Occupational Noise

Core Body of Knowledge for the
Generalist OHS Professional

Second Edition, 2019

22.1

Australian Institute
of Health & Safety

Australian OHS Education
Accreditation Board

Acknowledgements

The Australian Institute of Health and Safety (AIHS) financially and materially supports the *OHS Body of Knowledge* as a key requirement of the profession.

The *OHS Body of Knowledge* forms the basis of the AIHS OHS capability agenda and informs the other platforms of the agenda: education assurance through accreditation; role clarity, capability assurance through individual certification and continuing professional development.

Thus, the *OHS Body of Knowledge* is strategically important to the AIHS and vital for the profession. (www.aihs.org.au).

The *OHS Body of Knowledge* provides a framework for OHS professional education and continuing professional development. As the body managing accreditation of OHS professional education, the Australian OHS Education Accreditation Board influences, supports and monitors the *OHS Body of Knowledge*, and has a major role in the development and review of individual chapters to ensure that the quality and evidence base reflects current OHS research and leading-edge thinking, and so provides a suitable standard for OHS education and professional development.

www.ohseducationaccreditation.org.au

The AIHS and the OHS Body of Knowledge appreciate the support of Beno Groothoff and his company *Environmental Directions* in the development of this chapter. Environmental Directions Pty. Ltd. is a consultancy specialising in the provision of occupational hygiene and environmental services to a broad range of clients from small and medium enterprises to large companies, universities and government departments within Australia.

https://environmentaldirections.com.au

Bibliography

ISBN 978-0-9808743-2-7

First published in 2012

Author

Beno Groothoff , Managing Director, Environmental Directions Pty Ltd

Peer reviewers

Jane Whitelaw, Lecturer, Postgraduate OHS Program, University of Wollongong

Marion Burgess, Research Officer, Acoustics and Vibration Unit, University of NSW, Canberra

Gary Foster, Managing Director, Foster OHS Pty Ltd

Second Edition published in 2019

In this edition the original chapter has been split into two chapters: 22.1 Occupational Noise and 22.2 Vibration. The changes incorporated into this chapter on occupational noise consist mainly of updating the Model Work Health and Safety legislation references to reflect latest editions of regulations and codes of practice and the inclusion of the guidance material on noise management as published by Safe Work Australia

Author

Beno Groothoff , Managing Director, Environmental Directions Pty Ltd

Citation of the whole *OHS Body of Knowledge* should be as:
AIHS (Australian Institute of Health and Safety). (2019). *The Core Body of Knowledge for Generalist OHS Professionals*. Tullamarine, VIC: Safety Institute of Australia.

Citation of this chapter should be as:
Groothoff, B. (2019). Occupational Noise. In *The Core Body of Knowledge for Generalist OHS Professionals*. Tullamarine, VIC: Australian Institute of Health and Safety.

Occupational Noise

Beno Groothoff MHlthSc, GDipOHS, DipMechEng, FAIOH, COH, MAAS

Managing Director, Environmental Directions Pty Ltd

Email: beno@environmentaldirections.com.au

Beno has over 45 years' experience in the fields of occupational hygiene and health and environmental control, gained both in the Netherlands and in Australia. In Brisbane he has worked in private practice, worked with the Environmental Protection Agency followed by 22 years with Workplace Health and Safety Queensland. As Managing Director of Environmental Directions Pty Ltd he provides occupational hygiene services and has written and presented workshops and two day training courses on noise for a number of organisations, including Brüel & Kjær in Sydney and the Australian Institute of Occupational Hygiene (AIOH). He was the course coordinator at QUT's Occupational Hygiene and Toxicology course, updating and presenting lectures to post graduate and masters' students. He now lectures in occupational noise and vibration management in the Occupational Hygiene course at the University of Queensland to post graduate and masters' students. He is a member of the AV10 Committee of Standards Australia on occupational noise and vibration.

Core Body of Knowledge for the Generalist OHS Professional

Occupational Noise

Abstract

The health impacts of noise hazards are well recognised with noise-induced hearing loss identified as a priority work-related disease for Australian workers. Although noise-related legislation focusing on reduction at source has existed for many years, provision of hearing protectors is still the predominant control strategy in many workplaces. This chapter discusses the concept of noise as a hazard and its effects on individuals. It provides a basic understanding of acoustics and the factors that impact on hearing loss and health together with the principles of noise measurement and control. It concludes with an examination of the role of the generalist OHS professional in the management of noise hazards.

Keywords

noise, hearing, hearing loss, ototoxic, tinnitus, audiometry, control

Contextual reading

Readers should refer to 1 *Preliminaries* for a full list of chapters and authors and a synopsis of the OHS Body of Knowledge. Chapter 2, *Introduction* describes the background and development process while Chapter 3, *The OHS Professional* provides a context by describing the role and professional environment.

Terminology

Depending on the jurisdiction and the organisation, Australian terminology refers to 'Occupational Health and Safety' (OHS), 'Occupational Safety and Health (OSH) or 'Work Health and Safety' (WHS). In line with international practice this publication uses OHS with the exception of specific reference to the Work Health and Safety (WHS) Act and related legislation.

Jurisdictional application

This chapter includes a short section referring to the Australian model work health and safety legislation. This is in line with the Australian national application of the *OHS Body of Knowledge*. Readers working in other legal jurisdictions should consider these references as examples and refer to the relevant legislation in their jurisdiction of operation.

Table of contents

List of Tables

1 Introduction

The terms noise and vibration are often linked as in, for example, 'noise and vibration engineering.' This is because exposure to vibration is usually associated with exposure to noise, and the physics of vibration and noise are similar.[1] While the specific health effects of noise exposure are often insidious and can manifest after a long period of latency. The health effects of noise should be taken seriously by their creators as part of their business activities. Management of noise hazards is a specialist area with advice able to be sourced from acoustic consultants, noise and vibration engineers, occupational hygienists and audiologists. This chapter deals with occupational noise from the perspective of the generalist OHS professional and so addresses the basic knowledge required to understand, identify, assess and control noise hazards in the workplace and to engage with the appropriate specialists.

1.1 Definitions

Noise has been defined in several ways. The *Code of Practice: Managing Noise and Preventing Hearing Loss at Work* under the national model Work Health and Safety legislation defines hazardous noise in relation to hearing loss as "noise that exceeds the exposure standard for noise in the workplace" (SWA, 2018a, p. 36). This is the definition used by regulators. *AS/NZS 1269.0: Occupational Noise Management: Overview and General Requirements* (SA/SNZ, 2005a) defines noise as "all sound [in the workplace], whether wanted or unwanted." However, neither of these definitions acknowledges the damaging effects on people's health associated with noise occurring from exposure at work, in the community or both.

The World Health Organization (WHO) describes the distinction between occupational and environmental noise:

> Noise is present in every human activity, and when assessing its impact on human well-being it is usually classified either as occupational noise (i.e. noise in the workplace), or as environmental noise, which includes noise in all other settings, whether at the community, residential, or domestic level (e.g. traffic, playgrounds, sports, music) (Concha-Barrientos, Campbell-Lendrum & Steenland, 2004, p. 1).

This chapter concerns occupational noise.

[1] See *OHS BoK* 22.2 Vibration for information on identifying, assessing and controlling work-related vibration hazards.

2 Historical context

The problem of noise affecting health and hearing has been recognised throughout history. Probably the earliest notation is attributable to Pliny the Elder's (23–79AD) *Naturalis Historiæ* (*Natural History*), which referred to the noise of the falling water in the Nile cataracts and its ill effects on the hearing of the local inhabitants (NIOSH, 1988; Rosen, 1974). In ancient Rome, carts were banned from cities at night as their wheels made too much noise on the cobblestoned streets (Berglund, Lindvall & Schwela, 1999). Bernardo Ramazzini (1633–1714) described the hearing impairment of coppersmiths in *De Morbis Artificum Diatriba* (*Diseases of Workers*) (Rosen, 1974). With the onset of the industrial revolution, the incidence of noise-induced hearing loss increased; works by Thomas Barr (1886) on hearing loss in Scottish boilermakers, and Gottstein and Kayser (1881) on German personnel in railway works, were landmark studies in the development of our modern day understanding of occupational noise-induced hearing loss (Atherley & Noble, 1985). Georg von Békésy (1899–1972) discovered the 'travelling wave' by which sound is analysed and communicated in the cochlea, and for which he received a Nobel Prize in 1961 (see PBRC, n.d.).

Since the early part of the 20th century, much research has been conducted into the relationship between noise exposure and hearing loss. Notably, in 1970, Burns and Robinson "proposed the concept of immission, which is based on the equal-energy hypothesis, to describe the total energy from a worker's exposure to continuous noise over a period of time (i.e. months or years)" (NIOSH, 1998). The equal-energy hypothesis, which states that "equal amounts of sound energy will produce equal amounts of hearing impairment, regardless of how the sound energy is distributed in time" formed the basis for the US National Institute for Occupational Safety and Health recommendation for a 3-dB exchange rate (for a 3-dB increase in noise level the exposure time must be halved to maintain the acoustic energy balance concept) (NIOSH, 1998). This concept was adopted in *ISO 1999 Acoustics – Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment* (ISO, 1990). The 3dB equal energy concept has been adopted in Australian Standard 1269 for several decades now and is again used in the current 2005 edition of the AS/NZS 1269 series, "Occupational noise management" (SA/SNZ, 2005a). Modern noise regulations use the equal energy concept as related to the normalised 8-hour shift.

3 Extent of the problem

Occupational noise-induced hearing loss (ONIHL) is listed as a priority disorder for the Australian Work Health and Safety Strategy 2012-2022 (SWA, 2012, p. 17). However, current data on the prevalence of ONIHL is difficult to obtain.

The report *Work-related Noise Induced Hearing Loss in Australia* (ASCC, 2006) estimated that about 1 million employees in Australia were exposed to hazardous levels of noise (in the absence of hearing protection), accounting for about 16% of adult-onset hearing loss. The 2010 publication by Safe Work Australia National Hazard Exposure Workers Surveillance (NHEWS) (de Crespigny, 2010) found that between 28% and 32% of Australian workers are likely to work in an environment where they are exposed to non-trivial [>84dB(A)] loud noise generated during the course of their work. Manufacturing and Construction industries were the main industries in which workers reported exposure to loud noise. Technicians and trades workers, machinery operators and drivers, and labourers were the main occupations in which workers reported exposure to loud noise.

Due to the long latency and cumulative effect of ONIHL, workers' compensation claims do not give a true indication of the health impact. The inadequacy of compensation data as a measure of the extent of the problem of noise-induced hearing loss is further exacerbated by changes in definitions and method of data collection for workers compensation claims. Between July 2002 and June 2007 there were about 16,500 successful workers' compensation claims for industrial deafness (SWA, 2010a, p 1.). In 2007–8, there were 4,000 claims for occupational noise-induced hearing loss (ONIHL) (up from 3,250 in 2003-4) at a median cost of $11,200 per claim with no time lost reported for the claims (SWA, 2011). In contrast, the current method of data collection refers only to 'serious claims' where a serious claim is defined as "an accepted workers' compensation claim for an incapacity that results in a total absence from work of one working week or more". This definition also includes common-law payments. (SWA, 2018b, p. 10.) As ONIHL is not usually associated with time lost, it does not register as a serious claim and under mechanism of injury "sound and pressure" only 115 serious claims were recorded. This apparently low number of claims is not representative of the people suffering ONIHL. A 2006 report by Access Economics titled *Listen Hear!* stated that in 2005, 37% of all hearing losses were noise induced from occupational and leisure activities. The report estimated that the direct and indirect costs to the community amounted to about 4.3 billion dollars annually (Access Economics, 2006). A more recent study estimates that the 4.3 billion dollars has blown out to about 5.9 billion dollars (Hearing Care Industry Association, 2017). Besides hearing loss, occupational noise is associated with tinnitus, cardiovascular disease, depression, increased risk of accidents, and decreased productivity (SWA, 2010a, p 1.)

4 Understanding noise

Noise and vibration are closely linked in that noise originates from a vibrating body and both noise and vibration are transmitted as waves through a medium. In the case of noise the medium is usually air. Knowledge of units of measurement such as hertz and decibels together with some understanding of the physics of waves including frequency, wavelength, amplitude and reflection, absorption and transmission is important in understanding the behaviour of noise and so the development of controls.[2]

4.1 Basic acoustics

Sound consists of very small pressure changes, which are superimposed on the atmospheric pressure. Air molecules move in a pendulum motion backwards and forwards from their resting position, causing momentary compression and rarefaction of the air pressure. The air molecules pass some of their energy on to neighbouring molecules and so spread their energy over an increasingly larger volume, much like the ripples when a stone is thrown into water. The pressure changes are detected by the eardrum, which vibrates in response. The vibrations are transferred via a lever system consisting of three tiny bones in the middle ear to the fluid-filled inner ear. In the inner ear, tiny hair cells convert the vibrations into electrical pulses that are sent to the brain. The brain is then able to process these electrical pulses into meaningful sounds.

A primary indicator that noise may be hazardous to hearing is when a person has to raise their voice to talk to someone who is about an arm's length away in a noisy workplace. A risk assessment, including noise measurement, should then be conducted to identify the processes, noise sources and workers likely to be exposed above the exposure standard. The *Code of Practice: Managing Noise and Preventing Hearing Loss at Work* (SWAa, 2018, Appendix C) includes a basic noise hazard identification checklist.

4.2 Noise and its measurement

A noise assessment may be simple or quite complex depending on circumstances such as the type and size of the workplace, the number of workers and whether previous noise-assessment data is available.

A noise assessment can be carried out with a sound level meter (SLM) or a noise dose meter (NDM). In recent years noise dose badges have become available. A noise dose badge is basically a smaller version of the traditional noise dose meter but, apart from being much smaller, has no cable between the meter and microphone that can get in the way of the worker, and are small enough for workers to literally forget they are wearing it and so results may be more reliable. Just like sound level meters these badges can measure several parameters simultaneously. An SLM is usually hand held and therefore the assessor is present as the measurements are made; this has the advantage that the assessor can observe firsthand what is being measured. An NDM is designed to be worn on a person for a period of time whilst that person conducts work. In practice, the assessor is not always

[2] See *OHS BoK* 14 Foundation Science.

present during the entire assessment period and therefore may have to rely on the wearer to provide input to the survey. In each case, the meter's microphone should be held within a sphere of 10 to 20 centimeters of the ear, in accordance with the requirements of *AS/NZS 1269.1 Occupational Noise Management – Measurement and Assessment of Noise Immission and Exposure* (SA/SNZ, 2005b). Both ears may need to be assessed and the worst exposed ear results used for noise management purposes. Both types of instruments measure the sound pressure variations as a sound pressure level expressed in decibels (dB). The decibel scale is logarithmic, or compressed, as the human ear is capable of hearing over a large range of sound pressures.[3]

Measurements are normally made using a weighting scale, which is A-weighting for sounds such as the '$\mathbf{L_{Aeq,8h}}$' (i.e. sound measured over a period of time), and C-weighting '$\mathbf{L_{C,peak}}$' for impulsive type sounds (i.e. sounds of less than 1 second duration, such as explosions and impact sound). The A-weighting is an electronic frequency filter used in sound level measuring instruments to simulate the measured sound as if perceived by the human ear. The human ear's sensitivity varies with the pitch of sound (frequency). It is less sensitive at low-pitched sounds, and more sensitive at high-pitched sounds. The A-weighting filter follows this variability by reducing the sensitivity of the sound level meter at low and high frequencies compared to those within the 1000Hz to 4000Hz frequency range.

A person carrying out a noise assessment should meet the competency requirements listed in *AS/NZS 1269.1*, including:

- the objectives of the assessment
- the basic physics of sound
- the correct usage and limitations of sound-measuring instruments required to gather data for noise assessments
- the information needed and methods used to determine occupational noise exposures
- how to record results and explain them to people in the workplace
- the method for evaluating personal hearing protectors
- when to advise that someone with more specialised knowledge on noise measurement or noise control is required, and
- the relevant statutory requirements, codes of practice and standards used in Australia.

A competent person should also have a basic understanding of the:

- mechanisms of hearing
- harmful effects of noise, and
- principles of engineering noise control and noise management measures. (SWA, 2018a, p. 17-18)

[3] Commercially available sound measuring 'apps' for smart phone and tablets are useful *indicative* tools for estimating sound levels but cannot be used to demonstrate legislative compliance.

4.3 Noise-induced hearing loss

Except for extremely loud noise of an explosive or impact nature where some amount of hearing loss and/or structural damage occurs (*acoustic trauma*) immediately, loud noise initially fatigues the delicate hair cells in the inner ear causing a shift in hearing threshold. This is called a *temporary threshold shift* (TTS). A simple test can be conducted by workers to assess the effects of occupational exposure to noise and its impact on hearing acuity:

> *Drive to work and switch off the engine, but not the ignition. Switch on the car radio and reduce the volume to just audible. Do not switch off the radio, but switch off the ignition and go to work. After work, switch on the ignition. The radio should come on as well. If the radio cannot be heard, a temporary threshold shift has occurred during the workday. The change in hearing threshold is experienced as dull or blocked hearing and sometimes ringing in the ears (tinnitus). This may last from hours to days after the exposure.*

Generally, hearing recovers overnight, giving a false impression that all is well. However, the effects of regular exposures are cumulative. The hair cells are eventually destroyed causing a *permanent threshold shift* (PTS) that normally is not noticed until the damage is well advanced. Damaged hair cells are incapable of repairing themselves; the loss of hearing is therefore permanent as there is no cure available and hearing aids cannot restore the natural hearing. (SWA, 2018a, p. 11.)

Noise-induced damage to the inner ear hair cells usually occurs in the high-pitched frequency range of 4000–6000 Hz. This range is critical for understanding speech and the nuances involved with speech. In contrast to other forms of hearing loss, the person suffering from noise-induced hearing loss can hear well, but cannot understand the words because sounds such as ‘fff,’ ‘th’ and ‘shh,’ and high-pitched consonants such as ‘s,’ ‘t,’ ‘k’ and ‘c,’ are harder to hear or not heard at all. This causes misunderstandings in conversations, particularly where there is background noise. Audiometric tests can be conducted to assess the degree of noise-induced hearing loss. (SA/SNZ, 2014a; SWA, 2018a)

4.4 Audiometric testing

Under the model *Work Health and Safety Act* (*WHSA* s 19.3g) persons conducting a business or undertaking (PCBU) are required to monitor the heath of workers (SWA, 2016). Under certain conditions (as described in SWA, 2018a) where workers are likely to be exposed to noise, ototoxins and/or vibrations, this requirement to monitor health includes audiometric testing. *AS/NZS 1269.4 Occupational Noise Management – Auditory Assessment* (SA/SNZ, 2014a) describes audiometric testing as: “… pure tone audiometric testing of threshold sensitivity is the method of auditory assessment usually used in noise management programs…”. Audiometric testing requires specialised equipment that is appropriately calibrated and the testing must be conducted by suitably qualified persons as described in *AS/NZS 1269.4*.

It is important to note that while audiometric testing forms an important part of identifying and managing the risks from noise exposure at the workplace, “such testing is not itself a protective mechanism and is relevant only in the context of a comprehensive noise management program” (AS/NZS 1269.4, p. 4). Any changes in a person’s hearing levels as revealed by audiometric testing should be investigated as to the cause and the need for corrective action.

4.5 Ototoxicity

During the last four decades, research (see, for example, Prasher et al., 2004, Morata. T.C, 2007) has been conducted on ototoxic agents, which are chemical substances that either alone or in concert with noise may have a more detrimental effect on hearing than noise (oto = ear, toxic = poisonous). There are three main classes of ototoxins: solvents, heavy metals and asphyxiants. Also, some medications such as anti-inflammatory, anti-thrombolitic, antibiotic and chemotherapy drugs, and salicylic acid (aspirin) are considered to be ototoxic. A list of common otoxins can be found in Appendix B, Table 6, of the *Code of Practice* (SWA, 2018a).

The most common routes of entry into the body of these ototoxins are via inhalation, skin absorption and, to a lesser extent, ingestion due mainly to poor personal hygiene practices at work. Because of the action variability between the many chemicals identified to date it is difficult to come up with a ‘safe’ method of risk assessment. Also, Safety Data Sheets (SDS) generally do not give information on the ototoxic effects of a substance. However, workplaces using known or suspected ototoxic chemical substances should look for information on the chemical’s general toxicity, neurotoxicity and nephrotoxicity as such chemicals also may affect the auditory system.

Exposure limits of chemical substances are stated in Safe Work Australia’s (2010b) Hazardous Chemicals Information System.[4] However, exposure standards for chemicals and for noise have not yet been altered to take account of increased risk to hearing. The *Code of Practice* (SWA, 2018a) recommends that until revised standards are established, the daily noise exposure of workers exposed to ototoxins should be reduced to a maximum of 80 dB(A). Workers then should also undergo audiometric testing and be given information on

---

[4] See: http://hcis.safeworkaustralia.gov.au.

ototoxic substances. Monitoring hearing with regular audiometric testing is recommended where workers are exposed to:

- Any of the ototoxic substances listed in Appendix B where the airborne exposure (without regard to respiratory protection worn) is greater than 50 per cent of the national exposure standard for the substance, regardless of the noise level
- Ototoxic substances at any level and noise with $L_{Aeq,8h}$ greater than 80dB(A) or $L_{C,peak}$ greater than 135dB(C) [5] (SWA, 2018a)

A listing of ototoxic substances most commonly used in industrial settings is given in Table 6 of Appendix B of the *Code of Practice*. More information on ototoxins can be found in *AS/NZS 1269.0* (SA/SNZ, 2005a, Appendix C).

4.6 Social and community noise

Community noise has been acknowledged throughout the centuries as a health issue (section 2). Since the early 1900s, many studies have investigated the effects of noise in communities. To date, the main findings include health effects such as stress, annoyance, sleep disturbance, interference with concentration and activities, increased blood pressure and heart rate, and ischaemic heart disease (Department of Health, 2018). Furthermore, there is some evidence that the intellectual development of children in noisy suburbs may be compromised compared to those living in quiet suburbs (e.g. Tamburlini, von Ehrenstein & Bertollini, 2002).

The enormous popularity of personal media players is another source of community concern as they can be used for many hours at high volume, often with ear buds that concentrate the noise, and insufficient warning is provided by the makers of the devices on the potentially damaging effects of regular exposure to loud noise on hearing (see SCENIHR, 2008). Unlike the situation in Europe where the maximum volume of personal media players is regulated, Australian regulators do not deem the risks important enough to deal with the issue. In 2010, Australian Hearing found that almost 40% of young Australians had trouble hearing in background noise and 13% received “a yearly noise dose from nightclubs, concerts and sporting activities which alone exceeds the maximum acceptable dose in industry”

The Access Economics report *Listen Hear!* (2006) stated that 37% of all hearing losses are noise induced from occupational and leisure activities. This amounts to direct and indirect costs to the community of about 4 billion dollars annually (Access Economics, 2006).

---

[5] See Section 6.1 for explanation of terms of measurement for noise exposure.

4.7 Noise ‘stress’

While the *Code of Practice* (SWA, 2018a) comments on noise levels that do not damage hearing but may have other adverse health effects, there is no regulation of noise levels below $L_{Aeq,8h}$ 85 dB(A). These lower noise levels are typically found in open plan offices, hospital and call centre environments. The Code notes that relatively low levels of noise can “chronically interfere with concentration and communication [and that] persistent noise stress can increase risk of fatigue and cardiovascular disorders including high blood pressure and heart disease” (SWA, 2018a, p.13). While safe levels of noise to guard against health problems other than hearing loss have not yet been determined, the code advises that the risk of adverse health effects can be minimised by; “keeping noise levels below 50 dB(A) where work is being carried out that requires high concentration or effortless concentration, and below 70 dB(A) where more routine work is being carried out that requires speed or attentiveness or where it is important to carry on conversations” (SWA, 2018a, p. 13). To mitigate the chances of adverse health effects occurring in workers careful consideration must be given to the acoustic environment in which open plan offices and particularly call centres operate. Guidance in this regard can be obtained from AS/NZS 2107: *Acoustics-Recommended design sound levels and reverberation times for building interiors*. (SA/SNZ, 2016). This Standard provides design sound levels for a range of occupancies in the un-occupied state but ready for occupancy.

4.8 Acoustic shock

As outlined in the *Code of Practice*:

> Acoustic incidents are sudden, unexpected loud noises occurring during telephone headset use, including crackles, hisses, whistles, shrieks or high-pitched noises. Acoustic shock is not caused by the loudness of a telephone, as all phone noise is electronically limited to a peak noise level of 123 decibels, but by a sudden rise in noise levels. (SWA, 2018a, p. 40)

It is important that the acoustic environment of a call centre is optimal, e.g. meets the recommendations of AS/NZS 2107 (SA/SNZ, 2016), and the space between telephone operators not too cramped as that enables the operators to keep their conversation volumes low and in turn keep the volume in their headsets low.

Noises that may cause acoustic incidents can originate from two main sources, i.e. either from within the call centre telephone system or from the customer end. Sources from within the telephone system may include; mobile phones or fax machines used in a call centre, faulty telephones or headsets, individual telephone systems not protected by shriek rejection devices (Volume limiter amplifiers), or the whole of the call centre telephone network not protected by an Uninterrupted Power Supply (UPS). Sources from the customer end may include; loud noise in a workplace close to the phone, oscillation feedback from an old style cordless phone, misdirected fax tones over the telephone line and deliberate abuse by customers. In most cases these noises may cause an acoustic incident in the telephone operator but the operator is likely to be able to continue work, after having reported the incident. Where these noises are severe however, they may lead to an acoustic shock and the operator may not be able to continue work, either for a limited period or not at all. (Groothoff, 2005).

The symptoms of acoustic shock – experienced by only a small proportion of people after an acoustic incident – are grouped into three categories:

Primary (immediate) symptoms, which can include but are not limited to:

- a feeling of fullness in the ear
- burning sensations or sharp pain around or in the ear
- numbness, tingling or soreness down the side of face, neck or shoulder
- nausea or vomiting
- dizziness, and
- tinnitus and other head noises such as eardrum fluttering.

Secondary symptoms, which include but are not limited to:

- headaches
- fatigue
- a feeling of being off-balance, and
- anxiety.

Tertiary symptoms, which include but are not limited to:

- hypersensitivity (sensitivity to previously tolerated sounds such as loud noises, television and radio); and
- hyper vigilance, i.e. being overly alert. (Safe Work Australia, 2018a, p. 41.)

The likelihood that acoustic shock will result from an acoustic incident is low; however, factors including high background noise, the operator's psychosomatic state (e.g. experiencing feelings of tension) and physiological state (e.g. suffering a middle ear infection) may increase the likelihood of occurrence. While acoustic incidents may occur in any workplace, call centres are the most common sites. Control strategies for acoustic incidents should target:

- Workplace design, including acoustic requirements
- Systems of work, performance monitoring of workers, training and stress management, systems for reporting and measures for dealing with acoustic incidents and shock
- Technical control systems including compliance with telecommunication requirements, suitable shriek rejection devices such as Volume Limiter Amplifiers for each telephone operator, and uninterrupted power supply (UPS) systems to prevent brown-outs and black-outs causing signals in headsets (Groothoff, 2005).

4.9 Impact of noise on human performance

Since the early 1900s there have been, and still are, many studies investigating the effects of noise in communities. The main findings so far include health effects such as: stress; annoyance; sleep disturbance; interference with concentration and activities; increased blood pressure and heart rate; and ischaemic heart disease (Babisch, 2013, p. 13. WHO, 2013.)

In the work environment, relatively low noise levels in office situations, range typically between about 40 and 70 dB(A) depending on the interior construction of the office and the activities carried out. These noise levels are not capable of causing noise induced hearing loss. However, because noise is known to interfere with concentration and thought processes, they are known to cause stress and other health effects in susceptible individuals. (Groothoff, 2015).

Noise related stress factors include: stress, leading to irritability, headaches, moodiness and insomnia, disturbance of psychomotor reactions, loss of concentration, speech interference. Health related effects include; reduced productivity, reduced quality of work and/or service, increased absenteeism. All of these effects affect the productivity of workers and therefore noise reduction would be expected to improve productivity (Groothoff, 2015).

5 Legislation and standards

The national model legislation (SWA, 2016) requires a person conducting a business or undertaking (PCBU) to ensure, so far as is reasonably practicable, the health and safety of workers (*WHSA* s 19). This obligation requires elimination of risks to health and safety so far as is reasonably practicable or, if elimination is not reasonably practicable, minimisation of those risks so far as is reasonably practicable (*WHSA* s 17). The Work Health and Safety legislation applies also to designers, manufacturers, suppliers and installers of plant with regards to their obligations to provide plant and information so that it is safe for use. This requirement also applies to the prevention of noise-induced hearing loss for the end user. (See WHSR s 59.) Because the risks of sustaining occupational noise-induced hearing loss are foreseeable, exposure limits are set under health and safety and mining legislation. The *Model Work Health and Safety Regulations* (SWA, 2019) stipulate exposure standards for noise as:

- $L_{Aeq,8h}$ of 85 dB(A) or
- $L_{C,peak}$ of 140 dB(C). (WHSR, s 56(1))

In this regulation:

$L_{Aeq,8h}$ means the eight-hour equivalent continuous A-weighted sound pressure level in decibels (dB(A)) referenced to 20 micropascals, determined in accordance with AS/NZS 1269.1:2005 (Occupational noise management – Measurement and assessment of noise immission and exposure).

$L_{C,peak}$ means the C-weighted peak sound pressure level in decibels (dB(C)) referenced to 20 micropascals, determined in accordance with AS/NZS 1269.1:2005 (Occupational noise management – Measurement and assessment of noise immission and exposure) (*WHSR* s. 56(2)).

These limits are determined without taking into account any protection that may be provided to the person by the use of personal hearing protectors. Due to the recovery time for temporary hearing loss, the eight-hour equivalent exposure limit must be adjusted for longer shifts. For example, the *Code of Practice* advises that for shifts of “10 hrs or more to less than 14 hrs,” 1 dB(A) should be added to the measured $L_{Aeq,8h}$ dB(A) (SWAa, 2018, p. 19).

The *Code of Practice* (SWA, 2018a) provides information on noise and occupational noise-induced hearing loss (ONIHL), and how to control risks and so comply with the regulated exposure limits. The Australian/New Zealand Standard series *AS/NZS 1269 Occupational Noise Management Set* (SA/SNZ, 2005c) provides extensive information on all facets of noise assessment, including instrumentation, evaluation of results and noise management. By following the guidance in the *Code of Practice* and the relevant sections of *AS/NZS 1269* (particularly Part 1), a PCBU or other responsible person should, in most cases, be able to demonstrate compliance with the regulated exposure standard and thus prevent ONIHL.

As noted in section 4.4, audiometric testing is an important element in identifying exposure to hazardous noise. The WHSR (s 58) require audiometric testing within 3 months of a worker commencing the work; and at least every 2 years when:

- A worker is frequently required to use personal protective equipment as protection risk of hearing loss associated with noise that exceeds the exposure standard for noise.
- Personal protective equipment is provided as a control measure.

Relevant standards include:

SA/SNZ (Standards Australia/Standards New Zealand). (2005). *AS/NZS 1269 Set:2005 Occupational Noise Management Set*. Sydney and Wellington: Standards Australia/Standards New Zealand.

Includes:

AS/NZS 1269.0:2005 Overview and General Requirements

AS/NZS 1269.1:2005 Measurement and Assessment of Noise Immission and Exposure

AS/NZS 1269.2:2005 Noise Control Management

AS/NZS 1269.3:2005 Hearing Protector Program

AS/NZS 1269.4:2014 Auditory Assessment

AS/NZS 2107: 2016 Acoustics-Recommended design sound levels and reverberation times for building interiors

AS/NZS 1270: 2002 Acoustics – Hearing Protectors

AS 2436: 2010 Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites

6 Control of noise hazards

Generally, workplaces contain various noise sources that are not always used at the same time, or consistently, throughout shifts. Therefore noise levels will vary with time. Also, worker movement around machines and work areas may result in variations in noise exposure. In production areas, it may be costly or not possible to stop production to measure individual noise sources. However, effective noise control requires identification and analysis of noise sources to determine the priority sources for attention (see SWAa, 2018).

Where noise sources have been identified that are likely to produce excessive noise, the next step is to prioritise noise control by determining the duration of use of each machine or item of equipment during a typical shift and the time the operator spends using them or working near them. For instance, a machine or equipment item with a high noise level, but with short usage per shift may well have a lower priority for noise reduction than a machine or equipment item with a lower noise level, but long usage per shift. For example, a milling machine operated for six hours per day at 88 dB(A) at the operator's ears, needs more urgent noise reduction than an auger operating for 15 minutes per day at 94 dB(A). The Ready Reckoner in Appendix D of the *Noise Code of Practice* shows clearly that at 88dB(A) the exposure can be up to 4 hours before the red (danger) area has been reached. It also shows that at 94db(A) it only takes one hour to reach the red area. Therefore the auger needs more urgent treatment than the milling machine.

The national model legislation (*WHSR* s 57) requires that the hierarchy of control (*WHSR s 36*) be followed, the effectiveness of the controls be monitored (s 37) and reviewed (s 38).

Workplaces cannot automatically rely on the use of hearing protectors, or other forms of personal protective equipment, where it is reasonable and practicable to use higher-order controls. In practice, provision of hearing protection is the predominant method employed for preventing ONIHL. The original November 2008 *National Hazard Exposure Worker Surveillance* report found that of the 4500 workers interviewed:

- 17% were at workplaces where no controls were implemented
- 63% were provided with earplugs
- 60% were provided with earmuffs
- 41% received training on how to prevent hearing loss
- 36% had job rotation
- 36% were at workplaces where quieter machinery was purchased whenever possible
- 22% were at workplaces where places where noisy equipment was placed in an isolated room (ASCC, 2008, p 25).

The *Code of Practice: Managing Noise and Preventing Hearing Loss at Work* (SWAa, 2018) and the *AS/NZS 1269* series (SA/NZS, 2005c) provide information on managing occupational noise. Information on noise control also may be found in other codes of practice such as those for plant, risk assessment, construction and tunneling.

6.1 Elimination or minimisation through safe design[6]

Workplace noise that exceeds the exposure standard must, so far as reasonably practicable, be reduced to non-hazardous exposure levels. The best way to do this is by eliminating the source of noise emission. One way of doing this is by no longer carrying out the work that creates the noise. Where this is not practicable, substitution of the activity or process by changing the noisy components of the activity or process for a quieter one should be considered, e.g. instead of hammering a piece of metal to bend it, the metal could be heated and then bend with pliers or a press.

Workplace noise can also be minimised through design by replacing old plant and equipment with new quieter plant and equipment through a "Buying Quiet" program.

6.2 Engineering controls

Engineering noise controls address control at the source by modifying the noise source itself or through enclosures (e.g. made from a solid material and lined internally with a sound-absorbent lining), modifications and/or additions (e.g. silencers or mufflers to existing noise sources), placing barriers in the noise path or by enclosing the receiver end (e.g. a control

[6] See also *OHS BoK* 34.3 Healthy and Safe Design

room). Generally, engineering noise control is the most effective way of controlling noise, but may sometimes be cost prohibitive.[7]

Some basic principles of engineering noise control consist of:

- Mounting vibrating sources within machines on isolators or dampeners
- Replacement of metal components with quieter materials such as plastic, nylon or compound components
- Installing local enclosures around particular noisy machine components
- Incorporation of sound absorbent materials
- Provision of air and gas exhausts with silencers
- Change to a quieter type of fan, fan blade pitch or number of blades, or fitting sound attenuators in ventilation ducts.

Most of the above options are commercially available from suppliers and much of the work can be done in-house by maintenance or engineering departments.

6.3 Administrative controls

Administrative noise control measures aim to reduce the amount of noise to which a worker is exposed via organisational methods, for example, delineating hearing protection areas, noise mapping to identify safe/unsafe noise areas, rescheduling workers' duties to limit exposure times, optimising maintenance (e.g. SWA, 2018a).

6.4 Hearing protection

Hearing protectors should be worn where hazardous noise levels exist in the workplace that cannot be reduced by higher-order controls or until such times that the noise levels have been reduced to non-hazardous levels through elimination, substitution or engineering noise-control measures (SWA, 2018a). There are three basic types of hearing protectors available:

- Disposable or individually molded earplugs
- Ear canal caps
- Passive or active earmuffs.

---

[7] For more information on engineering controls, see Tillman, 2007, Chapter 10.

Passive earmuffs are the conventional type while electronically active noise level-dependent earmuffs allow noise up to 82 dB to enter the ear after which an electronic system shuts the reception down and they act like passive earmuffs. Noise-cancelling earmuffs reduce (mainly) low-frequency noise by monitoring the noise environment outside the earmuff, feeding it through electronics inside the ear cup and creating an anti-sound of 180-degree phase difference to the original sound sine wave. The principle of this is that a positive and a negative cancel each other out, hence the term 'noise cancelling'. In reality while not all noise is cancelled out a significant noise reduction is obtained.

The ideal in-ear noise level under the protector should fall between 75 and 80 dB(A) to reduce workplace noise to safe levels while enabling hearing and communication without over-protection and thus the likely removal of the protector in noisy environments.

> Removing personal hearing protectors for even short periods significantly reduces the effective attenuation (noise reduction) and might provide inadequate protection. For example, a worker wearing a hearing protector of 30dB rating for a full 8-hour day will receive the 30 dB maximum protection level. However, one hour without wearing the hearing protector causes the maximum protection level to fall to 9 dB. (SWA, 2018a, pp. 24-25)

While there are several methods for selecting hearing protection AS/NZS 1269.3 (SA/SNZ, 2005) recommends the classification method for selection in most circumstances (Table 1). The class of the specific hearing protection is determined by a testing regime as prescribed under AS/NZS 1270 *Acoustics and hearing protection* (SA/SNZ, 2002) and is marked on the packaging of the protective device. A selection is then made based on the measured $L_{Aeq,8h}$ noise level. (e.g. if the worker's $L_{Aeq,8h}$ noise level is 96dB(A) then a Class 3 hearing protector would be required for that worker).

Table 1: Class of hearing protection (SA/SNZ, p. 20)

$L_{Aeq,8h}$, dB(A)	Class
less than 90	1
90 to less than 95	2
95 to less than 100	3
100 to less than 105	4
105 to less than 110	5

A common misconception is that hearing protectors control noise. Hearing protectors do not control workplace noise as the noise in the workplace is still there but the wearing of a hearing protector reduces the in-ear noise level. Exposure is not reduced by the wearing of personal hearing protectors. A person wearing hearing protectors in a sound field is in a situation of protected exposure, not non-exposure (SA/NZS, 2005b, p. 8). Thus hearing protectors should be used only when other means of control are not reasonably practicable. When hearing protection is required, there should be a systematic approach that includes:

- Selection of hearing protection by a suitably qualified person
- Training in fitting and wearing of the hearing protection for those required to use the hearing protection
- Establishment of arrangements to fit the hearing protectors before entering the noisy work area
- Establishment of arrangements for cleaning, maintenance and secure storage
- Marking of areas where hearing protection is required
- Appropriate documentation
- Monitoring of the effectiveness of the hearing protection use
- Management and oversight by a suitably qualified person (See, for example, SA/NZS, 2005d).

AS/NZS 1269.3 Occupational Noise Management – Hearing Protector Program (SA/SNZ, 2005d) provides information on the details and scope of the requirements for a systematic approach to implementing a hearing protector program as well as a training program for hearing protectors.

6.5 An occupational noise management program

Where noise is likely to be in excess of the noise exposure standard, the workplace should implement a systematic noise management program.[8] The basic steps of a noise management program are outlined in *AS/NZS 1269.0–2005 Occupational Noise Management – Overview and General Requirements*.

> A cost effective way to manage noise is to apply noise control measures to existing noisy equipment and processes and to purchase quieter equipment in the future...While these control measures are being formulated and implemented, people need to be protected from the effects of excessive noise through hearing protector programs (SA/SNZ, 2005a).

[8] While some workplaces may refer to 'hearing conservation programs,' generally this implies the prevention of noise-induced hearing loss in workers by protecting their hearing through the use of hearing protectors.

A noise management program contains the following key elements:

- Hazard identification
- Risk assessment
- Hearing conservation policy statement
- Noise level and noise level exposure surveys
- Engineering and administrative noise-control measures
- Education and training
- Personal hearing protection
- Audiometric testing
- Evaluation of effectiveness of the program
- Record keeping system (See, for example, SA/NZS, 2005a).

The *AS/NZS 1269 Occupational Noise Management* series of standards (SA/SNZ, 2005c) provides full details of effective noise management programs. Additional information can be found in the *Code of Practice* (SWA, 2018a).

7 Implications for OHS practice

Noise can be a hazard in any industry and any workplace. Noise control and prevention of hearing loss is not only a legal obligation under WHS legislation and mining legislation, but also an ethical issue as people with hearing loss suffer from social isolation and have reduced career prospects. While there are simple tests for the presence of hazardous noise levels, identification and analysis of noise sources as a basis for control can be complex, requiring specialist expertise. The generalist OHS professional has an important role in identifying the presence of hazardous noise, undertaking basic noise measurements, and providing preliminary advice on noise control measures, including the role of hearing protection. The Code of Practice—Managing Noise and Preventing Hearing Loss at Work (SWA,2018), introduces in Appendix D a point system in the form of a ready reckoner. It assigns 100 points to $L_{Aeq,8h}$ of 85dB(A). The points can be added in the normal arithmetic way to give the total exposure for the shift and a table (Table 11) can then be used to find the daily exposure level in L_{Aeq} dB(A). The Code provides a few worked examples on how to determine the total daily exposure. Knowing the noise emission and duration may give useful information to the generalist OHS professional for the management of noise hazards The generalist OHS professional should recognise when specialist advice is required, including the nature of the advice (e.g. acoustic engineering or occupational hygiene) and be able to coordinate and work with the specialists.

The generalist OHS professional has a key role in ensuring that a noise management program is an integral part of the OHS management system. This includes ensuring that:

- Policies and procedures are developed for the noise management program
- 'Buy quiet' principles are included in purchasing policies
- Hazard-identification processes and workplace inspections include subjective and/or objective assessment of noise levels
- When indicated, risk-assessment processes include noise surveys conducted by suitably qualified persons
- Maintenance processes address noise and vibration issues, and include monitoring of condition of plant and equipment for noise and vibration
- Managers, supervisors and workers receive appropriate information and training on noise and vibration hazards and, where required, the fitting, wearing and maintenance of hearing protectors
- Areas where hearing protection are required are identified and signposted
- Where required, appropriate processes are in place for selection and supply of hearing protectors
- The need for audiometric testing is identified and appropriate processes are in place for conduct and documentation of hearing testing
- The effectiveness of the noise management program is monitored through audit, noise survey and other appropriate measures.

8 Summary

Blue collar occupations are most affected by noise as it is a hazard in many workplaces and occupational noise-induced hearing loss has been classified as one of eight priority diseases in Australian workplaces. Identification of noise hazards in the workplace is fairly simple; however, awareness of individual hearing deficit may be delayed due to the cumulative nature of noise exposure and the complicating impact of leisure noise and age-related hearing loss. Although regulations and guidance for noise hazards that emphasise the importance of control at source have existed in Australia for many years, hearing protectors are reported to be still the predominant control measure. Thus, in many workplaces, there is a need for change in the approach to control of noise hazards.

The generalist OHS professional has a role in identifying, assessing and controlling noise hazards, and particularly in implementing a noise management program as part of an OHS management system. Specialist expertise may be required to conduct noise surveys, and to advise on development of control strategies.

Key thinkers

T. Barr, E. Berger, W. Burns, G. von Bekesy, J. Gottstein, R. Kayser, C. M. Harris, L. Beranek, K. Kryter, T. Morata, P. Niall, M. Sliwinska-Kowalska

References

Access Economics. (2006). *Listen Hear! The Economic Impact and Cost of Hearing Loss in Australia*. Retrieved from https://hearnet.org.au/wp-content/uploads/2015/10/ListenHearFinal.pdf.

ASCC (Australian Safety and Compensation Council). (2006) *Work-related noise induced hearing loss.* Retrieved from https://www.safeworkaustralia.gov.au/system/files/documents/1702/workrelated_noise_induced_hearing.pdf.

ASCC (Australian Safety and Compensation Council). (2008) *National hazard exposure worker surveillance.* Barton ACT.

Atherley, G., & Noble, W. (1985). Occupational deafness: The continuing challenge of early German and Scottish research. *American Journal of Industrial Medicine*, *8*(2), 101–117.

Babisch. W., 2013. 'Quieter Cities of the future'; CAETS – Source Book.

Berglund, B., Lindvall, T., & Schwela, D. H. (1999). *Guidelines for Community Noise.* Geneva: WHO. Retrieved from http://www.bvsde.paho.org/bvsci/i/fulltext/noise/noise.pdf.

Concha-Barrientos, M., Campbell-Lendrum, D., & Steenland, K. (2004). *Occupational Noise: Assessing the Burden of Disease from Work-related Hearing Impairment at National and Local Levels* (Environmental Burden of Disease Series, No. 9). Geneva: WHO. Retrieved from http://www.who.int/quantifying_ehimpacts/publications/en/ebd9.pdf.

de Crespigny, F. (2010). *National Hazard Exposure Worker Surveillance: Noise Exposure and the Provision of Noise Control Measures in Australian Workplaces.* Canberra, ACT: Safe Work Australia. Retrieved from https://www.safeworkaustralia.gov.au/doc/national-hazard-exposure-worker-surveillance-noise-exposure-and-provision-noise-control-measures.

Department of Health. (2018). *The health effects of environmental noise*. Commonwealth Government of Australia. Retrieved from https://www.health.gov.au/internet/main/publishing.nsf/Content/A12B57E41EC9F326CA257BF0001F9E7D/$File/health-effects-Environmental-Noise-2018.pdf.

Groothoff, B., (2005), *"Acoustic Shock in Call Centres"*, Proceedings of Acoustical Society Conference, Busselton Western Australia.

Groothoff, B., (2015) *Training Module – Occupational Noise Management*, Brüel & Kjær Australia Pty Ltd, Sydney.

Hearing Care Industry Association (2017) *Social and economic costs of hearing loss in Australia*, Retrieved from: http://www.hcia.com.au/hcia-wp/wp-content/uploads/2015/05/Social-and-Economic-Cost-of-Hearing-Health-in-Australia_June-2017.pdf.

ISO (International Organization for Standardization). (1990). *ISO 1999:1990 Acoustics – Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment.* Geneva: ISO.

Morata, T.C, (2007) *Promoting hearing health and the combined risk of noise-induced hearing loss and ototoxicity". Audiological Medicine 5, no.1: 33-40.*

NIOSH (National Institute for Occupational Safety and Health). (1988). *Proposed National Strategies for the Prevention of Leading Work-related Diseases and Injuries: Noise-induced Hearing Loss* (Publication No. 89–135). Cincinnati: OH: US Department of Health and Human Services. Retrieved from http://www.cdc.gov/niosh/docs/89-135/pdfs/89-135.pdf.

PBRC (Pacific Biosciences Research Centre). (n.d.). Georg von Békésy (1899–1972). University of Hawaii at Manoa. Retrieved from http://www5.pbrc.hawaii.edu/bekesy/von_bekesy.html.

Prasher, D., Campo, P., Fetcher, L., Johnson, A.-C., Lund, P., Morata, T. et al. (2004). *NoiseChem. Noise and Industrial Chemicals: Interaction Effects on Hearing and Balance* (Key Action 4: Environment and Health 2001–2004 Final Report). Retrieved from http://ec.europa.eu/research/quality-of-life/ka4/pdf/report_noisechem_en.pdf.

Rosen, G. (1974). A backward glance at noise pollution. *American Journal of Public Health*, *64*(5), 514–517.

SWA (Safe Work Australia). (2010a). *National Hazard Exposure Worker Surveillance: Vibration Exposure and the Provision of Vibration Control Measures in Australian Workplaces*. Barton, ACT: Commonwealth of Australia. Retrieved from https://www.safeworkaustralia.gov.au/doc/national-hazard-exposure-worker-surveillance-vibration-exposure-and-provision-vibration-control.

SWA (Safe Work Australia). (2010b). Hazardous Chemicals Information System. Retrieved from http://hcis.safeworkaustralia.gov.au.

SWA (Safe Work Australia). (2011). *Compendium of Workers Compensation Statistics Australia 2008-09.* Canberra, ACT. Retrieved from https://www.safeworkaustralia.gov.au/doc/compendium-workers-compensation-statistics-australia-2008-09.

SWA (Safe Work Australia). (2012). *Australian Work Health and Safety Strategy* 2012-2022. Canberra, ACT. Retrieved from https://www.safeworkaustralia.gov.au/doc/australian-work-health-and-safety-strategy-2012-2022.

SWA (Safe Work Australia). (2016). *Model Work Health and Safety Bill.* Canberra, ACT: Safe Work Australia. Retrieved from https://www.safeworkaustralia.gov.au/system/files/documents/1702/model-whs-act-21march2016.pdf.[9]

SWA (Safe Work Australia). (2018a). Code of Practice: Managing noise and preventing hearing loss at work. Canberra, ACT. Retrieved from https://www.safeworkaustralia.gov.au/doc/model-code-practice-managing-noise-and-preventing-hearing-loss-work.

SWA (Safe Work Australia). (2018b). Australian Workers Compensation Statistics 2016-17. Canberra, ACT. Retrieved from https://www.safeworkaustralia.gov.au/doc/australian-workers-compensation-statistics-2016-17.

SWA (Safe Work Australia). (2019). *Model Work Health and Safety Regulations*. Canberra, ACT: Safe Work Australia. Retrieved from https://www.safeworkaustralia.gov.au/system/files/documents/1902/model-whs-regulations-15-january-2019.pdf.

SA/SNZ (Standards Australia/Standards New Zealand). (2002). *AS/NZS 1270:2002 Acoustics – Hearing Protectors*. Sydney and Wellington: Standards Australia and Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2005a). *AS/NZS 1269.0:2005 Occupational Noise Management. Part 0: Overview and General Requirements.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2005b). *AS/NZS 1269.1:2005 Occupational Noise Management. Part 1: Measurement and Assessment of Noise Immission and Exposure.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2005c). *AS/NZS 1269 Set:2005 Occupational Noise Management Set*. Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2005d). *AS/NZS 1269.3:2003 Occupational Noise Management. Part 3: Hearing Protector Program.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2014a). *AS/NZS 1269.4:2014 Occupational Noise Management. Part 4: Auditory Assessment.* Sydney and Wellington: Standards Australia/Standards New Zealand.

SA/SNZ (Standards Australia/Standards New Zealand). (2016). *AS/NZS 2107 Acoustics – Recommended Design Sound Levels and Reverberation Time for Building Interiors*. Sydney and Wellington: Standards Australia and Standards New Zealand.

SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks). (2008). *Potential Health Risks of Exposure to Noise from Personal Music Players and Mobile*

[9] Safe Work Australia updates the model Act, regulations and codes of practice from time to time. OHS professionals should check the SWA website (www.safeworkaustralia.gov.au) for the latest editions.

Phones Including a Music Playing Function. Brussels: European Commission. Retrieved from http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_017.pdf.

Tamburlini, G., von Ehrenstein, O. S., & Bertollini, R. (Eds.). (2002). *Children's Health and Environment: A Review of Evidence* (Environmental Issue Report No. 29). European Environment Agency & WHO: Copenhagen & Rome. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0007/98251/E75518.pdf.

WHO (2013) *Burden of disease from environmental noise*, Brussels, Belgium.