working in these businesses are detailed in Table 1, and indicate a very wide range of personal exposures (10-600 %), with wood processing and sawmills, engineering and construction operations experiencing the highest dose and widest dose range. The medium risk industry sector (hospitality, specifically cafes) surveyed had a median $L_{Aeq,8h}$ values of 74 dB, and median L_{Cpeak} level of 105 dB. Noise dose estimates for cafes employees ranged between 8-26 %.

The low risk industry sector (preschools) had median $L_{Aeq,8h}$ values of 70 dB, and median L_{Cpeak} level of 110 dB. However, the noise dose estimate ranges for employees working in preschools (4-98 %) was very large in comparison to café measurements. Two employees in preschool facilities had daily dose estimates of 194 % and 316 %. These values were outliers and were excluded from the analysis in Table 1.

3.3. Noise control conformance assessment

This assessment audited employers and employees responsibilities under the Health and Safety in Employment Act 1992 with respect to noise, utilising the Approved Code of Practice for the Management of Noise in the Workplace [16]. Data was collected through semi structured interviews, observational data and investigation of archival data and information. Conformance values ranged from 0 to 6 out of 10, with the median 2 and mean 1.9 (SD 1.7).

The conformance element most commonly addressed was the provision of personal hearing protection (element 6), followed by the requirement to investigate and if practical, control noise at source (element 4). A number (16 of the 20) did indicate that they had investigated control at source options, but had not pursued these options. The reasons most commonly given for not pursuing these was cost of putting in controls or replacement equipment and technical expertise on how to reduce noise further. Nine of the 33 businesses had undertaken some form of preliminary noise survey (element 2), although only 2 businesses could provide documentation that the surveys had been carried out. Five businesses indicated they had provided information on noise to employees (element 9) as part of their hazard management programme.

Table 1: Summary of sound levels and dose estimates of workplace surveys by industry sector

	Agriculture / Dairy	Manufacturing				Construction	Hospitality Cafes	Education Preschool
		Bottling	Engineering	Textile	Sawmills			
# workplaces	4	3	3	3	8	3	4	5
# work areas	9	10	10	6	10	6	10	10
Median $L_{Aeq,8h}$ (dB)	85	83	92	80	95	90	74	70 *
Median L_{Cpeak} (dB)	115	105	125	100	130	120	105	110
Dose range (%)	70 – 125	10 – 147	10 – 588	10 – 50	60 – 600	30 – 400	8 – 26	4 – 98 *
Median dose (%)	89	72.5	227	27	400	200	13	23 *
% work areas ≥ 85 dB $L_{Aeq,8h}$	55	30	80	0	90	66	0	0

* Range excludes recorded dose values for two subjects of 194% and 316% (outliers)

Less than 10 % of the businesses undertook audiometry of employees, isolated noise sources or had notified the Department of Labour of a hearing loss case (elements, 7, 5 and 8). As a consequence only two businesses were evaluated as taking all practical steps to provide a safe place of work.

With few exceptions, there was insufficient evidence that the key requirements of the Approved Code were being met. Noise tended to be identified as an issue by management and employees and some informal assessments were undertaken (e.g. difficulty having a conversation). Little evidence existed that noise was identified as a significant hazard, that is, preliminary noise assessments were undertaken.

There was some evidence that elimination and isolation strategies were explored to reduce noise exposure, but were not generally pursued or utilised. Administrative controls were not used in any of the organisations surveyed. There was substantial evidence that minimisation (use of hearing protection) tended to be employed as the key control strategy.

There was little evidence that information or training was provided for noise control/ management in the workplace. Similarly, there was little evidence that noise monitoring or audiometry was routinely undertaken in

the cases studied.

Mean conformance scores by industry sector were calculated and shown in Figure 1.

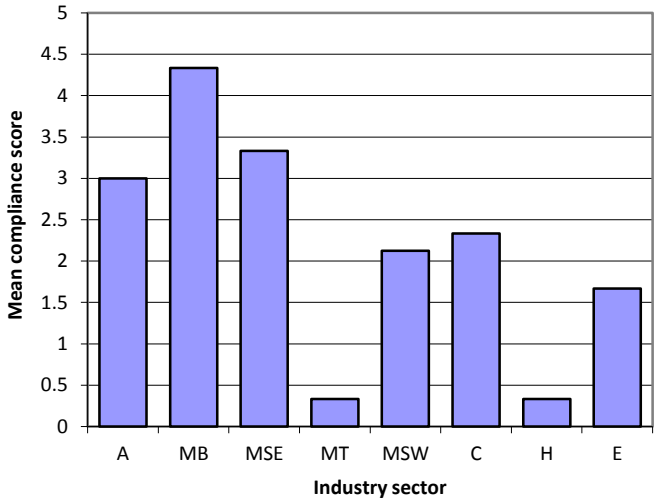

Figure 1: Mean conformance scores by industry sector

Key: A=Agriculture (n=4); MB=Manufacturing Bottling (n=3); MSE=Manufacturing Engineering (n=3); MT=manufacturing Textiles (n=3); MSW=Manufacturing Sawmills/Wood processing (n=8); C=Construction (n=3); H=Hospitality (n=4); E=Education (n=5).

Of the "high risk" industry sectors surveyed the bottling, engineering businesses and farms were the most compliant (mean (standard-deviation) conformance scores; 4.3 (2.1), 3.3 (2.3) and 3 (0) respectively). Construction and saw mill/ wood processing businesses had mean (standard deviation) conformance scores of 2.3 (0.58) and 2.1 (0.35) respectively. Of the remaining "high risk" industry sectors, textile manufacturing had the lowest mean conformance score of 0.33 (0.57), which was comparable with the "medium risk" hospitality sector (mean 0.33 (0.57)). The "low risk" sector, education, had a mean conformance score of 1.7 (1.5).

4. Discussion

4.1. Noise sources and paths

The noise sources and paths identified in this study are consistent with those identified in a range of surveys from a variety of traditionally noisy industry sectors (construction, agriculture, manufacturing, mining) and are primarily impact generated (metal on metal) and rotational components of engine and machinery operation [3,18,1,2,19,20,21]. The noise sources for specific pieces of equipment and operations/ tasks have also been reported.

Noise sources in agricultural work identified in this study are consistent with those identified in other studies and usually linked to specific equipment and tasks [1,2,19]. Sources included engines and gears, pneumatic and hydraulic noise, compressor noise and radio noise. It was suggested however [2], that the common and everyday sources of noise exposure in farming are not intense but because of this, the effects could be subtle and the onset of hearing loss insidious.

Noise sources in the manufacturing sectors in this study were extremely varied and very much dependent on the manufacturing process and machinery used in the process in a similar way to those identified by earlier studies [20,21]. The key feature of noise sources found in the manufacturing sectors was the relationship of the sound emission to an enclosed or semi-enclosed workspace (bottling plant, engineering workshop and textile factory). The sound fields in the workplaces were complex, due to the involvement of many sources including air-borne noise and structure-borne noise, reflections from the floors, walls, ceilings and machinery surfaces and absorption on surfaces. The basic mechanism of noise generation was due to mechanical noise, impact noise, fluid noise and/or electromagnetic noise.

The noise sources identified in the construction activities in this study were compatible with the categories identified by Hattis [3] and capture broad groups of problem types with different opportunities for abatement. Suter [18] suggests that controlling construction noise at the source is the most reliable way to protect worker hearing. United States (and New Zealand) manufacturers and contractors should benefit from the activities of the European Community, where noise control and product labelling in construction has been carried out for more than 20 years.

The noise sources in the cafés were consistent with those identified by Christie and Bell-Booth [22], including impact noise due to the banging of cutlery and crockery, mechanical/equipment noise from the operation of the till, appliances such as food processors and the coffee machine and fan and extractor noise. Other important sources of noise include traffic, patron generated and radio/music background noise. A large proportion of noise sources contributing to background noises were those associated with kitchen areas, especially coffee machines and grinders. These sources may contribute a great deal to the overall acceptability of the workspace.

Two principal sources of noise identified in the preschool centres surveyed included noise generated from the children and the activities they are engaged in, such as: music, and noise intrusion from outside activities; traffic and transportation noise sources. This is consistent with surveys undertaken by McLaren and Dickinson [23] and [24], where some activities and equipment were found to be especially noisy, indicating that controls on the level of noise for these were needed. This included some music sessions from amplified music and the use of percussion instruments such as claves. In addition, major construction work carried out in the vicinity of centres was another source of noise generated at the time of the survey and highlighted the influence of external sources on individual noise exposures.

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Rocker Dave Grohl has written a support letter urging British officials to lift a ban against a loud teen metal band.

Black Leaves of Envy were recently ordered by city council officials in Cornwall, England to keep their garage band practices around 30 or 40 decibels.

However, after receiving noise complaints, the council banned the group from playing completely and they have subsequently not been able to practice for the past three months, according to local newspaper the Plymouth Herald.

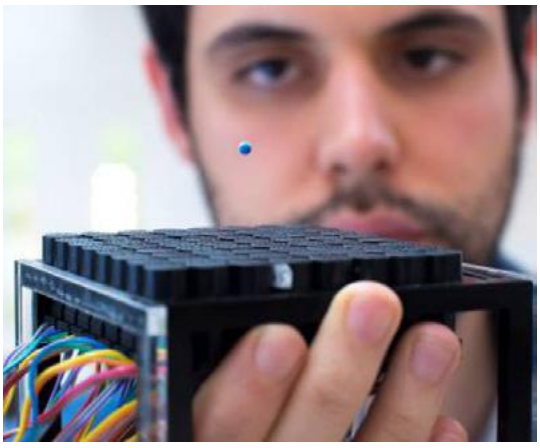
One of the young rockers' fathers, Andrew Plenty - a lead singer in his own rock band - tells the publication he launched a campaign to help garner community support in hopes of overturning the ban.

From science fiction to reality - sonic tractor beam invented

The world's first sonic tractor beams that can lift and move objects using soundwaves have been built by a team that includes researchers at the University of Sussex.

Tractor beams are mysterious rays that can grab and lift objects. The concept was created by sciencefiction writers but has since come to fascinate scientists and engineers.

Researchers at the Universities of Sussex and Bristol, in collaboration with Ultrahaptics (http://ultrahaptics.com), have now built a working tractor beam that uses high-amplitude soundwaves to generate an acoustic hologram that can pick up and move small objects. The technique, published in Nature Communications today (27 October 2015), could be developed for a wide range of applications. For example, a sonic production line could transport delicate objects and assemble them, all without physical contact. Or a miniature version could grip and transport drug capsules or microsurgical instruments through living tissue.



The researchers used an array of 64 miniature loudspeakers (driven at 40 kHz with 15Vpp. The whole system consumes 9 Watts of power) to create high-pitched and high-intensity sound waves to levitate a spherical bead (of up to 4 mm in diameter) made of expanded polystyrene.

See the Nature communications documentary: https://youtu.be/6hE6KjLUkiw

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In general, although many operations were complex, noise control strategies aimed at the noise source and noise paths could have been investigated further, including more specific and direct enclosure of machinery and equipment, use of vibration isolation, regular maintenance of machinery and equipment, elimination or replacement of old machinery and implementation of a "buy quiet" purchasing policy. Any noise control measure should be carried out after a source ranking study, using identification and quantification techniques.

4.2. Exposure to noise and dose measurements

The results of this study shows that of the "high risk" industry sectors surveyed, most had median sound levels that were at or above 85 dB $L_{Aeq,8h}$. These results are consistent with exposures reported by numerous researchers [3,20,25,2,26,27,21].

Median noise exposures recorded in "moderate" and "low risk" industry sectors (cafes and preschools respectively) were below 85 dB $L_{Aeq,8h}$ and also consistent with those reported in previous studies [23,24,22].

In addition, and possibly more significantly, although not obviously covered by the health and safety legislation, children can also be affected by excessive noise levels in early childhood centres. The recently enacted legislation requires that all reasonable steps are taken to promote the good health and safety of children enrolled in the centre or service [28]. Underpinning that, the Health and Safety Criterion No 15 [29] requires that all practicable steps are taken to ensure noise levels do not unduly interfere with normal speech and/or communication or cause any child attending distress or harm.

4.3. Noise control conformance assessment

The results of the compliance assessment in this study (range 0/10 to 6/10 with score 10 being fully compliant; median 2; mean 1.9 (standard-deviation 1.7)) provide disappointing evidence that businesses are not identifying, assessing or putting in place and supporting appropriate noise controls strategies for their industry sector. This contrasts the results of the Williams et al. [25] Australian study, where in 45 % of workplaces surveyed (n=113), managers reported that there was a noise control policy and 76 % of managers stated that a noise assessment had been conducted. In addition, 46 % were aware of the noise exposure standards and 47 % were aware of the code of practice. However, Williams et al. [25] noted that awareness of noise regulations and self-compliance was lower in small businesses (employing fewer than 20 people) compared to medium and large businesses. Approximately, 20 % of managers in small businesses were aware of the noise exposure standards and code of practice, compared with 62 % in medium and large businesses. This was not the case with the New Zealand workplaces surveyed in this study.

However, some results of this study are also consistent with those of Williams et al. [25] in that it was found that industry in general tends to be heavily reliant on the use of hearing protective devices (HPDs) for exposure control. Moreover, small businesses place more reliance on the use of HPDs and much less reliance on hazard control using structured programme involving engineering, administrative and maintenance controls [25]. These issues have been extensively reviewed in the wider OHS context [30].

As the owner-manager is the key person in the small enterprise, it is their values that determine the businesses approach to health and safety management. Many owners however, consider health and safety to be the employees' responsibility and often are not aware of legislative requirements [30]. This has the effect that compared with large and medium sized businesses, small businesses appear to be less aware of noise exposure standards, and less likely to have noise management policies or to have undertaken sound level surveys. This was evident in the findings of the present study where few managers of the small businesses were aware of any specific occupational noise exposure standards.

A lack of financial resources in small businesses is also important from an OHS intervention perspective, as paying for health and safety advice, information, tools and controls will always be implicitly or explicitly evaluated by a cost-benefit analysis [31]. Tight budgetary constraints often mean that there is a lack of financial resources to implement health and safety initiatives, such as noise surveys, the installation of engineering controls or personal protective equipment. Economic incentives are therefore an important encouragement for small businesses to improve health and safety practices generally [32].

In the United Kingdom (UK), Wilson [33] reports that there have been significant changes in Health and Safety Executive (HSE) (the equivalent of Worksafe NZ) expectations with respect to policing the requirements of the UK noise regulations. The emphasis is now on noise control, and it is mandatory to evaluate the options to reduce noise levels. This means that protective hearing devices are not an "acceptable long-term solution unless noise control can be shown to be impractical". In this risk based approach, there is a much stronger duty to reduce noise by engineering means. Risk assessments should identify a programme of work where there is less emphasis on assessment and "process" and more on action. If solutions have been identified - "stop assessing and start controlling". Health surveillance is required above time weighted average levels of 85 dB L_{Aeq}, which can be considered to be - "a tax on failure to control the

risks". This approach by the HSE has yet to be evaluated but highlights the conceptual shift from a "protection" to a "prevention" focus on noise management. Similarly, Williams et al. [25] suggests that the approaches that could be adopted to achieve better compliance within the small business sector (e.g. regulatory enforcement, or an assistive and educational approach) need to be determined.

5. Conclusions

Generally noise sources and paths could be readily identified in the workplaces and were consistent with those identified in a range of surveys from a variety of traditionally noisy industry sectors (construction, agriculture, manufacturing, mining). These noise sources are primarily impact generated (metal on metal) or come from rotational components of engine and machinery operation.

The noise sources in the moderate and low risk industry sectors (hospitality and education) were due to mechanical/equipment noise from the operation of appliances, person generated noise (patrons and children respectively), and sources of noise intrusion from outside activities (e.g. traffic and transportation noise sources).

The predominant noise control strategy in the majority of industry sectors surveyed was that of minimisation, specifically the use of hearing protection. Although many operations were complex, noise management strategies aimed at the noise source and noise paths could have been investigated further. In agriculture and construction, however, prevention through either noise reduction at source or isolation of the noise, even though best practice, may not always practicable so that hearing protection could be the only control option available. Administrative controls were not used in any of the organisations surveyed.

There was evidence that businesses are not identifying, assessing or putting in place and supporting appropriate noise management strategies for their industry sectors. It was found that industry in general tends to be heavily reliant on the use of hearing protective devices (HPDs) for exposure control. Moreover, small businesses place more reliance on the use of HPDs and much less reliance on hazard control using structured programme involving engineering, administrative and maintenance controls. Compared with large and medium sized businesses, it was found that small businesses appear to be less aware of noise exposure standards, and less likely to have noise management policies and to have undertaken sound level surveys.

This study supports evidence that there needs to be significant changes in expectations with respect to policing the requirements of noise legislation. The first (and sometimes only) strategy in the management of noise is to adopt the use of hearing protection devices. This is not an acceptable solution unless in working through the formal risk management process, this is found to be the only practical solution.

In the new Health and Safety at Work Act 2015 and the pursuant Health and Safety at Work (General Risk and Workplace Management) Regulations 2016, the principles of managing risk have been significantly strengthened. The Act prescribes a duty to eliminate risks as far as reasonable practicable and if not possible, risks are to be minimised far as reasonable practicable. To implement control measures to minimise risk, the above regulations prescribe the following five steps:

(a) substitution (wholly or partly) with something that gives rise to a lesser risk

(b) isolating the hazard giving rise to the risk to prevent any person coming into contact

(c) implementing engineering controls

(d) if risk remains – implement administrative controls

In addition, national strategies on the prevention of NIHL need to be designed from a small business perspective

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where noise management interventions are seen as a benefit to the enterprise rather than a cost.

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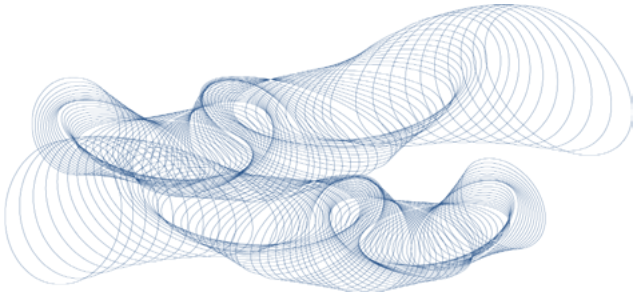

Christchurch

3 Cows, Kaiapoi	(1)	★★★★
Abes Bagel Shop, Mandeville St	(1)	★★★★
Alchemy Café, Art Gallery	(1)	★★★★★
Anna's Café, Tower Junction	(1)	★★★★
Arashi	(1)	★★
Beach Bar, Sumner	(4)	★★★
Becks Southern Ale House	(11)	★★★★½
Black & White Coffee Cartel	(1)	★½
Bloody Mary's, Rydges on Latimer	(3)	★★★½
Bridge (The), Prebbleton	(1)	★★★★★
Buddha Stix, Riccarton	(1)	★★★★
Bully Haye's, Akaroa	(1)	★★
C1 Espresso	(1)	★★★★½
Café Valentino (St Asaph St)	(2)	★★★
Casbah Moroccan Grill	(2)	★★★½
Cashmere Club	(1)	★★★★★
Chillingworth Rd	(2)	★★★½
Chinwag Eathai, 104 Victoria St	(1)	★★
Christchurch Casino	(1)	★★
Christchurch Museum Café	(1)	★★★★
Cobb & Co, Bush Inn	(1)	★★★
Coffee Culture, Riccarton	(1)	★★
Cookai	(3)	★★½
Coriander's, St Asaph St	(3)	★★★★
Cortado, Colombo Street	(7)	★★★★
Curator's House	(25)	★★★½
Drexels Breakfast Restaurant, Riccarton	(1)	★★★★
Duo	(2)	★★★★★
Fava, St Martins	(1)	★★
Fiddlesticks	(1)	★★★★★
Foo San, Upper Riccarton	(1)	★★★½
Fox & Ferrett, Riccarton	(1)	★★★★★
Fox & Ferrett, Shirley	(1)	★★
Freemans, Lyttleton	(11)	★★★★
Gloria Jean's, Rotheram St	(1)	★★★★
Golden Chimes	(1)	★★★★★
Governors Bay Hotel	(1)	★★★★
Green Turtle	(1)	★★★★
Indian Fendalton	(2)	★★
Joyful Chinese Rest., Colombo St	(1)	★★★★★
Kanniga's Thai	(1)	★★★
Kenzo, Ferrymead	(3)	★★★★½
La Porchetta, Riccarton	(4)	★★½
Leinster Rd Bistro	(13)	★★★★
Lone Star, Manchester Street	(1)	★★
Lone Star, Riccarton Road	(6)	★★★
Madam Kwong's	(1)	★★★★
Maharaja, Papanui Rd	(16)	★★★½
Manee Thai	(6)	★★½
Merrin Street (Monteiths)	(2)	★★½
Mexican Café	(6)	★★★
Mexicano's	(1)	★★★
Myhanh, Church Corner	(4)	★★★½
Number 4, Merivale	(2)	★★★★
Oasis	(1)	★★★★½
Old Vicarage	(3)	★★★½
Opawa Café	(1)	★★½
Phu Thai, Manchester Street	(1)	★★★
Protocol, formerly Elevate, Cashmere	(6)	★★★
Pukeko Junction, Leithfield	(1)	★★★★
Red, Beckenham Service Centre	(1)	★★★★
Red Elephant	(1)	★★★★
Retour	(1)	★★★
Riccarton Buffet	(2)	★★★★½
Robbies, Church Corner	(2)	★★★★½
Route 32, Cust	(1)	★★★★
Saggio di Vino	(2)	★★★

Saggio di Vino, Victoria Street

Sakimoto, Cathedral Junction	(4)	★★★½
Salt on the Pier, New Brighton	(7)	★★★½
Sand Bar (The), Ferrymead	(2)	★★★½
Seven	(1)	★★½
Speights Ale House, Ferrymead	(3)	★★★★★
Speights Ale House, Tower Junction	(1)	★★★★
Spice Paragon, Victoria St	(2)	★★
Subway Shirley	(1)	★★★
Tokyo Samurai	(1)	★★★★★
Town Tonic	(2)	★★★★½
Tutto Bene, Merivale	(2)	★★
Twisted Hop (The), Woolston	(3)	★★★★½
Untouched World Cafe	(1)	★★★★★
Venuti	(3)	★★★★★
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Waitikiri Golf Club	(1)	★★
Waratah Café, Tai Tapu	(1)	★★★

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★ Lip-reading would be an advantage. ★★ Take earplugs at the very least. ★★★ Not too bad, particularly mid-week.
★★★★A nice quiet evening. ★★★★★The place to be and be heard. (n) indicates the number of ratings.

Occupational noise law in New Zealand – Where will it go?

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Abstract

With the introduction of the Health and Safety at Work Act 2015, many of the existing health and safety regulations are being replaced. The first suite of new regulations supporting the Act was released by the Government on 15th February 2016 but this did not include occupational noise regulations. This discussion paper considers the direction that occupational noise law in New Zealand may take over the next few years. This paper identifies some of the issues in the translation of the Australian model regulations into the New Zealand context and identifies other gaps that the author thinks needs addressing. It also considers the approach taken with the new 'Asbestos' regulations and whether or not a similar detailed approach should be taken in addressing occupational noise issues.

Original peer-reviewed article

1. Introduction

Imagine if, in every workplace, in every home, on every street and in every country there was an invisible harm which caused irritation and annoyance at low levels, lost productivity and diminished health at medium levels, and permanent disability at high levels.

Then, you would expect this imaginary harm to be monitored, easily assessed and comprehensively covered by ACC (Accident Compensation Corporation) as well as specified in law.

The harm is real. The harm is Noise Induced Hearing Loss (NIHL).

Yet, for most SMEs[1] in New Zealand, NIHL is not generally monitored. Worksafe NZ barely mentions NIHL it in its 12,500 annual workplace assessments. And the burden of proof is so high that very few people who need support for NIHL actually make a claim.

And when major law reform took place in Health and Safety, leading to the new *Health and Safety at Work Act 2015* which has the stated purpose that workers "*should be given the highest level of protection against harm*", someone forgot to include this particular harm - even though it has been listed in the previous Act for 23 years.

This is a harm that at high noise levels over a period of time causes permanent disability, so by the time you retire to enjoy the good life, you have a severe social handicap, can't hear your grandchildren on Skype and struggle to have a conversation in your favourite café.

So what can be done about it?

2. 2. New regulations due

Regulation 11 of the Health and Safety in Employment Regulations 1995 [1] sets out the current law regarding occupational noise and is due for replacement. Such replacement would likely be drawn from the Australian '*Model Work Health and Safety Regulations 2011*'[2] which have already been referenced in the new Act's regulations.

An example of these regulations is the '*Health and Safety at Work (General Risk and Workplace Management) Regulations 2016*'. This regulation sets out duties and responsibilities for managing general risk in a workplace. A PCBU (a person conducting a business or undertaking) who fails in their duties and responsibilities may be convicted of an offence, leading to a possible fine up to $6,000-10,000 for an individual and $30,000-$50,000 for any other person.

In 2016, these fines are significant - but what about in ten or even twenty years' time? Will they lose their impact, particularly if the regulations remained unamended for a long time? The issue of fines remaining current and relevant has been addressed in Australian regulations where fines are stated in terms of the number of penalty units (PUs)[3]. The value of a PU varies between Australian States and Territories and it is adjusted annually based on the Consumer Price Index. Thus, the value of a fine will maintain its significance. However, although New Zealand has followed the Australian model regulations (which serve as a template for the state and territory versions), New Zealand did not adopt the use of PUs for fines. The reason for this is not clear as over the past few years there have been two Bills (the '*Therapeutic Products and Medicines Bill*' and the '*Patents (Trans-Tasman Patent Attorneys and Other Matters) Amendment Bill*') put forward for consideration and they both include the use of PUs. Also, the New Zealand 'Legislation Design and Advisory

1 Small and Medium-sized Enterprises

2 Model regulations in Australia are the basis for the legally binding regulations enacted or passed by Parliament in each jurisdiction of Australia. This means that each State/Territory in Australia has a slightly different version of the regulations but largely they are the same as the model regulations.

3 Is an amount of money used to compute pecuniary penalties for many breaches of statute law. Fines are calculated by multiplying the value of one penalty unit by the number of penalty units prescribed for the offence.

Committee' whose '*mandate is to promote quality legislation in its guidelines*' states that "*New Zealand has not adopted the inflation-adjusted "penalty unit" system found in many other jurisdictions. Therefore, when comparing offences in different statutes, the penalties may be unduly low simply because of the age of the statute, and not provide an accurate guide*".

In the '*Health and Safety at Work (General Risk and Workplace Management) Regulations 2016*' (HSW-GRWM Regulations 2016), Part 2 'Management of particular risks' identifies a number of specific risks, including: 'Remote or isolated work', 'Raised and falling objects', 'Substances hazardous to health' etc. But occupational noise is not listed in the set of general risks to be managed. Given noise is an issue in many workplaces, it ought to have been included in these general regulations.

Chapter 4 of the Australian model regulations, 'Hazardous work', begins by defining the "*exposure standard for noise*" in Part 4.1, with reference to the joint Australian New Zealand Standard, AS/NZS1269.1:2005 *Occupational noise management–Measurement and assessment of noise immission and exposure* [2]. The next section covers '*Managing risk of hearing loss from noise*' where it is mandatory for a PCBU to manage the risks to health and safety relating to hearing loss associated with noise. However, the appropriate part of the AS/NZS1269 *Occupational noise management, 'Part 2: Noise control management*', is not referenced. The next section covers 'Audiometric testing', but again does not reference the appropriate part of the AS/NZS1269 *Occupational noise management, 'Part 4: Auditory assessment*'. A potential reason for this is these regulations state that audiometric testing must be done "*at least every 2 years*" whereas in the current version (updated in 2014, almost three years after the model regulations were first released) of this standard does not provide clear guidance on the frequency of testing. However, the forward of this standard acknowledges this by saying "*Most jurisdictions have... laws with general requirements for health monitoring workers exposed to hazards and specific regulatory requirements for regular audiometric testing of workers whose noise exposure is such that they need to rely on hearing protectors from risk management*". The final section of Part 4.1 of the Australian model regulations titled '*Duties of designers, manufacturers, importers and suppliers of plant*', is a very worthwhile section as it attempts to address the issue noise at the source by ensuring "*that the plant is manufactured so that its noise emission is as low as is reasonably practicable*".

2.1 Exposure standard for noise

As above, Part 4.1 of the Australian model regulations sets out the "*exposure standard for noise*". As stated, it gives the impression that action should only be taken when the sound level exceeds 85 dB $L_{Aeq,8h}$ or 140 dB $L_{Cpeak,}$ for a worker. Contrast this with the United Kingdom where Section 4 of the '*The Control of Noise at Work Regulations 2005*' [3], has two exposure action values:

1) Lower exposure action values are— a daily or weekly personal noise exposure of 80 dB (A-weighted); and a peak sound pressure of 135 dB (C-weighted).
2) Upper exposure action values are— a daily or weekly personal noise exposure of 85 dB (A-weighted); and a peak sound pressure of 137 dB (C-weighted).

The advantage of having a lower exposure action value is that it provides PCBUs (and workers) with clear guidance on when they must take action. This is more than a practical issue, as often when noise surveys are completed and levels are shown to be in the range 80-84 dB $L_{Aeq,8h}$, the PCBU will say it is less than 85 dB so I don't need to do anything.

This leads to the issue of the accuracy of the sound level measurements in the first place. In AS/NZS1269.1:2005, Section 7 'Instrumentations and calibration', it states that "*if Class 2/Type 2 meter is used, allowance should be made for the reduced accuracy of this type of instrument*". Then in Section 8.4 'Measurement period' it says "*The choice of measurement time intervals shall be such that the measurements result is determined by the desired accuracy and is representative of the person's long-term noise exposure*". Then finally in Section B6 'Evaluation of noise', it says that training courses on noise assessment should include "*standing waves in rooms and their effect on measurement accuracy*". None of this deals directly with the issue of the accuracy of the measurements and provides no real guidance on working out an uncertainly budget for the measurements. Straight out of the box a Class 1 sound level meter is going to have about +/- 1.9 dB (the tolerance on the accuracy at 1 kHz) [4] uncertainty before any measurements are made. Environmental effects are likely to increase this by approximately another 2 dB, producing a tolerance of about +/- 4 dB[4]. The practical impact is that when the measured exposure is say, 83 dB $L_{Aeq,8h}$, the real value could be as high as 87 dB. Knowing that it could be this high puts greater pressure on the PCBU to take action to reduce the noise exposure risk.

2.2 Approved code of practice

The Australian regulations are supported by the Approved Code of Practice (ACoP) from Safe Work Australia, titled '*Managing noise and preventing hearing loss at work* (December 2011)'. The introduction to the ACoP begins in a holistic way by stated that "*Hazardous noise can destroy the ability to hear clearly and can also make it more difficult to hear sounds necessary for working safely, such as instructions or warning signals*". It then goes on to say that managing risks related to noise will assist in:

- protecting workers from hearing loss and disabling tinnitus (ringing in the ears or head);
- improving the conditions for communication and hearing warning sounds, and
- creating a less stressful and more productive work environment.

4 The tolerance would double if extended to a 95% confidence as would normally be the case for environmental noise assessment.

However, the opening sentence in Section 3.1 'How to find noise hazards' says, "*You may not need specialist skills to identify sources of hazardous noise*". The authors interpretation of this is that it gives the impression that any person can do noise risk assessment by simply following the ACoP guidance, which in most cases is unlikely to be true, except perhaps at a 'screening level'.

Later on the ACoP introduces '*noise exposure points*' with 85 dB $L_{Aeq,8h}$ equal to 100 points. It then provides various tables with point values for different combinations of time-averaged sound level ($L_{Aeq,T}$) and their corresponding duration, T. In reality these points are just percentage dose ($L_{Aeq,8h}$ = 1.0 Pa^2h = 100 % dose) and in the authors view, most people would be much more competent and comfortable with idea of percentage noise dose (% dose) than what appears to be a somewhat arbitrary points system. A key advantage with using the % dose or the points system is they are both linear units and can simply be added together to give the total noise dose or exposure.

At this point the question should be asked: Who is the ACoP aimed at? In the ACoP, the answer is clearly the PCBU. But do they have the equipment and expertise to measure the sound pressure levels required in order to use the 'noise exposure points' tables? For most SMEs, the answer will most likely be 'No'. So by following the ACoP, a PCBU would be taking on duties and responsibilities that are likely to be well outside their competence.

3. Where are the gaps?

So assuming we follow the Australian model regulations and address the issues above, what other gaps are there?

3.1 Duty

One of the first regulations released by the Government supporting the HSW Act 2015, is the '*Health and Safety at Work (Asbestos) Regulations 2016*' (HSW-A Regulations 2016), dated 15th February 2016. These regulations are based on the Australian model regulations. The reason this set of regulations needs consideration is as follows, there is a:

1. Duty to ensure it is identified at workplace;
2. Duty to ensure presence and location is indicated;
3. Duty to prepare a management plan;
4. Duty to review the management plan;
5. Duty to provide health monitoring;
6. Duty to ensure that appropriate health monitoring is provided, and;
7. Duty to train workers about the risk.

So rather than having a minimalist section titled something like '*Managing the health risk of asbestos*', they have chosen to, in significant detail, spell-out all the duties this entails. In the author's option, similarly detailed sections should apply to occupational noise.

3.2 Cost

Clearly asbestos is not in every workplace, in fact it is rather uncommon nowadays and issues tend to only arise during renovations, demolition and disposal work. Asbestos has certainly gained prominence as a result of the rebuild work after the Christchurch earthquakes of 2010 and 2011 in particular.

Many of the diseases associated with asbestos exposure do not develop for 15 to 40 years after first exposure and they lead to severe disability through to death. The timeline for NIHL is similar, with early signs of NIHL showing up after about 10 years exposure and severe symptoms occurring after 30-40 years exposure. People do not directly die from NIHL, as noted above, but the severe social handicap that results means that an individual's quality of life is significantly diminished which in turn leads to a significant public health burden.

In regards to asbestos, about 10,000 (0.003%) Americans die each year of asbestos-related diseases and a further 200,000 (0.06%) are living with asbestosis [5]. In contrast with NIHL [6], where in 2007, 10 million (3.1%) people in the United States had NIHL and 22 million (6.8%) workers were exposed to potentially damaging noise each year. Furthermore, reported cases of hearing loss in the United States accounted for 14% of all occupational illness.

"*Worldwide, 16% of the disabling hearing loss in adults (over 4 million DALYs[5]) is attributed to occupational noise, ranging from 7% to 21% in the various subregions*" [7]. Closer to home the Australian authors of the provocatively titled paper '*Occupationally-Acquired Noise-Induced Hearing Loss (ONIHL): A Senseless Workplace Hazard*' [8] states that "*Data suggest that excessive noise attributes to =37% of all adult causes of hearing loss and remains a significant contributor to employment-related morbidity internationally.*" It then it goes on to say that the "*...impact of ONIHL on the global transition toward dominant communication-rich white-collar employment roles is difficult to quantitate, but is likely to be substantive upon the afflicted individual*". Using the Australian author's estimates of the burden associated with hearing loss, the cost of ONIHL is in excess of AU$4.3 billion or about 0.5% of the gross domestic product (GDP) and thus represents a significant burden on health and social services. For New Zealand the cost of ONIHL as a percent GDP is likely to be similar to Australia, meaning the real cost is closer to NZ$900 million per year. Contrast this with the $40 million per year in new claims it costs ACC and the few million dollars per year allocated by Worksafe NZ to occupational noise and you can see there is a huge gap that needs addressing.

3.3 Competent person

Throughout the Australian model regulations the phrase "*competent person*" is used, typically with guidance that jurisdictions will insert in paragraph a reference to a licenced or required authorisations or membership.

5 Disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

When the asbestos related sections of these Australian model regulations were enacted in Australia, and in New Zealand turned into the HSW-A Regulations 2016, it was clear that:

1. Focus is on removal of the contaminant by a practitioner holding a current certificate;
2. Licensing of removalists and assessors;
3. Register of removalists and assessors.

This means that professionals working in this area must be certified and registered and probably belong to a professional organisation. The author's opinion is that the same should be required for people working in occupational noise.

3.4 Access to standards

If regulations refer to a Standard (New Zealand Standards in particular) and there is reasonable expectation that in order to meet the regulations the PCBU has read and understood the Standard, then it seems reasonable that access to the standard, like access to the regulations, should be at minimal cost. Currently to purchase the AS/NZS1269 occupational noise management series would cost more than $630 from the Standards New Zealand webstore. However, this might change now that Standards New Zealand is part of Ministry of Business, Innovation and Employment (MBIE) as a result of the new '*Standards and Accreditation Act 2015*', which came into full force on 1st March 2016. One of the stated purposes of the new Act is "*make provision for access to New Zealand Standards*".

4. Conclusions

This discussion paper has attempted to identify where the noise legislation in New Zealand is likely to go over the next year or two. Along the way some issues have been identified in the translation of the Australian model regulations into the New Zealand context as well as identify other gaps that the author thinks needs addressing.

It will be interesting to revisit this in two years' time to reflect on what actually happens to occupational noise law in New Zealand.

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Future Events

2016

23rd International Congress on Sound and Vibration [ICSV23]. Athens, Greece. 10-14 July 2016. www.icsv23.org

4th International Conference on The Effects of Noise on Aquatic Life. Dublin, Ireland. 10-16 July 2016. www.aquaticnoise2016.org

Inter-Noise 2016. Hamburg, Germany. 21-24 August 2016. www.internoise2016.org

International Congress of Theoretical and Applied Mechanics [ICTAM]. Montreal, Canada. 21st to 26th August 2016. www.ictam2016.org

22nd International Congress on Acoustics [ICA 2016]. 5-9 September 2016. Buenos Aires, Argentina. www.ica2016.org.ar

International Symposium on Music and Room Acoustics [ISMRA 2016]. La Plata, Argentina. 11-13 September 2016. www.iwrn12.acoustics.asn.au

International Workshop on Rail Noise [IWRN]. Terrigal, NSW, Australia. 12-16 September 2016. www.ica2016.org.ar

2nd Australasian Acoustical Societies Conference. 9-11 November 2016, Brisbane Convention Exhibition Centre, Brisbane Australia. www.acoustics2016.com.au

2017

24th International Congress on Sound and Vibration [ICSV24]. London, UK. 23-27 July 2017. www.icsv24.org

Acoustics 2017 Joint meeting of the Acoustical Society of America and the European Acoustics Association. Boston, USA. 25-29 June 2017. www.acousticalsociety.org

46th International Congress and Exposition on Noise Control Engineering [Inter-Noise 2017]. Hong Kong. 27-30 August 2017. www.internoise2017.org

2017 International Congress on Ultrasonics. Honolulu, Hawaii, USA. 8-10 December 2017. http://www4.eng.hawaii.edu/~icu2017

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