NON-NOISE CONTRIBUTORS TO OCCUPATIONAL HEARING LOSS

Marion Burgess

Acoustics and Vibration Unit, UNSW@ADFA, Canberra, ACT 2600

Warwick Williams

National Acoustics Laboratory, 126 Greville St, Chatswood, NSW 2067

Noise exposure at work is a major workplace occupational health problem. Legislation exists internationally and throughout Australia requiring limits to the occupational noise exposure of employees. There are clear standards specifying the noise exposures above which noise management plans to protect the hearing of the employees must be implemented. It has been acknowledged for some decades that, in addition to hearing loss, high levels of noise can cause other adverse health effects. There is now increasing evidence that the combination of non-noise factors in the work environment plus noise can lead to a greater hearing loss than would be experienced from the noise alone. This paper provides a review of the effects of the various factors and comments on their importance for consideration when undertaking occupational noise exposure assessments in the workplace.

1.0 INTRODUCTION

Noise exposure at work is one of the largest workplace occupational health problems with thousands of new and ongoing claims for occupational hearing loss per year (ASCC: 2006), not to mention the ongoing disability and handicap experienced by those affected (Access Economics: 2006). Legislation exists throughout Australia requiring limits to the occupational noise exposure of employees, for example the NSW OHS Regulation 2001 (WorkCover 2001). These exposure limits are consistent with world's best practice and although in the long term it would be of advantage to the health of the nation that the noise exposure standard be lowered, there is insufficient compelling evidence to justify such a change at this time. The introduction of 'action' levels below the exposure limits, as recommended in the European Union Directive [EC: 2003], would provide further opportunities for minimising occupational hearing loss. Exposures to high levels of noise can have effects other than hearing damage. Also there is increasing evidence that some non-noise exposures combined with noise can lead to increased risk of occupational hearing loss. The effects of these contributing factors are still under investigation by researchers around the world. This paper provides a review of the current information on the effects of these various factors and comments on their importance for consideration when undertaking occupational noise exposure assessments in the workplace.

2.0 NOISE EXPOSURE STANDARDS

The exposure limits for employees throughout Australia are specified in legislation in each State and Territory and are consistent with the 'National Standard for Occupational Noise' (NOHSC 1007: 2000). This standard currently requires that employees should not be exposed to noise levels in excess of an eight-hour equivalent continuous A-weighted sound pressure level, $L_{Aeq,8h}$, of 85 dB for continuous noise and a C–weighted peak sound pressure level, L_{Cpeak}, of 140 dB for peak or impulsive noise.

For continuous noise this means that the amount of hearing damage from an eight hour, A-weighted sound exposure level of 85dB is considered to be an acceptable risk for the working population. It is important to understand that this does not represent a safe exposure level where there would be zero percentage risk of damage to hearing. As explained in Appendix G of the Australian/New Zealand Standard (AS/NZS 1269.4: 2005), after an exposure to an $L_{Aeq,8h}$ of 85 dB over a 40 year working life, 74% of an otologically normal male population could be expected to show a mean percentage loss of hearing of 6%, while for a similar female population the figures would be 47% with a mean percentage loss of hearing of 5%. Otologically normal implies that the individuals have been screened for any other ear or possible hearing difficulties (excluding ageing).

The implication for the Australian population is that, even with compliance with the current National Standard exposure levels, a large percentage of the work force can expect to have a significant hearing loss when they retire. This is a large potential social and economic problem. Currently it is estimated that there are 3.55 million Australians experiencing hearing loss with a *"real financial cost of $11.75 billion or 1.4% of GDP"* (Access Economics: 2006. p 5). This report estimates that 37% "*is due to excessive noise exposure which is preventable*" (p 7).

While some of the variation in hearing loss can be related to individual characteristics, there is increasing evidence that some may be related to the synergistic effects of noise plus non noise exposures that in combination lead to a greater hearing loss than would be experienced from noise exposure alone.

3.0 NON-AUDITORY EFFECTS OF NOISE

Non-auditory effects of workplace noise are currently not visibly included in published statistics of workers' compensation as a perusal of the mechanism of disease classification will show (WorkCover NSW: 2000; AASC: 2006; enHealth: 2004).

Some of these non-auditory effects of noise exposure were identified by the World Health Organisation over 25 years ago (WHO: 1980) and include:-

- Annoyance
- Task distraction
- Clinical Health Effects – such as hypertension, peripheral circulatory system irregularities, ischaemic (cardiovascular) heart disease, pupillary reaction, neuro-physiological stress and mental health.
- Sleep disturbance.

These non-auditory effects, which occur for exposures to noise well below the National Standard level, are often cited as effects of higher than acceptable community noise levels (enHEALTH: 2004).

Some effects of higher level occupational noise that have been studied more recently include:

- **Noise and the Unborn Child.** Concerns about the effects of noise on the foetus during pregnancy have been investigated since the 1980s. An early study showed an increase in the risk of having a high-frequency hearing loss in children whose mothers were exposed to noise between 85 and 95 dB(A) (Lalande, Hetu & Lambert: 1986). A review of the literature undertaken for the UK Heath and Safety Executive (Hepper & Shahidullah; 1994) comments that "*low frequency sounds (250 Hz and below) which pass unattenuated through the maternal abdomen to stimulate the foetal ear may be most likely to harm hearing*" and consequently the use of the A weighting may be inappropriate. This review concluded that further studies were necessary.

During the 1990s a number of studies showed some effects, the most common being low birth weight (Hartikainen, Sorri, Anttonen, Tuimala & Laara: 1994; American Academy of Paediatrics: 1997). Contrary statements have been made by other researchers (Stanfield et al: 2000), who stated that "*in carefully controlled studies, noise exposure does not seem to be related to low birth weight or to congenital birth defects*" (p 43). However, the American Academy Of Paediatrics: (1997) in a study of the effects of noise on the foetus and the newborn in an intensive care unit concluded that "*exposure to noise during pregnancy may result in high frequency hearing loss and may be associated with prematurity and intrauterine growth retardation*" (p 726).

As there is some evidence of a confounding effect of noise on the unborn child and it would be wise for reports on a workplace noise assessment to alert management to the potential risk.

- **Vibroacoustic disease.** Vibroacoustic disease is a recent area of research and is also controversial in that almost all the research findings are from the one small group and there have been few supportive studies from workers elsewhere in the world. The claim is that vibroacoustic disease is characterised by a "*pericardial thickening in the absence of an inflammatory process, and with no diastolic dysfunction*" (Castelo Branco & Alves-Perira: 2004, p 5; Holt: 2000) and is a progressive disease that develops over many years in three stages (Castelo Branco & Alves-Perira: 2004). The main cause appears to be regular exposure to areas of low frequency noise, less than 500 Hz, at amplitudes of 90 dB or greater. There also seem to be measurable effects on the respiratory system in the long term (greater than 20 years) (Reis Ferreira, Couto, Jalles-Tavares, Castelo Branco & Castel Branco: 1999). These researchers suggest that "*VAD [vibroacoustic disease] is not acknowledged as a pathological entity, and individuals who exhibit VAD clinical pictures are malingerers (if workers) or neurotic (if females and/or housewives). At best, they are considered "overly sensitive" individuals and its presence in the workplace noted*.

Vibroacoustic disease is currently undergoing extensive examination by experts with respect to its validity and recognition as a recognised condition (ATSDR: 2001) but it does appear to be an important, emerging area of the consequences of noise exposure.

4.0 NON NOISE CONTRIBUTORS TO HEARING LOSS

The major contributor to occupational hearing loss is exposure to excess noise levels (WHO: 1980 & 1997). Physiological studies of the ear clearly show the effects on the hearing mechanism when it is required to respond and react to high level sound stimuli. Continued or repeated exposure to high levels of sound will lead to permanent damage to the hearing mechanism (Sataloff & Sataloff: 1987). Criteria and exposure limits for occupational noise levels have been based on studies where noise level was determined to be the main stimulus (IS0 1999; Robinson: 1991) for the ear. Further studies however have indicated that other factors in the environment can have a confounding effect on the resultant hearing damage. This means a combination of high noise plus other non-noise factors can change the risk of hearing damage below the exposure limits. Unfortunately, for the majority of these factors the risk of damage to hearing is increased. A number of non-noise contributors have been suggested and these are discussed in the following sections.

4.1 NOISE EXPOSURE AND OTOTOXIC AGENTS

Ototoxic substance are defined "*chemical substances that have a detrimental effect on an individual's hearing*" (AS/NZS 1269.0: 2005). Morata (2003) identified groups of chemicals, such as:-

- Organic Solvents - toluene, styrene, benzene, n-hexane;
- Asphyxiants – carbon monoxide, hydrogen cyanide;
- Metals – lead, mercury; and
- Pesticides/herbicides – Paraquat, organophosphates

In addition, ototoxic effects have been identified with some medically used drugs such as the aminoglycoside antibiotics (Niall: 1998) and in particular the anti-cancer drug cisplatin (Sockalinham, Murdoch & Charles: 1999). Recently the question of a link between lead poisoning and tinnitus has been raised (Chartrand: 2004).

It has also been demonstrated that there is a synergistic effect between simultaneous ototoxic chemical exposure and noise exposure. The simultaneous exposure tends to intensify, in particular, the effects of noise, resulting in a more rapid progression of the noise injury and subsequent hearing loss (Morata, Dunn & Sieber: 1994; Cary, Clark & Delic: 1997; Fechter: 2004). This is a particular problem in industries that use organic solvents such as chemical refineries (Morata, Engel, Durao, Kreig, Dunn & Lozano: 1997), the printing industry (Morata, Fiorini, Fischer, Kreig Gozzoli & Colacioppo: 2001) and dockyards (Sliwinska-Kowalska et al: 2004). A study in a plastic factory in Japan showed that the combination of organic solvents such as styrene, methanol and methyl acetate may affect the ability to hear high frequency sounds and hearing loss even when legal limits on both were adhered to (Morioka et al: 2000). A recent study in the US (Kaufman et al: 2005) has shown an increase in hearing loss for those exposed to both jet fuel and noise.

One of the main effects of organic solvents also appears to be high frequency hearing loss (Morioka, Miyai, Yamamamoto & Miyashita: 2000). This study examined workers exposed to styrene and found that high frequency hearing loss was experienced by both noise exposed and non-noise exposed groups such that "*even if workers were exposed to styrene alone, their upper limit of hearing was reduced*" (p 257).

The most well known ototoxic medications are cisplatin, used as part of the treatment for some cancers, and some of the more aggressive antibiotic drugs (Niall: 1998). A recent study by Guimaraes et al [2006] has indicated from studies of aged women that the presence of progestin in hormone replacement therapy may lead to poorer hearing ability. While such medicines are known to cause hearing loss on their own, it is not yet known how they interact with simultaneous noise exposure. From the evidence cited above concerning ototoxic chemicals in the workplace, it appears probable that there will similarly be some synergistic effects between ototoxic medicines and noise exposure. However, advances in the understanding and mitigation of the side effects of such medications, including their ototoxic effects, may well reduce this risk in the future (Salvi, Ding & Jeong: 2006).

There is an active body of research in this area and although the exact extent of the problem is not fully understood the awareness of employers, occupational health professionals and employees needs to be raised. AS/NZS 1269.0, Appendix C includes an informative appendix on this topic and recommends that for those exposed to "*known or suspected ototoxic agents their noise exposure limits should be reduced as a precautionary measure*".

At this time there is insufficient evidence to recommend the introduction of a new National Noise Exposure Standard for those exposed to both ototoxic substances and noise. However there is a strong body of evidence supporting concerns about the synergistic effects. It is therefore important that the presence of ototoxic chemicals be considered as part of a workplace noise assessment. If such chemicals are a necessary part of the workplace and high levels of noise are also found the employer should be alerted to the possibility of the confounding effect even when both are below the stated exposure criteria. Until the effect is clearly quantified, it can be suggestedv that the noise exposures for such people should be reduced (USACHPPM: 2003) by allowing, for example, a 5 dB 'safety buffer'.

4.2 NOISE EXPOSURE AND SMOKING

In some studies, smoking has been found to have an effect on hearing. One explanation is that the increased need for oxygen in the body, because of the increased presence of carbon monoxide in the blood, cuts the supply of fresh oxygen in the cochlea thus affecting its efficiency. However there are conflicting findings. For example a US study, Cruickshanks, Klein, Klein, Wiley Nondahl and Tweed (1998) concluded that smokers are more likely to damage their hearing ability. However a conflicting finding has been reported more recently (Nondahl, Cruickshanks, Dalton, Schubert, Klein, Klein & Tweed: 2004).

There have been some studies investigating the combination of cigarette smoking and occupational noise. A Japanese study on workers in steel mills (Mizoue, Miyamoto, & Shimizu: 2003) showed an increased risk of high frequency hearing loss amongst those individuals who smoked. A recent Japanese study, conducted as part of on-going research by the National Institute for Longevity Sciences, has demonstrated a relationship between noise exposure and smoking (Uchida, Nakashima, Ando, Niino & Shimokata: 2005). This relationship showed an additive correlation between smoking and noise exposure and a positive dose-response effect with smoking itself, particularly with middle aged male subjects. A statistically significant increased hearing loss existed at 4 kHz compared to non-smokers. This result was mirrored in Brazil where Ferrite and Santana (2005) found that the "*joint effects of smoking, noise and ageing contribute to increased hearing impairment*" (p 52) and in the UK by Wild, Brewster and Banerjee (2005) whose analysis "*demonstrates that hearing thresholds at 3 and 4 kHz of long term cigarette smokers are significantly elevated after long-term noise exposure when compared with non-smokers with a similar work history*" (p 30).

However Palmer, Griffin, Syddall and Coggon (2004) concluded that "*the extra risk to hearing incurred by smoking in high ambient noise levels is small relative to that from the noise itself, which should be the main target for preventative measures*" (p 340). This was following their large study of over 22,000 individuals plus a review of the studies by others.

Thus at this time there appears to be insufficient evidence to justify a specific alert to the employer on the confounding effect of smoking. With the ongoing Government policies aimed at reducing the incidence of smoking in the population as a whole, it is hoped that the incidence of smoking in the overall working population in Australia will decrease.

4.3 NOISE EXPOSURE PLUS VIBRATION

Exposure to whole of body vibration may or may not be encountered at the time of exposure to high levels of audible noise. At low levels of such vibration, individuals can feel unwell, develop nausea and experience headaches. At high levels, physical damage to the body can begin to occur. There is a strong link between vibration and noise, and control of vibration is often the basis for engineering noise control. A review for the HSE by Lawton and Robinson [1989] summarised the findings and identified the limitations in the research to that time of the combined effects of vibration and noise. They also commented that "*the prospects of useful results from further research in this area are far from promising*".

Since then a correlation has been demonstrated, for example, between vibration-induced white finger and increased hearing thresholds, although the exact causal mechanism is still speculative (Szanto & Ligia: 1999). Similarly, Palmer et al [2002] found an association between finger blanching and self reported hearing loss and recommended further investigations.

In addition to the vibration transmission from direct contact with the body, there is an air-borne infrasonic link. The effect of this infrasound seems to be less clearly understood, except in extreme cases such as jet engine test areas. There is no clear indication of the effects of infrasonic vibration, at frequencies below the range of audible sound, on the hearing mechanism (Goelzer, Hansen & Sehrndt: 2001). However, while low frequency sounds are not considered to have an appreciable effect on hearing (ISO 1999), as evidenced by the A-weighting curves, it is not difficult to imagine that continuous exposure to such vibration could have a long term effect on the delicate mechanism of hearing and the vestibular system.

4.4 NOISE EXPOSURE AND ANTI-OXIDANTS.

Studies on the biological basis for noise induced hearing loss and cell death have shown the involvement of anti-oxidants and in this case the effect can be positive in that the hearing loss is reduced. Henderson and Bielefeld (2003) report on studies showing intervention with anti oxidants at the round window prior to exposure can markedly reduce the extent of damage.

Work in the area of anti-oxidants to reduce and even to prevent damage to hearing due high intensity noise has now progressed to the state where a "Hearing Pill" is available on the US market (Johnston: 2004) based on research and development work carried out by the US Navy (Kopke, Coleman, Liu, Riffenburg & Campbell: 2002). The anti-oxidant medication is not intended to be used in place of other forms of noise management. It does however offer some additional protection for specific occasions when it may be essential for personnel to enter a high noise environment, for which traditional forms of hearing protection may be inadequate or inappropriate.

4.5 NOISE EXPOSURE AND TEMPERATURE

An interesting recent development seems to indicate that heat acclimatisation may confer some protection against noise exposure (Paz, Freeman, Horowitz & Shomer: 2003). So far this work has only been studied in animals (rats) but significantly the published results appeared to show that "*heat acclimation can lead to the long-term protection of tissues in the ear from acoustic injury*" (p 369). This could be interpreted as implying that increased temperature would protect workers from hearing loss when exposed to excessive noise.

This is in contrast to earlier work conducted by (Dengerink, Trueblood & Dengerink: 1984). This work concluded that

> *"Noise exposure which occurs in elevated ambient temperature may have greater damaging effects…than that which occurs in cooled ambient temperatures. …Persons who work in elevated temperatures may be particularly at risk" (p 408).*

In view of the conflicting findings of the limited studies to date it is clear that more research work is required in this area before any recommendations can be made.

4.6 NOISE EXPOSURE AND WORKPLACE STRESS

Stress for workers can be one outcome of psychosocial aspects of the workplace. A study on workplace stress has been undertaken for the VicHealth (2006) and identifies:

> *Three relationships are known to be important psychosocial determinants of the mental and physical health of working people: the relationship between the employee and his or her job, between the employee and other people at work, and between the employee and the organisation.*

There is increasing concern that stress can increase the risk of damage from physical hazards in the workplace. The VicHealth report (2006) states that:

> *Evidence indicates that job stress is rapidly emerging as the single greatest cause of work-related disease and injury, and as a significant contributor to the overall burden of disease in society.*

A description of stress is given by the UK Health and Safety Executive (HSE, 2006):

> "*The adverse reaction people have to excessive pressure or other types of demand placed on them.*"

While it has been accepted for some time that noise can increase stress (WHO 1980) at this time there is no clear evidence that workplace stress will increase the risk of hearing loss. However there is a strong indication that workplace stress can have an effect on the incidence of tinnitus and of the reaction referred to as Acoustic Shock (Patuzzi & Thomson: 1996; WHSQ: 2003).

Dillon and Fisher (2002) described the understanding of the mechanism of acoustic shock as the result of an 'acoustic startle' from an unexpected noise that may not be particularly loud. Acoustic shock is described in AS/NZS1269.0: 2005 as:

> "*Acoustic shock is a term used to describe the physiological and psychological symptoms a person may experience after having a sudden, unexpected loud sound, usually via a telephone headset or handset and usually does not result in hearing loss*".

In practice, an acoustic incident typically acts as a trigger after the culmination of various workplace stressors. Call centres are one such type of workplace where there may be challenging performance pressures, unrealistic performance targets, anxiety, poor working conditions, irate clients and general stress. The combination of a poor psychosocial workplace plus background noise can indirectly influence the likelihood of acoustic shock (Patuzzi & Thomson: 1996; WHSQ: 2003). For example, high background noise may require the call centre worker to use a high headset signal volume, thus increasing the level of any loud and disturbing signal that may occur. Thus for workers who need to listen through headsets it is important to minimise the background noise and to ensure that the psychosocial determinants of the work environment do not increase work place stress.

Tinnitus or 'ringing in the ears' is common, with estimates of 17 to 20 per cent of Australians suffering from some degree of tinnitus (Vic Government, 2005). Information on tinnitus acknowledges the two way interaction between tinnitus and stress, namely tinnitus itself leads to stress and stress itself can increase the effect of tinnitus in an affected person (Hazell: 1987). In addition, there are similar links between noise in the workplace and stress (Wilson, Walsh Sanchez & Read: 1998). Thus for high noise workplaces it is particularly important not only to take steps to reduce the noise exposures but also to ensure that the psychosocial determinants of the work environment do not increase work place stress.

5.0 CONCLUSION

The current state of knowledge on a number of emerging issues that may have an impact on occupational hearing loss has been reviewed. Most of these potentially confounding factors are still under investigation by researchers around the world and there may not yet be sufficient compelling evidence to justify inclusion in the National Standard at this time. However acoustic consultants and occupational professionals should be aware of the potential effects when undertaking occupational noise assessments. In particular, the potential for synergistic effects leading to increased risk of hearing damage should be drawn to the attention of management and considered in the development of the noise management plan for the work environment.

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