



# **Noise levels and noise exposure of workers in pubs and clubs -A review of the literature**

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## **RESEARCH REPORT 026**

# **Noise levels and noise exposure of workers in pubs and clubs -A review of the literature**

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The objectives of this work were to carry out a review of the literature, published since 1985 to establish what is known about the noise levels and noise exposure to workers in pubs and clubs.

The information provided by the literature is used to determine whether there is a noise problem, practical measures that can be adopted to control the level of noise exposure, methods adopted by Local Authorities to enforce control, and what needs to be done to ensure employees in pubs and clubs are provided with a safe work environment.

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## **Summary**

### **Objectives**

The objectives of this work were to carry out a review of the literature, published since 1985 to establish what is known about the noise levels and noise exposure to workers in pubs and clubs.

The information provided by the literature is used to determine whether there is a noise problem, practical measures that can be adopted to control the level of noise exposure, methods adopted by Local Authorities to enforce control, and what needs to be done to ensure employees in pubs and clubs are provided with a safe work environment.

### **Main Findings**

Differences in opinion, experimental rigour, and derived conclusions reported in the literature make it difficult to form definitive conclusions regarding the risk of hearing loss from noise exposure in clubs and pubs. However, it seems that there is a definite potential for harm to employees but it is not possible to establish the number of individuals whose hearing will be impaired as a result of this noise exposure.

The industry has often not taken action to reduce the volume level of the music because of their perception for the need to maintain a commercially viable business based on a fundamental demand to provide a venue which offers loud amplified music. In addition the design of many pubs and clubs is not conducive to effective noise control for employees.

The extent to which legislation is utilised to control the risk is restricted by the lack of understanding and appreciation of the risks to the general public, employers and employees and the lack of practical guidance and experience in these issues for Local Authority Health and Safety Inspectors [LA Inspectors].

### **Main Recommendations**

#### **Guidance**

Clear guidance is required to enable LA Inspectors to enforce the Noise at Work Regulations 1989 in pubs and clubs. Support documentation is required to assist owners of pubs and clubs to comply with the Noise at Work Regulations 1989. In addition the general public need to be informed of the possible risks associated with frequent attendance at places which play loud amplified music.

#### **Research**

A survey of the work patterns of employees in pubs and clubs in terms of the hours, days and years of service is required. The age span of existing longitudinal studies of the incidences of hearing loss should be increased. A method of assessing the effectiveness of the guidance documentation, issued to LA inspectors on compliance with the Noise at Work Regulations 1989 in pubs and clubs, should be developed. This method should provide an indication of compliance prior to the implementation of the guidance and should also review the state of compliance following implementation.



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## 1. INTRODUCTION

The relationship between noise exposure and its affect on hearing acuity has been extensively researched over the years. This research is the basis for legislation, encompassed by EU Directive 86/188/EC and implemented in the UK by the Noise at Work Regulations 1989 which places duties on employers to prevent damage to the hearing of workers from exposure to excessive noise.

Historically, concern has been voiced about the validity of this legislation when dealing with noise in the entertainment industry. This concern is, primarily, driven by two factors:

- there is a school of thought that suggests that noise from loud amplified music is not as damaging to hearing as the industrial noise on which the legislation is based,
- the legislation, if applied in night-clubs, would impose too great a restriction on an industry which is based around providing loud amplified music. Opponents of the application of the legislation in night clubs argue that the restrictions would not make night clubs commercially viable and would impose on civil liberties of those who wish to attend such venues.

This study has been prompted by these concerns, coupled with the fact that youth culture, and therefore the industry, has changed since the previous review conducted for HSE in 1985.

For the purposes of this study the 1985 review, conducted by the MRC Institute of Hearing Research, is taken as a baseline, defining the extent of the research prior to 1985. For this reason the literature reviewed in the current study is restricted to that published since 1985.

### 1.1 MRC Institute of Hearing Research, “Damage to hearing arising from leisure noise: A review of the literature” (Davies *et al*, 1985; 1) (MRC , 1986; 97).

HSE commissioned this study to review critically the relevant existing literature covering all noisy leisure activities to obtain a picture of the state of knowledge at the time. This study encompassed the risk of hearing damage to professionals and attendees from leisure activities which generate high sound levels.

The MRC review dealt with all forms of leisure noise. Only those sections relevant to the current study will be discussed.

Generally it was thought that the literature available in 1985 was poor in design, methodology and reporting. However a number of conclusions were drawn from the work which include:

- The major source of auditory hazard, in population terms, from nonoccupational noise is amplified music. However, widely differing hazard estimates were presented in the literature, with the worst cases presenting a hazard from nonoccupational noise comparable to the impairment and disability from occupational noise of 85-90 dB(A) ( $L_{EP,d}$ ). Conversely, the lower estimates would be equivalent to occupational noise of approximately 80 dB(A) ( $L_{EP,d}$ ).



- The lack of data regarding the population exposed, exposure rates, length of exposure and patterns of exposure made it very difficult to assess the risk to the overall population from leisure noise.
- The mean or median noise levels in clubs are very probably in the 95-98 dB(A) region giving initial grounds for concern. However, the exposure times, frequency of exposure and the proportion of attenders vs. nonattenders was not adequately defined in the literature. This led to the call for a comprehensive survey of the work patterns and attendance habits at pubs and clubs.
- The most likely range of sound levels near the centre of a live music pop concert may be between 101 and 105 dB(A). However, variations in the level, throughout the hall, of 7-10 dB(A) can occur. Noise exposure levels could not be determined due to the lack of time exposure information presented in the literature.
- The studies of the effects on hearing from exposure to music using temporary threshold shift (TTS), as a measure of noise induced hearing loss, encounter difficulties in the absence of proof of a strong link between TTS and subsequent hearing damage.
- Much of the work on permanent threshold shift (PTS), due to the lack of long term planning and experimental rigour, could only be ascribed 'pilot' status. However, PTS from exposure to pop/rock music was found to be greatest at approximately 6kHz. and linked positively with age and thus exposed duration. However, the PTS link with music exposure was based on smaller PTS amongst nonattenders and factors such as social class cannot be ruled out. PTS in non-performers was generally minor.
- It was suggested that more work is needed to establish any possible links between tinnitus and exposure to loud music.

It was recognised that the best attempt to quantify the hazard to social noise exposure was (Bickerdike and Gregory, 1980; 187). However, a number of questions were raised about the definitions of the exposure times and attendance habits used to assess the risk. According to Bickerdike and Gregory, about 600,000 people in the age range 11-49 years have received a lifetime Noise Immission Level [NIL] of 104 dB (the equivalent of 50 years or more exposure to an Leq of 87 dB(A)). The MRC study argues that this estimate may be a threefold or sevenfold overestimation and concludes that the importance of this noise is less than Bickerdike and Gregory imply.

In relation to the noise exposure to the sector of the public employed in places which play loud amplified music the authors state.

“An extremely difficult issue is the occupational noise received by employees in the leisure industry. Here there are defined risks and stronger application of current legislation and codes of practice is required. This in turn would frequently reflect on the noise doses sustained by attendees and might therefore help greatly in reducing such nonoccupational exposures - a matter that is otherwise extremely difficult to control or regulate.”

## 1.2 Current Study

The objectives of this work were to carry out a review of literature, published since 1985 to establish what is known about:

- the noise levels in pubs and clubs, the noise exposure of workers in pubs and clubs.

The literature review focuses on:

- whether there is a noise problem in pubs and clubs and how widespread the problem is,
- the noise levels and exposure periods experienced by both employees and members of the public,
- practical measures that can be adopted to control the level of noise exposure,
- methods adopted by Local Authorities to enforce control,
- what needs to be done to ensure employees in pubs and clubs are provided with a safe work environment.

The literature has been collated from a number of databases, contacts in the industry, secondary citations and experience from LA Inspectors. A breakdown of sources of literature is shown in Annex A.



## **2. IS THE NOISE A PROBLEM AND HOW WIDESPREAD?**

The criterion for noise induced hearing loss (NIHL) is generally accepted and is the basis of much of the occupational noise exposure regulations world-wide. NIHL can be developed in two ways depending on the level of exposure. Acoustic trauma can result from a peak sound pressure level of 140 dB or more. This is normally in the form of an impulse event and the hearing loss is a result of the mechanical damage. The damage caused by such an event is instantaneous and is usually accompanied by temporary tinnitus. Exposure to sound pressure levels between 90 and 140 dB may cause damage to the ear depending on the level and duration of exposure. This type of damage is cumulative and grows slowly over the years of noise exposure. Regulations, policy initiatives and guidance have been developed that aim to enforcing the regulations in industrial workplaces. However, this enforcement has not been carried out effectively in less traditional workplaces such as pubs and clubs where resistance to these regulations on the basis of commercial viability and customer demands make enforcement difficult. In addition there is a school of thought that believes that the risk of hearing damage from exposure to music is less than that posed by industrial noise. This, coupled with the difficulties associated with the calculation of noise exposure in terms of level and time period, makes the determination of risk for this type of exposure very difficult. Most research, to date, in entertainment noise exposure is aimed at establishing the influence of noise from clubs and concerts to the public in general. This of course cannot be used as a direct indication of the risks to employees in these establishments due to the different noise exposure patterns. However, these studies do provide valuable background information which is relevant to this study.

The majority of the work conducted in this area seems to be driven by the perception that the modern life style is damaging to the ears. In many cases researchers seem to have preconceived views on the risks associated with exposure to high levels of music and appear to be either blinkered or negligent of the limitations of the processes they adopt to prove their point. The conclusions drawn from these pieces of work vary considerably from fervent expression of the dangers to statements of possible risks to small numbers of individuals. Whatever the risk, few patients seem to attend clinics with more than minimal changes in their hearing sensitivity which can be attributed to high levels of amplified music (Knight, 1992; 157).

The risk to the general public from this type of noise is normally reduced due to the infrequent attendance and short duration of visits. This, however, is not the case for employees who may be subjected to a potential risk, frequently and for long periods of time.

The literature reviewed for inclusion in this section can be broadly split into three categories:

1. studies of permanent changes in the auditory function as a result of exposure to loud music,
2. studies of temporary threshold shifts as a results of exposure to loud music,
3. studies of the attendance rate and duration and the assessment of noise exposure from assumed sound pressure levels.

Much of the research conducted, to establish a possible correlation between exposure to loud music and permanent and temporary hearing loss, has utilised pure tone audiometry. Two distinct limitations of these approaches have been identified in the literature. The first is that

pure tone audiometry is recognised as a poor indicator of the slight cochlea damage which may be present in the majority of the studies, especially those conducted on young people. Secondly, it is thought that the damage caused to hearing by amplified music may manifest itself in the form of tinnitus and hyperacusis rather than a reduction in hearing thresholds. These symptoms are thought to affect individuals much more than having a slight hearing loss (Axelsson, 1999; 25). In addition, although only a few cases of hearing loss are diagnosed, there is an increase in the occurrence of tinnitus and hyperacusis (Axelsson, 1998; 28).

This chapter will present a summary of the work carried out between 1985 and 1999 in an attempt to determine the risk to employees in pubs and clubs.

## **2.1 Studies of Permanent Threshold Shift (PTS) as a result of exposure to music and other nonoccupational sources.**

The studies reviewed in this section use audiometry to establish the extent of Permanent Threshold Shifts in either the population as a whole or specifically controlled samples of the population.

The quality of the research and the reporting varies considerably between the articles reviewed. In many articles there is a failure to describe precisely the methods adopted and the scope of the work. However, more importantly, often the authors do not discuss the limitations of their work and in doing so form conclusions which seem to be unjustified. Specifically, a large proportion of the articles attribute the prevalence of hearing loss in young people to exposure to loud music without assessing the possible impact of other sources such as noisy toys, fireworks and non-noise related factors. Of the 31 articles identified for inclusion in this section 12 can be considered objective, well structured and communicate the limitations associated with the work.

The common aim of the articles reviewed in this section is to assess the effect of exposure to loud music on hearing acuity by determining the hearing thresholds of a sample of the population. Historically there has been a failure of researchers to reach a consensus of opinion of the risks to the general public from this type of exposure. However, what is important for the purposes of this study is to assess the risk to employees in pubs and nightclubs. The information presented in this section, although aimed at assessing the risk to the general public, is important since there is a school of thought that suggests this type of noise is less damaging than industrial noise (Axelsson A et al, 1995; 79), (Dibble K, 1995; 104), (Mawhinney and McCullagh, 1992; 136), (Strasser H, et al, 1999; 150).

This section discusses the methods adopted, the results obtained and the overall conclusions. A more detailed review of each piece of work is presented in Annex B. An attempt is made to identify reasons for the lack of agreement of the risk associated with exposure to loud music in order to form an opinion of the risk to employees in clubs and pubs.

### **2.1.1. Methods**

This section concentrates on those studies utilising audiometry to assess the hearing acuity of subjects. Other methods have been adopted and comparisons with audiometry have also been made.

The most common explanation for the different conclusions drawn from these studies is attributed to variations in the methodology used in the acquisition of the data and the subsequent analysis. This section will identify these differences.

It must be pointed out at the outset that there is a strong feeling that audiometry is not a very good indicator of the early signs of noise induced hearing loss (Axelsson A, 1991; 26), (West PD and Evans EF, 1990; 42), (Axelsson A et al, 1994; 113). Therefore, given that the majority of this work has focused on the prevalence of music induced hearing loss in children and young adults, this factor may have had a large impact on the results.

The quality of the articles can be generally divided into two distinct groups - (i) those which attempt to force control onto the study by analysing specific groups and (ii) those which do not. The quality articles identify groups of the population and assess differences in hearing acuity between either an exposed and control group and/or differences in hearing acuity with time.

A large proportion of the work conducted in this area aims to establish a correlation between hearing acuity and exposure to social noise (Axelsson A et al, 1994; 113), (Becher S et al, 1996; 30), (Davis AC et al, 1998; 44), (Henoch MA and Chesky K, 1999; 73), (Hoffmann E et al, 1997; 85), (Hohmann BW et al, 1999; 149), (Ising H et al, 1988, 62), (Lees R et al, 1985, 130), (Mawhinney and McCullagh, 1992; 136), (Mercier V et al, 1998; 53), (Merluzzi F et al, 1997; 55), (Mori T, 1985; 121), (Meyer-Bisch C, 1996; 4), (Panter CH, 1987; 116), (Persson BO et al, 1993; 60), (Smith PA and Davis AC, 1999; 39), (Standaert B et al, 1993; 132), (Struwe F et al, 1995; 128), (West PD and Evans EF, 1990; 42). To do this subjects completed a questionnaire as well as having their hearing tested. These questionnaires aim to estimate the noise exposure of an individual and any history of ear pathologies. The success of these studies is governed by the separation of the exposed groups and the control groups. However, in many situations an accurate estimation of the noise exposure level is very difficult to achieve due to:

- the estimation of the sound pressure level,
- the estimation of the hours of attendance,
- the estimation of the number of attendances,
- the history of noise exposure from other sources often very early in life.

Researchers have investigated the prevalence of hearing loss as a function of age to test the hypothesis that the increase in the level of social noise is detrimental to hearing. Two types of approach have been used to acquire the data for these studies -longitudinal and transectional. Longitudinal studies aim to assess the acuity of hearing of a fixed sample of the population at specific ages (Axelsson A et al, 1987; 119), (Axelsson A et al, 1995; 79), (Lindeman H et al, 1987; 112). By re-testing the same subjects at regular time intervals a more controlled and reliable set of data can be acquired. However this type of approach requires more planning and takes longer to achieve as long time intervals are required between tests. Transectional studies assess the acuity of hearing as a function of age by measuring the hearing of a sample of the population at specific ages at a fixed point in time (Borschgrevink HM, 1988; 103), (Borschgrevink HM, 1993; 137), (Carter N et al, 1985; 87), (Persson BO et al, 1993; 60), (Rosenhall U et al, 1993; 127). This approach can be used to assess differences in hearing acuity between generations but has more variability associated with it.

The analysis of the data acquired from audiograms is conducted either in terms of the sample population's average thresholds or the percentage of subjects whose hearing levels are worse than a set threshold. It is generally recognised that the latter approach highlights the percentage of individuals who are at risk (Fearn RW, 1986; 105). However, there is a tendency for researchers to define their own criteria which leads to vast differences in the reported prevalence of hearing impairment. In addition many researchers do not identify their definition of hearing loss as a possible reason for their overestimation of the risk. It is also possible to get large variations in results because this type of analysis is very sensitive to small variations around the definition threshold.

Fearn develops a different approach to identify subjects with hearing loss. Throughout this work the audiometric results are normalised by adjusting the pure tone audiometry thresholds at different frequencies to those at 2 kHz which helps to reduce the influence of audiometric variations introduced by background noise and calibration. Hearing damage is then identified by notches at specific frequencies in the audiogram.

### **2.1.2. Results**

Large variations in the perception of the risk of exposure to loud music exist between researchers. In some cases it is possible to see what factors are responsible for these differences. However, large differences still exist even in the work that can be considered thorough and objective. It is worth reviewing the conclusions from these works (more details of these studies are shown in Annex B).

(Axelsson A et al, 1987; 119) describes a longitudinal study of children at the age of 7, 10 and 13 and found that the prevalence of hearing loss (20 dB at any frequency or ear) was 13.7%, 15.7% and 15.6% respectively for boys and 11.7%, 12.2% and 9.0% respectively for girls. The authors analyse the data to identify the probable cause of any hearing loss and suggest that the increase in hearing loss for boys with age is due to noisy leisure pastimes and/or hereditary effects.

(Axelsson A et al, 1994; 113) measured the hearing levels of 500 randomly selected conscripts and used a questionnaire to assess their exposure to nonoccupational activities and found that there was no correlation between musical activities and the state of hearing. The high frequency hearing losses seen in the study were attributed to medical conditions, noisy toys and guns.

(Axelsson A et al, 1995; 79) describes a longitudinal study of rock and pop musicians conducted in 1975 and 1991/92. The authors were surprised that rock and pop musicians, after performing for 26 years, had such well preserved hearing.

(Carter N et al, 1985; 87) assessed the hearing of 16 to 21 year old and 28 to 33 year old subjects and used a questionnaire to assess the level of noise exposure. The results indicated that while hearing acuity declines measurably at high test frequencies between the ages of about 18 to 30, there is no evidence of the effect of amplified music during this time.

In a series of letters to the Journal of Sound and Vibration, Fearn uses the approach of identifying a notch in the subject's hearing between 3 and 4 kHz and shows a relationship

between an increase in exposure to amplified pop music and increasing hearing loss. Data from students and musicians were analysed in these studies.

(Hoffmann E et al, 1997; 85) describes a study of military recruits and found that 60% of the subjects had hearing loss in one form or other. However, the frequency range used was greater than most other studies. Analysis of the recreational activities gave no statistical significance of auditory effects due to exposure to loud music.

(Ising H et al, 1988; 62) analysed the data from 4000 hearing tests to identify important sources of noise exposure. It was found that the most frequent source of inner ear hearing loss was due to impulse noise trauma from fireworks or guns. The authors state that music induced hearing losses are more difficult to prove because normally they will aggregate slowly with advancing age.

(Lindeman H et al, 1987; 112) describes a longitudinal study of male students and concludes that the failure of a significant correlation to appear between noise exposure and hearing level indicates that hearing damage from exposure to loud music has not yet affected this group. However, a significant proportion of students are risking some, perhaps minor, hearing loss from their recreational pursuits though this may not appear until their mid twenties.

(Mawhinney and McCullagh, 1992; 136) describes a study to determine noise exposure levels and to measure the hearing of musicians. The authors conclude that it would appear that the mean hearing losses are relatively small for musicians and overall it was the authors' opinion that the hearing loss seen in musicians exposed to loud music was less than anticipated considering the levels of exposure.

(Meyer-Bisch C, 1996; 4) describes a survey of hearing loss and estimates the noise exposure from a questionnaire. They conclude that the risk to hearing from pub and club attendance is limited to those who go regularly but do not work in them. Also the author states that what has been said about the relatively low risk of hearing damage for customers is not true for staff.

(Rosenhall U et al, 1993; 127) compares the prevalence of hearing loss in conscripts between 1970/77 to 1992 and concludes that these data show that there is no indication that hearing loss affecting noise sensitive frequencies has become more common.

(West PD and Evans EF, 1990; 42) uses a number of techniques to determine if there is a risk to the hearing of young subjects exposed to amplified music. They conclude that, while the most exposed group did not show significantly greater average thresholds they did have 10-15% wider hearing bandwidths. The measurement of auditory bandwidth was identified as a better indicator of early signs of hearing loss than pure tone audiometry. In addition a sample of older subjects did show a significant increase in the prevalence of notches in the audiogram indicating noise induced hearing loss. The authors conclude that exposure to music can be harmful.

(Martinez, 1988; 156) studies the hearing of a sample of members of the Audio Engineering Society (the number of subjects n is 229) using pure tone audiometry and a questionnaire. The results showed that there was a small but consistent hearing loss found that could not be attributed to the average deterioration in hearing associated with the ageing process.



## **2.2 Studies of Temporary Threshold Shift (TTS) as a result of exposure to music and other nonoccupational sources.**

The studies reviewed in this section generally test the severity of TTS of a small number of subjects before and after exposure to an event. Pure tone audiometry is used and in many of the papers. Dosimetry is also used to determine the level of noise exposure.

TTS occurs as a result of the ear responding to loud sounds by reducing its sensitivity. As a result of this, the threshold of audibility shifts upwards by an amount dependent on the level and duration of the exposure. After the sound is removed the threshold of hearing will begin to reduce and return to its original level. If the duration of exposure is long enough and the level high enough the threshold may not return to the original value and a permanent shift in threshold has occurred. A great deal of research has been conducted in the past on the relationship between TTS and PTS. However, the precise nature of this relationship has never been established. Therefore, the validity of using TTS as an indicator of permanent damage to the ear has to be questioned when assessing the risk of hearing loss when exposed to high levels of amplified music.

Other factors, in addition to the imprecise nature of the relationship between TTS and PTS, have an impact on the quality and validity of the work conducted in this area. In general:

- the conclusions drawn from the work are based on very small samples of the population,
- the results are presented in such a way that the variation in susceptibility of individuals to TTS is difficult to establish,
- the possibility of changes in the measurement environment are not discussed. This should be considered given the test location is often near potentially high levels of background noise.

It is therefore surprising to find that, on the basis of their results, 10 out of 11 studies conclude that amplified music presents a hazard to hearing.

### **2.2.1. Relationship between hearing loss and TTS.**

A number of studies attempt to relate incidences of TTS with PTS in terms of possible risk. Further details of these studies are contained in Annex B.

(Clark WW and Bohne BA, 1986; 117) measured the hearing thresholds of 6 subjects before and after a rock concert. The authors conclude that although there was no PTS observed, studies of hearing damage in animals suggest that these subjects may have observed some sensory cell loss from the noise exposure.

(Jaroszewski A and Rakowski A, 1994; 90) compare their results with work carried out in the 1960s by Botsford, Kryter and Nixon that showed that if a noise exposure leading to a given threshold shift  $TTS_2$  (see glossary for the definition of  $TTS_2$ ) is repeated 5 times a week for about 10 years it results in a permanent hearing loss equal to the observed  $TTS_2$ . From this analysis the authors conclude that hazards of listening to music through high powered electronic equipment may be large for specific individuals and that in any case these hazards are substantial.

Although these studies have attempted to quantify the damage to hearing using TTS as a measure, it must be stressed that the relationship between PTS and TTS is not fully understood.

### **2.2.2. *Characteristics of TTS induced by exposure to loud music.***

The data from all the papers reviewed indicate that the extent of the TTS is very dependent on the subject. Significant variations in TTS, seen from the same noise exposure, suggest that this may be one of the difficulties in establishing a link between dose, TTS and permanent hearing damage. This is further complicated by the fact that the results from (Swanson SJ et al, 1987, 40) state that the amount of TTS is also governed by the subject's attitude to the music. In this study lower levels of TTS were seen in subjects who liked the music and vice versa for those subjects who disliked the music. Also (Vittitow M et al, 1994; 41) found that subjects were more susceptible to TTS during exercise and discuss the influence of metabolic rate.

All the studies show that some TTS occurs at 4 and 6 kHz test frequencies. However, 3 out of 9 studies show that low frequencies are predominant. Historically, it has been shown that for a given excitation frequency, the frequency maximum TTS occurs from half to a whole octave above the source frequency (Kinsler and Frey, 1982; 191). The authors who identify low frequency TTS attribute it to the spectrum of modern music with its characteristic bass content. Where TTS has been identified at low and high frequencies, the studies show that hearing recovers faster at high frequencies.

## **2.3 Other methods used to study hearing damage as a result of exposure to music and other nonoccupational sources.**

A number of methods, other than the use of audiometry to establish hearing thresholds, have been adopted to study the risk of hearing damage as a result of exposure to amplified music.

### **2.3.1. *Otoacoustic emissions (OAE)***

The vibrations of the outer hair cells in the cochlea of a healthy person can be detected by a microphone positioned in the ear canal. According to (Kemp D, 2000; 196), when an acoustic stimulus is presented to the ear, friction between the moving surfaces and fluids in the ear damp the vibrations of the outer hair cells which would have the effect of dulling the hearing if it were not for another group of hair cells which support the vibrations and replace energy lost by friction. The acoustic energy produced by these cells is detected by a microphone positioned in the ear canal during these tests. The magnitude of the emission gives an indication of the health of the outer hair cells with low levels indicating some damage.

Three different methods are used. Transient evoked otoacoustic emissions (TEOAE) are measured in the ear canal following a stimulation of the cochlea from a transient sound such as a click or gated tone pip. Distortion product otoacoustic emissions (DPOAE) are measured as a result of a stimulation of two pure tones with different frequencies. Spontaneous otoacoustic emissions (SOAE) are measured in the absence of any stimulus.

(Vinck BM et al, 1999; 147) measures the OAE in a controlled noise exposure in the laboratory (n = 10) and also exposure from pubs and clubs (n = 8). TEOAE and DPOAE as

well as pure tone audiometry were used to assess the change in hearing following the noise exposure in a similar manner to the studies of TTS discussed in section 2.2. The authors conclude that both TEOAE and DPOAE have a great potential in the detection of TTS after noise exposure. However, there is no discussion of the relationship between the reduction of the levels seen in the OAE tests and permanent hearing damage.

(Liebel J et al, 1996; 64) describes a study of the relationship between TTS (pure tone audiometry), TEOAE and DPOAE following noise exposure at a club (n = 46). Measurements were conducted before and after the exposure and the authors conclude that TEOAE and DPOAE are not ideal instruments in the detection of temporary threshold shifts after noise exposure.

(Tomasevic P, 1998; 52) conduct a similar study to assess the relative merits of pure tone audiometry and DPOAE in detecting TTS (n = 22) and concludes that “audiometry is more sensitive in detecting noise damage than DPOAE”. However there is no argument put forward to suggest that TTS is a good indicator of hearing damage.

All these studies have the same restrictions as the studies of TTS described in the previous section - there is no established relationship between TTS and permanent hearing loss. In addition the conclusions from these studies suggest that the ability of OAE techniques to identify the extent of TTS may not be as good as pure tone audiology. But this conclusion is not shared by all authors.

### **2.3.2. Questionnaires**

A number of the PTS studies utilised questionnaires to establish possible reasons to explain the extent of hearing loss. The studies reviewed in this section (DeLay S et al, 1991; 9), (Gunderson E et al, 1997; 12), (Ising H et al, 1997; 33), (Jokitulppo JS et al, 1997; 36) and (Meecham EA and Hume K, 1998; 139) differ in the fact that the data collected from the questionnaires are used to estimate the risk to hearing by establishing noise exposure levels based on the frequency of attendance and either measured or assumed sound pressure levels. The reliability of these studies depends on:

- the assumptions made about the sound pressure level,
- the accuracy of the data regarding the frequency, duration and number of years of attendance,
- the validity of the damage risk criterion used to assess the population who may be expected to have hearing loss.

Details of these studies are presented in Annex B.

All these studies suggest that there is a significant risk to hearing from exposure to amplified music. However, very little discussion of the limitations associated with these studies is presented. It is thought that, given the assumptions that have been made during these studies, a detailed analysis of the limitation of the techniques adopted and their effect on the results should play an important part of the study.

More interesting is the attitude of patrons, bar staff and managers to exposure to loud music.

The questionnaire data from (DeLay S et al, 1991; 9) shows that 60% of bar staff responded positively to the introduction of more stringent control of the level of noise whereas the majority of patrons and bar owners were not in favour of any restriction imposed on the level of the music.

The results from (Gunderson E et al, 1997; 12) indicate that hearing, in terms of the incidences of tinnitus and the perception of the quality of their hearing, may become worse with increased length of employment in clubs.

(DeLay S et al, 1991; 9), (Gunderson E et al, 1997; 12) also concluded that there is a definite need to educate people on the risks to hearing from amplified music.

### **2.3.3. National Survey Data (Jekel JF, 1996; 63)**

The data for this study were provided by a number of questions which formed part of the National Health Interview Survey in the U.S.. Respondents were asked if they could understand whispering in a quiet room and were asked to identify possible causes of any hearing trouble from a list provided. The data were then used to test the hypothesis that there is an increase incidence of hearing loss due to extensive listening to popular music over the last three decades. The age adjusted prevalence of hearing trouble of any kind increased from 7.7% in 1971 to 8.6% in 1991. Also, between 1971 and 1991 there was a doubling of severe hearing loss in the 18 to 44 year old and 45 to 64 year old age groups.

### **2.3.4. Study of patients attending a clinic. (Metternich FU and Brusis T, 1999; 71)**

In this study an attempt was made to establish the causes of music related acoustic trauma of 24 patients receiving therapy during a four year period. Pure tone audiometry was used to determine the type of hearing damage. The hearing loss of 67% of the patients was developed on the basis of one-time exposure at a rock or pop concert. 17% of the patients developed their hearing loss as a result of attending clubs. The majority of the patients showed a maximum hearing loss between 3 and 4 kHz. Many instances of tinnitus were seen and 13% of the subjects developed tinnitus without hearing loss. The authors conclude that the risk of permanent hearing loss resulting from short term exposure to amplified music is low compared to the risk of tinnitus.

## **2.4 Summary**

The studies of PTS as a result of exposure to amplified music provide the best indication of the risks of exposure to loud amplified music. However, it is difficult to draw any overall conclusion of the risk to hearing from exposure to loud music due to the variety of outcomes and the difficulties associated with this type of study. In summarising the findings it is important to recognise all the factors which can influence the results of this type of study. These include:

- the limitations of audiometry in identifying the early signs of hearing loss,
- the difficulties in estimating the exposure levels associated with various types of nonoccupational noise,

- the difficulties of highlighting the cause of hearing loss (i.e. noise induced, otitis media, genetic etc.),
- the effects of subjects being able to perform the test more effectively. This may be due to the ability of the subject to perform the test because of previous experience or being more capable of performing the test due to increased dexterity with age,
- the identification of single event noise exposure, especially an impulsive event which may traumatise the ear,
- the different audiometric methodologies used and the influence of different test environments,
- the different criteria used to define hearing loss.

The lack of information about the relationship between TTS/OAE and PTS severely restrict the conclusions that can be drawn from this type of study.

Although the majority of the quality research suggests that the risk to the general public from exposure to loud amplified music is small, a number of researchers suggest that this may not be the case for people working in this environment. It therefore seems appropriate to recognise that there is a definite risk to the hearing of employees in places which have amplified music played but it is not possible to establish the number of individuals whose hearing will be impaired as a result of this exposure.

It is suggested that new studies in this area should aim to extend the depth of data and the age range of longitudinal studies. In addition, a common approach to the definition of hearing loss should be agreed to enable data from a number of sources to be compared.

### **3. NOISE LEVELS AND EXPOSURE TIMES**

The data supplied in the literature show that noise levels in pubs and clubs vary considerably depending on venue.

The work carried out to assess exposure to professionals from amplified music can be broadly divided into three categories:

- Workers in concert venues,
- Musicians,
- Workers in pubs and clubs.

The nature of the noise exposure for each of these categories differs in terms of level and exposure patterns and therefore should be dealt with independently. This study will only deal with workers in pubs and clubs. References containing information on the noise exposure levels of the other groups are included in the bibliography.

#### **3.1 Methods**

This section will only deal with exposure to employees from amplified music. The work conducted on the risks to the general public is reviewed in section 2.

The literature reviewed for this section describes the methods and results from noise assessment type studies, used to determine the risk to employees in pubs and clubs. The Noise at Work Regulations 1989, Regulation 4 specifies that:

“Every employer shall, when any of his employees is likely to be exposed to the first action level (daily personal noise exposure of 85 dB(A)) or above or to the peak action level (peak sound pressure of 200 Pascals) or above, ensure that a competent person makes a noise assessment...”

The purpose of a noise assessment is to:

- identify those people at risk from hearing damage so that the employer can formulate an action plan for controlling noise exposure in accordance with the Noise at Work Regulations 1989,
- determine the daily personal noise exposure ( $L_{EP,d}$ ) of those who are likely to be exposed at or above the first action level or peak action level,
- identify any additional information which might be needed to comply with the Noise at Work Regulations 1989, such as where and what type of noise control or ear protection is appropriate.

An overview of the noise exposure levels reported in the literature is presented in Table 1 with a discussion about the implication of these levels also presented in section 3.2.

Guidance regarding the compliance with the Noise at Work Regulations 1989, produced by the HSE (HSE, 1998; 193), suggests that dosimeters or fixed microphones can be used to assess the noise exposure of employees in pubs and clubs. Both techniques have their advantages and disadvantages. These are discussed in more detail in the following two sections.

### **3.1.1. Dosemeters**

Dosemeters indicate the total noise dose received over the measurement period in either  $\text{Pa}^2\cdot\text{h}$  (i.e. the total acoustic energy for the exposure period) or as a percentage of the allowed daily dose ( $L_{EP,d}$ ). The microphone for the dosimeter is worn on the body and therefore makes it feasible to measure the  $L_{EP,d}$  of a highly mobile worker. However, a measurement correction is required due to the proximity of the microphone to the body, this correction is dependent on the microphone location, clothing and the nature of the sound field. Mechanical shock to the microphone can influence the measured level and therefore it can be difficult to obtain reliable information from dosimeters in crowded pubs and clubs. This is recognised by many authors as the reason for the often high incidences of peak levels greater than 200 Pa. A dosimeter is the only practical method of measuring the noise exposure of mobile workers such as floor staff and security staff due to the high variation in noise levels throughout their shift.

### **3.1.2. Microphones in fixed positions**

Microphones in fixed positions have been used successfully to measure the sound pressure level (SPL) in situations where the employee works at one or more fixed workstations. In these situations care must be taken to get accurate measurements of the time the employee spends at each workstation. The  $L_{EP,d}$  can be determined from this data.

## **3.2 Employee noise exposure levels**

Table 1 shows a summary of the SPL and  $L_{EP,d}$  measurements from the literature surveyed. Either the average or range of the SPL data are presented for each subset of employee where specified. The average  $L_{EP,d}$  data from all the measurements presented in each study is presented for each subset of employee where specified. In addition the average number of hours worked per week and the period of service is presented where this data is available.

**Table 1. Reported noise exposure information.**

Reference	Personnel	SPL dB(A)	L <sub>EP,d</sub> dB(A)	Average hours per week	Length of service months	Comments
Davis et al, 1985; 1		82-113	-	-	-	Information on attendees from various discos
Dibble, 1988; 153	DJ	103	99	20	14.5	Information presented are averages of the data from 12 discos. SPL measurements were collected using a sound level meter. Dose levels were measured using a dose meter.
	Manager	98	92	22.5	15	
	Bar staff	90	92	17.5	9.5	
	Floor staff	90	93	17.5	6	
	Security	84	94	20	8.5	
Tan et al, 1990; 5	DJ	94	93			Information are averages from 5 discos. The dose figure was calculated from a 1 hour exposure and normalised to the 8 hour period.
	Bar Staff	94				
	Entrance	73				
	Dance Flr	97				
Fox, 1992; 191	DJ	100	93			Information presented are averages from 4 discos visited 3 to 4 times. The dose measurements were conducted over 5 hours and then normalised to 8 hours.
	Bar staff		89			
	Floor staff		90			
	Dance flr					
Lavender, 1993; 177	Bar staff	96	93	17.5		Information presented is the average from 5 venues (including 2 pubs). The dose measurements were conducted with a dosimeter for a “representative period” and then normalised to 8 hours.
Fortin & Hetu, 1994; 129	DJ		96	15		The daily dose was calculated from a weekly dose presented in the paper. The information presented is an average from three sets of measurements.
Whitfield, 1995; 134 1998; 151	Bar staff	94	89			Information presented is based on fixed position measurements and dosimeter measurements conducted in 19 clubs.
Fleming, 1996;11	Bar staff		93			Information presented is based on dosimeter measurements conducted in 11 venues.
Howley, 1996;142	Bar staff	78 - 104	99			The dose information is based on the average of measurements conducted in 7 night clubs.
Gunderson et al, 1997; 12	Bar staff	84 - 97	97 -99			Not enough information is presented in the paper to extract individual exposures
Clarke, 1997; 148	DJ	91 - 107	97	14.6		The dose information was calculated from the SPL at a fixed location. and is based on the average of measurements conducted in 12 nightclubs.
	Bar staff	87 - 100	91	14.2		
Edelston, 1998; 125	Bar staff	75 - 105	91	16.2	32	The dose information was calculated from the SPL at a fixed location and the exposure time and is based on the average of measurements conducted in 4 nightclubs, 15 pubs .
Dunbabin, 1999; 131	DJ		99			The information is based on data from two nightclubs
	Bar staff		94			
	Floor staff		96			
Lane, 1999; 143	Bar staff	89 - 103	91	13		The information is based on the average of measurements conducted in 4 nightclubs.
	Floor staff		92			
Gatland, 1999; 178	Bar staff	96	97			The information is based on the average of a number of measurements conducted in one night-club. The SPL measurements are measured with a SLM and the dose measurment with a dosimeter
	Door staff	92	99			
	Floor staff	102	100			



All the individual  $L_{EP,d}$  data from these studies have been collected for each work task and the overall average and standard deviation of the sample are shown in table 2.

**Table 2. Summary of the individual noise exposure data calculated from data presented in the literature.**

Task/occupation	Number of measurements	Average $L_{EP,d}$ dB(A)	Standard deviation dB(A)	Average hours per week
DJ	53	96.3	4.8	16.5
Bar Staff	204	92.3	4.2	15.7
Floor staff	32	92.9	4.4	
Security	10	96.2	3.2	

Using the procedure in ISO 1999 (Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment) a prediction of the effects of the  $L_{EP,d}$  levels, shown in table 2, on the hearing threshold can be determined. This analysis assumes that the damage to hearing from loud music is the same as industrial noise. The results are shown in figure 1 for bar staff (section 8) and figure 2 for DJs (section 8) and table 3 below. These graphs show the predicted noise induced permanent threshold shifts (NIPTS) as a function of time based on the daily exposure  $L_{EP,d}$ . Four curves are shown in each graph which correspond to the predicted NIPTS for the following conditions;

- predicted NIPTS at 4 kHz for 50% of the population based on the average  $L_{EP,d}$  from the literature.
- predicted NIPTS at 4 kHz for the 5% of the population worse effected by the noise based on the average  $L_{EP,d}$  from the literature.
- predicted NIPTS at 4 kHz for 50% of the population based on the average  $L_{EP,d}$  plus one standard deviation from the literature (i.e. accounts for the levels in 80% of clubs).
- predicted NIPTS at 4 kHz for the 5% of the population worse effected by the noise based on the average  $L_{EP,d}$  plus one standard deviation from the literature (i.e. accounts for the levels in 80% of clubs).

**Table 3. Predicted noise induced permanent threshold shift (from ISO 1999) as a function of years of exposure for Bar staff and DJs.**

	Level	Percentage effected	NIPTS after x years exposure (dB)			
			x = 10 years	x = 5 years	x = 2 years	x = 1 year
Bar staff	average	50%	15	11	7	4
	average	5%	22	17	11	7
	average + SD	50%	23	17	11	7
	average + SD	5%	34	26	16	11
DJ	average	50%	23	17	10	7
	average	5%	33	25	16	10
	average + SD	50%	34	25	16	10
	average + SD	5%	50	38	24	15

This analysis shows that significant NIPTS can occur at the levels of noise exposure reported in the literature depending on the length of service.

This assessment assumes a level of noise exposure based on a 40 hour week. However, the average working week for employees in clubs is approximately two days and therefore 2/5 of the assumed 5 day week. In this situation ISO 1999 states that when the noise is not the same from day to day the analysis is valid if the  $L_{EP,d}$  on the worst day does not exceed the equivalent continuous A-weighted sound pressure level averaged over a longer period by more than 10 dB. In this situation the analysis conducted here is valid for a period of 4 weeks. It is therefore assumed that as long as the employee works a 16 hour week every week the analysis is valid.

It would seem from this analysis that there is a significant risk for employees to damage their hearing whilst working in pubs and clubs but the severity is very much dependent on the duration of service. There is very little information in the literature regarding the period of service of these types of employee. However, there is a suggestion from a number of sources in the literature that the noise from loud music is not as damaging to the ear as the industrial noise sources on which ISO 1999 is based (see section 2.1). It must be re-emphasised this analysis assumes that loud amplified music has the same damage potential as industrial noise.

### **3.3 Summary**

In general the studies reviewed in this section have been well designed and the authors recognise the factors which influence the results and the limitation of their work. This is most probably due to recognised methods of conducting these surveys and the advice that is available. However, it is worth pointing out that there are some papers, excluded from the discussion presented here, that are of poorer quality. When conducting studies of this nature it is critical to:

- either measure the noise exposure using a personal dosimeter and apply a mounting correction and sufficient care to avoid mechanical shock, or, measure a “representative” fixed microphone positions. It is not adequate to assess the noise exposure to employees by measuring levels on the dance floor only.
- determine the time taken at each work location including rest periods.
- determine the weekly work patterns for the employees and get an indication of the length of time the employees have been in this occupation. In addition it is useful to have information regarding other employment and other noise exposure.

Differences in  $L_{EP,d}$  measurements conducted with dosimeters and fixed microphone measurements can be attributed to either the accuracy on the dosimeter in terms of the amount of mechanical shock it is subjected to and the effect of microphone mounting, or the ability of fixed microphones to measure the true noise exposure of mobile members of staff.

All of the  $L_{EP,d}$  values reported in the literature, with the exception of a few conducted in pubs, exceed the first action level of 85 dB(A) which means that employers should conduct noise assessments. In the majority of cases employees are subjected to exposure levels greater than 90 dB(A). Even taking into account the casual nature of this form of employment there is a significant potential for employees to incur some level of NIPTS the extent of which is dependent on the noise levels and the period of employment.



## **4. METHODS OF REDUCING AND CONTROLLING NOISE EXPOSURE.**

The implementation of noise reduction and the introduction of noise control techniques in pubs and clubs is limited by:

- the desire of a significant proportion of the population to attend venues which play loud music,
- the practical limitations of isolating employees from the loud music,
- the common perception that this type of noise exposure will not damage hearing and is therefore not important,
- the suitability of hearing protection for employees and their willingness to wear it.

The literature addressing these problem can be broadly split into three sections -noise control methods, education and regulation. The section covering regulation will be dealt with in chapter 5.

### **4.1 Noise Control and Exposure reduction**

A number of studies have developed practical methods which can be adopted to control noise levels and exposure. In addition a number of research papers suggest additional methods which, if adopted, may assist in the control of exposure levels.

#### **4.1.1. Noise survey and risk assessments**

Although this is not a noise reduction technique, a number of authors state that the starting point of any reduction process should be a noise survey to identify possible problem areas. Also under the Noise at Work Regulations 1989, employers who are likely to subject employees to noise levels greater than 85 dB(A) should conduct a noise assessment. These should be conducted in accordance with the regulations.

(Macpherson, 1990; 171), (Macpherson and Parker, 1991; 101) ( Worksafe Western Australia, 1999; 144) suggest a method of conducting noise assessments based on “room loss”. The principle behind this method is to measure the sound pressure at workstations relative to a reference position. From this data noise assessments can be conducted from measurement at a single location. The authors state that the room loss is constant for each venue. The influence of changes in the spectrum of the noise are not dealt with in the paper which may affect the results if the spectrum of the noise changes significantly.

#### **4.1.2. Level setting**

Historically, there has been an ongoing debate regarding the setting of an upper limit on the level of the music in pubs and clubs. This debate has addressed the setting of the level and the effectiveness and difficulties in monitoring and regulating this technique in reducing the noise exposure. There is obviously a compromise that needs to be established to enable the public to enjoy the experience of loud music in pubs and clubs whilst maintaining a safe environment for employees and patrons. It is suggested that the minimum level that provides satisfactory entertainment is typically 94 to 96 dB(A) (Dibble, 1988; 153) (Mawhinney and McCullagh, 1992; 136).

It is worth extending the time frame of the literature review for this section to include the work that was carried out before 1985. Again only the data applicable to pubs and clubs is presented.

**Table 4. Suggested maximum sound level setting criteria.**

Study	Level	Comment
Leeds City Council, 1973 (information taken from Gittins, 1986; 99)	96 dB(A)	Level measured not less than 2m away from loudspeaker with SLM set to slow and repeated throughout the premises
GLC, 1976	93 dB(A)	$L_{Aeq, 8 \text{ hrs}}$
GLC, 1985	$L_{EP, event}$ 90 dB	an $L_{eq}$ of the event equivalent to an $L_{EP, d}$ 90 dB
Bickerdike J, 1986; 21	100 dB(A) 102 dB(A) 87 dB(A)	$L_{eq}$ at loudspeaker nearest the public over the duration of the event. $L_{eq_{5 \text{ min}}}$ should not exceed this level on the dance floor $L_{eq_{5 \text{ min}}}$ should not exceed this level in rest areas
Meyer-Bisch C, 1996; 4	100 dB(A) 85-90 dB(A)	on the dance floor other parts of club
Ising H, 1997; ;33	95 dB(A)	
HSE, 1999, 15	107 dB(A)	event $L_{eq}$ in any part of the audience
Hohmann BW, 1999; 149	93 dB(A)	$L_{eq}$ based on one hour.

(Whittle and Robinson, 1974; 195) suggested that the action levels should be raised by 3 dB above the EU directive to take account of the intermittence of the noise.

In addition a number of authors include a peak sound pressure level limit of 140 dB in accordance with the peak action level in Noise at Work Regulations 1989.

Although the aim of these studies was to limit the sound pressure levels in pubs and clubs, the evidence provided by the literature review of sound level, presented in section 3.2, (Griffiths, 1991;17) and (Griffiths and Staunton, 1991; 155) suggests that very few establishments adhere to any guidance on level setting.

The practicalities of installing monitoring equipment and the location and calibration of such a device as well as the policing of the level to which the limiter is set all influence the effectiveness of level setting techniques.

#### **4.1.3. Loudspeaker location**

The literature suggests that a number of loudspeakers should be used to ensure the level is uniformly distributed over the dance floor and to prevent “hot spots” where excessively high levels may occur close to the loudspeakers.

(HSE, 1999; 15) states that the public should not be allowed within 3m of a loudspeaker and under no circumstances should the audience and loudspeaker separation distance be less than 1m. (Bickerdike, 1986; 21) states that members of the public should at no time be allowed to approach nearer than 2m from any operational loudspeaker.

Loudspeakers should be directional and located so that they concentrate their radiation onto the dance floor and away from staff working locations.

#### **4.1.4. Acoustic design**

Employee workstations areas should be positioned away from the dance floor.

(Worksafe, Western Australia, 1999; 144) suggests increasing the acoustic absorption in the room through the use of absorbent materials used to reduce the reverberation and using local screening adjacent to bars. (Dunbabin, 1999; 131) adopted these technique with some success.

#### **4.1.5. Quiet areas**

(Bickerdike, 1986; 21) suggests that a rest area or areas equivalent to at least 25% of the total public area of the premises should be provided. In these areas it is suggested that the  $L_{Aeq}$  averaged over the floor area for a period of 5 minutes should not exceed 85 dB. This approach has been suggested by a number of authors who also suggest that bars should be positioned in these areas.

In practice it is difficult to achieve the sound isolation required to achieve the sound pressure limit of 85 dB(A) in the quiet area especially in small clubs. In addition many clubs are not purpose built so the modification of the building to form a quiet area may be impractical or excessively expensive.

#### **4.1.6. Staff/Job rotation**

(BEDA, 1991; 152) (Dibble, 1991; 184) suggest the use of staff rotation to limit the time periods spent in noisy areas. They suggest that this can be achieved by zoning the club into a number of areas depending on the sound pressure level. The practical implementation of this technique is very much dependent on the design of the club. The daily noise exposure of employees is strongly influenced by the period of time the employee spends in the loud areas of the club and to make an appreciable difference to the exposure level the employee must spend significant amounts of time in the quiet areas. In practice the effectiveness of this approach has been shown to be limited (Howley, 1996; 142), (Edelston, 1998; 125).

#### **4.1.7. Hearing conservation programmes**

A number of authors suggest that hearing conservation programmes should be developed for employees of clubs. However, they do not present details of such programmes. The following issues are suggested in the literature.

- routine audiometry,
- conduct a noise assessment,
- notify employees of the risk to their hearing,
- supply hearing protection and training on their use,
- conduct regular sound level measurements to assess deviation away from original noise assessment,
- maintain record of staff noise exposure levels.

However, a number of these functions of a hearing conservation programme are limited due to the temporary and mobile nature of employment.

#### **4.1.8. Personal Protective Equipment**

From the literature it is apparent that the effectiveness and practicality of using hearing protection in pubs and clubs is dependent on the function that the individual is performing.

It is argued in many papers that hearing protection is not suitable for bar staff due to the need to communicate.

Many authors suggest that hearing protection should be used at all times by glass collectors.

It is suggested in a number of papers that DJs should use ear muffs with sound restoration devices fitted to enable them to monitor the music and also isolate them from the ambient noise of the pub or club.

However it must be pointed out that providing hearing protection does not remove the duty placed on the employer to reduce the noise exposure of employees “so far as is reasonably practicable”.

## **4.2 Education**

The most commonly suggested method of reducing the risk is to educate the general public and employees of the risk to hearing acuity from exposure to excessive amounts of loud amplified music. A number of approaches and target groups are suggested. These are summarised in this section.

### **4.2.1. Local authorities**

This subject will be dealt with in greater detail in chapter 5. However, it is apparent from personal communication with LA Inspectors, (Howley, 1996; 142) and (Edleston, 1998; 125) that there is a definite need to raise awareness of this issue and provide practical advice in this specific area.

### **4.2.2. Employees**

(RNID, 1999; 2) suggest that publicity is required to raise awareness of the risks to employees of the total exposure to noise through all activities. They state that “studies in America point to young people being less likely to take the warnings about noise seriously and are more concerned about how they look”.

(BEDA, 1991; 152) suggest that notices in staff rest areas and at work stations should be used to warn of the risks of high noise levels and to avoid going on the dance floor where the noise levels are generally the loudest.

### **4.2.3. General Public**

In concluding their work (Yassi A et al, 1993; 43) state that “communicating risk is a complex undertaking particularly in the context of voluntary risk. However, education is a widely recommended prevention strategy. Unlike controlling legislation, providing information does

not threaten liberty or autonomy, individuals remain free to decide whether to act on the information.”

(Axelsson A, 1991; 26) states that “the comparatively poor results of warnings and scare tactics should be recognised and accepted. It would probably be better to try to influence young people to appreciate their wonderful sense of hearing”.

#### **4.2.4. Pupils**

Numerous studies have been performed to assess the effectiveness of education of the risks to hearing posed by modern living. From these studies it is apparent that it is not only the pupils who are negligent of the risks, often the educators are also not familiar of the risks. This literature is not reviewed at great depth since it is thought to be outside the scope of this study. However, it is worth pointing out that authors have suggested that the risks should be presented in context with other risks. References on this subject are contained in the bibliography.

#### **4.2.5. Owners**

Duties are placed upon employers by the Noise at Work Regulations 1989 to carry out specific functions and these will be dealt with in greater detail in chapter 5. However, (Worksafe Western Australia, 1999; 144) gives a good review of the responsibilities of club owners. Any educational information should include an outline of the employers obligation to:

- ensure the health and safety policy includes preventing risks from excessive music noise,
- communicate this information to employees and performers,
- be familiar with the Regulations,
- be familiar with relevant codes of practice,
- arrange for noise assessments,
- evaluate and implement noise reduction methods with the help of professionals,
- supply hearing protection and education.

The indications from the literature (Clark, 1997; 148), (Howley, 1996; 142) and (Edelston, 1998; 125) are that very few employers are aware of the Noise at Work Regulations 1989 and therefore fail to carry out their duties. Therefore, some form of industry specific guidance is appropriate.

#### **4.2.6. DJs**

(Meyer-Bisch C, 1996; 4) concludes that training is required for staff responsible for sound levels in clubs by giving them a basic understanding of hearing risks and the means and measures to reduce them.

#### **4.2.7. Attenders**

(HSE, 1999; 15) states that where an event is likely to be greater than 96 dB(A) audiences should be made aware of the potential risk of hearing damage.



(Bickerdike, 1986; 21) suggests a notice should be placed in the entrance to the premises stating “Patrons are reminded that high sound levels can damage their hearing. Ask at the cash desk for the leaflet giving further information”. The leaflet contents are also outlined in his report and includes:

- stand well away from loudspeakers when not dancing,
- take frequent rests from dancing,
- do not go to the loudest discos frequently,
- identification of TTS and tinnitus,
- identification of additional risks if the individual works in a noisy environment.

(BEDA, 1991; 152) suggest the maximum sound pressure levels should be displayed on a plaque in the entrance.

### **4.3 Summary**

It is apparent that perfectly good practical guidance, aimed at reducing the exposure to employees in this industry, has been available for some time (Bickerdike, 1986; 21), (BEDA, 1991; 152), (HSE, 1999; 15) and (Worksafe Western Australia, 1999; 144). However, there is no indication that this guidance has had any effect on the levels reported in chapter 3.

The literature suggests that there is a need to educate club owners, DJs and employees of the risk from exposure to loud music and their duties under the Noise at Work Regulations 1989. In addition a large proportion of the literature suggests that education of the general public regarding the potential risk of loud amplified music is also required.

## **5. ROLE OF THE LOCAL AUTHORITY**

Control of employees noise exposure has come about due to the implementation of the Noise at Work Regulations 1989. These Regulations define the duties of employers and are intended to prevent damage to the hearing of workers from exposure to excessive noise at work. The Regulations are based around three action levels:

- the first action level is a daily personal noise exposure of 85 dB(A),
- the second action level is a daily personal noise exposure of 90 dB(A),
- the peak action level is a level of peak sound pressure of 200 pascals.

Clearly the night-club owner is in a difficult situation. On one hand the owner has to run a commercially viable business providing a venue which offers loud music and on the other hand the owner has a legal obligation under the Noise at Work Regulations 1989 to provide a working environment which will not damage the hearing of the employees. In addition under Section 3 of the Health and Safety at Work etc. Act 1974 every employer has the duty to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected are not exposed to risks to their health and safety.

The evidence seen in the literature review shows that there is no doubt that the daily personal exposure levels of workers in clubs exceeds the first and second action levels in the majority of cases. However, enforcement of the Noise at Work Regulations 1989 has been made difficult in this industry due to the “so far as is reasonably practicable” in the statement regarding the reduction of the noise level in Regulation 7. This statement has been used as a method to effectively exempt this industry from the Noise at Work Regulations 1989 due to the commercial implications of reducing the level of the music. Clearly some form of guidance is required if employees are to be protected whilst maintaining commercial viability for the club. This guidance also needs to address the wishes of the general public to attend venues which play loud music and must not be seen to infringe on their liberty. In addition, it is apparent from the literature and personal communication that many LA Inspectors are reluctant to deal with noise in nightclubs without the support of national guidance and are therefore reluctant to attempt to address these issues.

This section will review the information assimilated during this survey which may help in defining guidance aimed at LA Inspectors and Night-club Owners to help control the noise in this industry. It must be pointed out that previous attempts to control the noise in nightclubs has, by and large, failed. It is the opinion of the author that the autonomous approach taken previously by providing Codes of Practice for Night-club Owners has failed and an approach aimed at LA Inspectors providing support and enforcing legislation is the best way of controlling noise in the industry. This method has been successful in some Local Authorities in the UK and in Australia (Groothoff, 1999; 190). However the guidance has to be seen as necessary, practical and shown not to impinge on civil liberty.

## **5.1 Relevant Work**

### **5.1.1. Womack**

Although not strictly a review of literature, the personal communication with David Womack from Blackpool Borough Council has provided valuable information regarding the enforcement of the Noise at Work Regulations 1989 in pubs and clubs. Samples of his enforcement experience are produced in two case studies presented in Annex C.

### **5.1.2. (Groothoff, 1999; 190)**

A study of 30 music venues was conducted following a number of complaints in Brisbane Australia. Twenty nine out of the thirty venues were shown to have levels over the exposure limit of  $L_{Aeq, 8h} = 85$  dB(A). Following the noise surveys venue operators were visited to present them with the results of the survey and to establish their knowledge of their legal obligations. Only two operators had any significant knowledge of the local work place noise regulations.

Information was provided to the owners by the Health and Safety Inspectors to assist them in meeting their duties and improvement notices were issued outlining a range of options for the reduction of noise exposure. One venue failed to comply with the requirement to enforce the wearing of hearing protection and was eventually prosecuted.

Two years later fourteen of the original venues were revisited. Although the noise levels were generally excessive there were a number of positive points illustrated by the survey:

- operators' knowledge of their obligation to prevent exposure of workers to excessive noise had increased since the initial visit,
- eight venues had sound limiters installed,
- hearing protectors were available in twelve venues with seven businesses actively enforcing their use.

The author concludes that it can be argued that effective control can be successfully incorporated in the running of music entertainment venues without them going out of business.

### **5.1.1. (Hohmann, 1999; 49)**

This paper presents the results of a survey of the hearing of young people in Switzerland and gives an outline of a Swiss hearing conservation campaign. Details of the survey are presented in Annex B. A summary of the hearing conservation campaign is presented below.

The Swiss Federal Office of Public Health developed a concept for a prevention campaign that was based on three factors: Legislation, information and material for schools and exhibits. Legislation:

- maximum sound pressure level of 93 dB(A) $L_{eq, 1hour}$  is set. Exemptions may be granted if this limit would lead to "unacceptable restriction",
- if an exemption is granted, the organiser must offer hearing protection to all persons attending the event and warn the public in an appropriate manner of the potential damage to their hearing,

- to assist DJs and Sound Engineers, sound level meters are offered to rent.

Information at the “point of danger”:

- the authorities provide a poster and an information leaflet “Protect your ears” which may be used by organisations to inform the audience,
- this poster and leaflet fulfil the requirements mentioned above.

Information material for schools and exhibitions:

- 300000 copies of “Music and Hearing Loss” were distributed,
- Information packs containing a sound level meter were produced.

No information is presented in the paper about the effectiveness of this campaign.

### **5.1.3. (Dibble, 1988; 153)**

This paper suggests that Regulations 4, 5, 6, 7, 8, 9, 10, 11 and 13 of the, then draft, Noise at Work Regulations 1989 should be implemented by employers in the pub and club industry providing the following points are observed:

- the high turn over of staff within the industry may make the keeping of accurate records, as stated in Regulation 5, difficult. It was suggested that such records should relate to the particular workstation or job description and be applied to any employee doing that job.
- Regulation 7, regarding the reduction of the levels if they exceed the second action level, should be enforced but based on an adjusted 2<sup>nd</sup> action level of 92.2 dB Leq to take account of the reduced working hours of the staff. However, since the action level is defined as an  $L_{EP,d}$ , in the Noise at Work Regulations 1989, the length of the shift is accounted for in the calculation and therefore the elevation of the second action level is not justified.
- Regulation 8(2) states that employees should be provided with suitable personal ear protectors when they are likely to be exposed to the second action level or above or to the peak action level or above. Dibble suggests that employees should be allowed an exemption from this Regulation 8(2) under the provision of 13(b)(i) which states that the Health and Safety Executive may exempt any employer from the requirement in Regulation 8(2), where the daily personal noise exposure of the relevant employee, averaged over a week... is below 90 dB(A) and there are adequate arrangements for ensuring that the average will not be exceeded due to the small fraction of the standard 40 hour working week worked.

Note: the Noise at Work Regulations 1989 are fully defined in (HSE, 1998; 193).

### **5.1.4. (Howley, 1996; 142) and (Edelston, 1998; 125)**

These two studies were conducted as undergraduate projects by students from Leeds Metropolitan University.

(Howley, 1996; 142) found a strong correlation between the category of non-compliance and the size and type of ownership of the premises. Some premises appeared to be able to demonstrate legislative compliance on paper while blatantly breaching the Noise at Work

Regulations 1989. In the Local Authority where the study was conducted there was a very low level of activity to promote compliance with the Noise at Work Regulations 1989 in the night-club industry. This was attributed to either a failure by the Local Authority to identify occupational noise exposure as a health and safety issue and lack of resources, training and methodologies to deal with these issues. The author suggests that industry specific guidance or information is required and the HSE should use existing communication links to raise awareness of the issues amongst Local Authorities.

(Edelston, 1998; 125) also found that inspectors in the Local Authority studied, were aware of the risks to hearing in this industry but were unable to commit to enforcing the relevant legislation due to the practicalities of performing inspections during the club's operational hours and the issue not being recognised as a high priority. The author suggested that Local Authorities should ensure that premises with a Public Entertainment Licence should be made aware of the Noise at Work Regulations 1989 and understand the actions required. The enforcing officer should provide advice on methods of controlling the noise. The Local Authorities should establish an enforcement strategy based on guidance from regulatory bodies.

Both authors state that their conclusions are drawn from experience within the Local Authority studied but suggest that the problem is likely to be widespread throughout the UK.

## **5.2 Guidance Documentation**

The data presented in the literature shows that there is a need to control the noise exposure of employees in nightclubs. Also, there is evidence that this control can be achieved and enforced through the Noise at Work Regulations 1989. However, the effectiveness of the enforcement is presently limited by:

- the lack of a clear policy defining a strategy that Local Authorities can adopt to facilitate enforcement,
- the limited availability and distribution of guidance for night-club owners regarding:
  - the risks associated with the noise,
  - their responsibilities under the Noise at Work Regulations 1989,
  - methods of controlling the noise, and
  - methods of complying with the Noise at Work Regulations 1989.

This guidance is clearly required and should provide:

- a level playing field, giving the licensing authority and proprietor a common objective and also ensuring that all premises are treated equally,
- a framework for event planning,
- a mutually understood benchmark for assessment and enforcement.

(Trevor Jones, 1992; 172).

When setting out guidance the effectiveness of previous studies such as those mentioned in section 4.1.2 and (BEDA, 1991; 152) should be taken into account.

## 6. CONCLUSIONS

The conclusions found in a similar review of the literature (Davies et al, 1985; 1), and reviewed in section 1.1, are still valid 15 years later.

This review has highlighted the conflicting conclusions that exist in the literature regarding the risk to hearing from exposure to amplified music. In most cases these studies have considered the risk to the general public from this noise and seem to be driven by the perception that the modern life style is damaging to hearing. In many cases researchers seem to have preconceived views of the risks and appear to be blinkered or negligent of the limitations of the processes they adopt to prove their point. For this reason the literature review concentrated on the more objective studies.

Although the majority of the objective research suggests that the risk to the general public from exposure to loud music is small, a number of researchers suggest that this may not be the case for people working in this environment. It therefore seems appropriate to recognise that there is a definite potential for harm to employees in places which have amplified music but it is not possible to establish the number of individuals whose hearing will be impaired as a result of this noise exposure.

It is apparent from this review that control of noise levels in pubs and clubs is very difficult to implement. A number of studies have addressed the difficulties associated with control of this noise in the UK; however it is apparent that the problem still exists. There are a number of reasons why control of this noise has not been successful. These include:

- uncertainty of the risk to hearing,
- lack of evidence to substantiate the perception of the risks,
- the need to provide people with the environment/experience provided by pubs and clubs,
- antagonism to rules imposed on people's leisure activities,
- the commercial implications of reducing the level of the music in pubs and clubs with the risk of losing custom,
- difficulties encountered by LA Inspectors in regulating against excessive levels of music in terms of the enforcement of the Noise at Work Regulations 1989 in clubs and pubs, limitation in the resources available, lack of experience in dealing with noise as an issue in pubs and clubs and the effectiveness of periodic regulatory visits.

A number of studies have been carried out to determine the risk to employees and establish codes of practice to alleviate the problems. However, since the problem of noise exposure to employees is still prevalent, the effectiveness of these autonomous approaches, without the enforcement power of the Local Authorities, has to be questioned. To achieve the objective of minimising the risk to employees in clubs and pubs, guidance and codes of practice should be developed to aid the enforcement of the Noise at Work Regulations 1989. This approach should be seen as being necessary, reasonable and practicable to all parties concerned.

Although not perfect for this application, the Noise at Work Regulations 1989 give LA Inspectors a legal base to insist that methods are put in place to control the noise exposure to employees in pubs and clubs. Armed with this, LA Inspectors have the unique power to

enforce the Noise at Work Regulations 1989 in this industry and provide sources of information as guidance to reduce the risk.

Education is also of paramount importance. Increasing the awareness of the potential risks of damage to hearing from amplified music specifically aimed at employees and employers can only serve to improve matters. Additionally, publicity aimed at the general public would help to educate people of the risks from exposure to leisure noise. This should be carried out in a manner that does not sensationalise, and therefore over-state, the risk.

## **7. RECOMMENDATIONS**

### **7.1 Guidance**

1. Clear guidance is required to enable LA Inspectors to enforce the Noise at Work Regulations 1989 in pubs and clubs. This guidance should be based on practical experience and should provide a framework which enables the enforcement of the Noise at Work Regulations 1989 to be achieved in an efficient and objective manner.
2. Support documentation is required to assist owners of pubs and clubs to comply with the Noise at Work Regulations 1989. This literature should explain the reasons for the enforcement of the legislation, methods of compliance and practical methods of reducing the employee's noise exposure levels. The guidance should be seen as being necessary, reasonable and practicable.
3. The general public need to be informed of the possible risks associated with frequent attendance at places which play loud amplified music. This information should be provided in a manner which does not sensationalise the problem but informs of practical steps that can be taken to avoid the possibility of hearing damage.

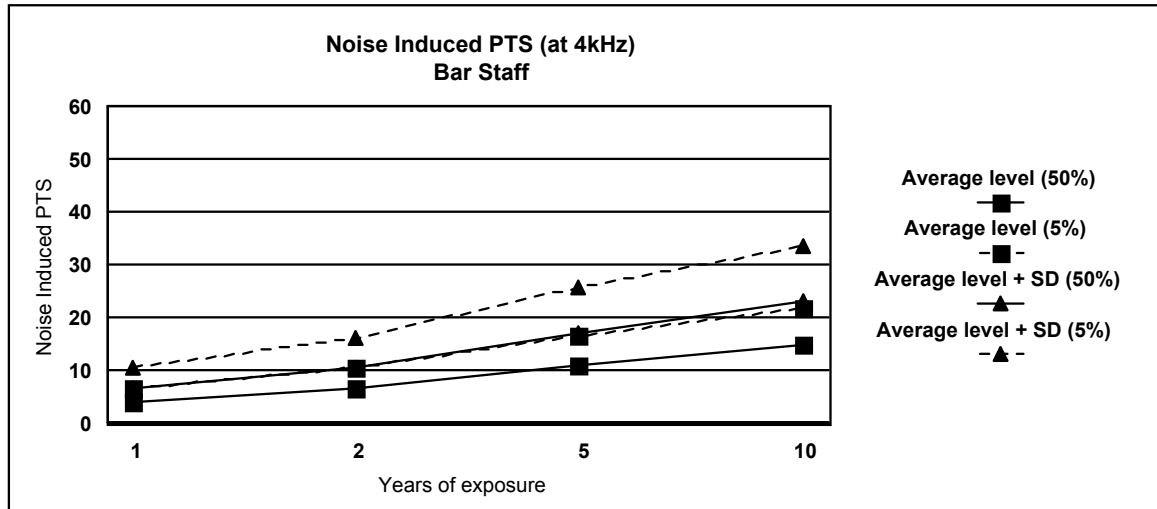
### **7.2 Research**

1. There is a lack of information reported in the literature regarding the work patterns of employees in pubs and clubs. A survey is required to estimate the hours, days and years of service of employees in this industry. This information will help to establish the risk of hearing impairment following a protracted period of employment. The acquisition of this data is difficult due to the transient and mobile nature of the work force. However, a study of the employment history of individuals would provide valuable information. Collaboration with the industry representative groups would be required for this process.
2. The age span of existing longitudinal studies of the incidences of PTS should be increased. Many of the studies have been conducted on teenagers and people in their early twenties and it is argued that the true hearing loss cannot be established on individuals so young. The data from this sort of study would provide valuable information regarding the effect of noise from leisure activities on individuals over a longer period of time and may give a better indication of the risks to hearing from exposure to leisure noise. Institutions who have conducted research in this area should be encouraged and supported to extend these studies.
3. The implementation of the guidance specified in 7.1 should include some form of monitoring to evaluate the effectiveness of the guidance. Initially, this could take the form of a questionnaire, issued with the guidance, that aims to establish:
  - a profile of the industry within the jurisdiction of the local authority,
  - the extent of previous experience in this industry,
  - an estimate of the compliance with the Noise at Work Regulations 1989 in Clubs and Pubs within the local authorities jurisdiction.

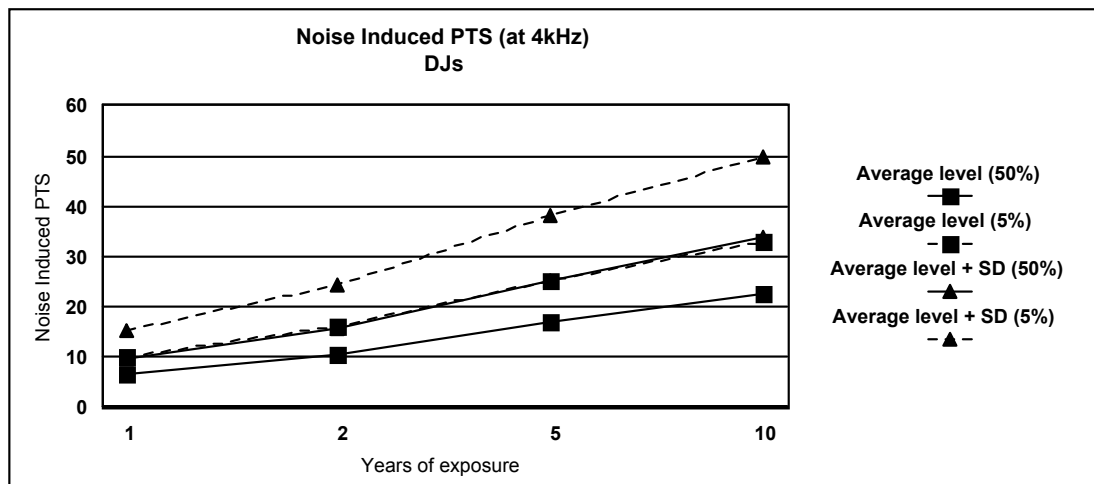


This process should be repeated, at a specified period following the implementation of the guidance, to establish the effectiveness of the guidance and to review the procedures if they are shown to be ineffective.

## 8. FIGURES



**Figure 1: Predicted noise induced PTS at 4 kHz for bar staff (from ISO 1999)**



**Figure 2: Predicted noise induced PTS at 4 kHz for DJs (from ISO 1999)**



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## ANNEX A - DETAILS OF SEARCH METHODS

The following Databases were searched during this study:

- Embase:
- Medicine: specialist medical and biomedical file, worldwide with strong US input.
- Excerpta Medica: specialist medical and biomedical file, European bias.
- HSEline: bibliographic file produced by HSE Information Services covering all aspects of occupational safety and safety health, and its related disciplines, covers monographs, conference papers, journal articles, HSE publication, and specialist reports from organisations worldwide in the field of health and safety.
- NTIS: file of US Government research covering the whole spectrum of science, medicine, engineering technology
- Compendex: worldwide file on a broad spectrum of engineering issues, including noise engineering. This service would also cover items featured in leading science journals such as New Scientist
- Conference Paper Index: produced by British Library, a file indexing worldwide conference papers across all disciplines.
- Inside conference:
- Urbaline:
- RILOSH:
- Inspec: specialist file produced by the Institute of Physics covering all aspects of physics, electrical and electronic engineering.
- Accompline: file produced by the London Research Council covering predominantly UK, of issues pertinent to local authorities
- Science Citation Index: this is a unique online file, analysing authors cited in papers/articles. The value of this tool is that searching acknowledged authors leads to other specialists in the same field.
- Clover Index: this service indexes feature articles in the 'popular' UK magazines.
- Lexus: database holding newspaper files.

Two letters were circulated to a number of manufacturers, professional bodies and industry representative bodies with a mixed response. In general La inspectors were very willing to help and supply information. Only one response was received from industry representative bodies or manufacturers.

The break up of the 195 references identified in this survey are as follows:

- 21 could not be located
- 14 were not in English
- 15 were not relevant

The remaining 145 were reviewed and used to provide information for the literature survey, the source of these references were:

- 64 were identified by secondary references from reviewed papers,
- 16 were identified by Embase database,
- 11 were supplied through personal correspondence,
- 10 were identified by HSE Line database,
- 9 were identified from personal records and personal review of current literature,
- 7 were identified by Inspec database,

- 6 were identified by Medline database,
- 6 were identified by Inside Conference database,
- 4 were identified by Science Citation Index database,
- 4 were identified by HSL Medical Files database,
- 3 were identified by Lexus database,
- 2 were identified by Conference Paper Index database,
- 2 were identified by RILOSH database,
- 1 was identified via the Internet.

## **ANNEX B - SUPPORTING DETAILS**

### **B.1 (Axelsson A, Aniansson G and Costa O, 1987; 119)**

This paper presents the results of a longitudinal study of children at approximate ages 7, 10 and 13 (n = 2325). Screening audiometry was used at a level of 20 dB with pure tone audiometry used to determine the hearing threshold at failed frequencies. The authors characterise three different factors which could be responsible for hearing loss in this age group and in doing so attempt to identify the cause of any hearing loss measured in this group.

1. Serious Otitis Media which would manifest itself as a low frequency hearing loss.
2. Noise induced hearing loss which has been shown to be more common in boys and would manifest itself as a high frequency hearing loss.
3. Genetic hearing loss which is also more common in boys and would manifest itself at middle frequencies.

The results show that, at all ages, the left ear was more commonly affected. The incidences of hearing loss at different ages were for boys: 13.7%, 15.7% and 15.6%; and for girls 11.7%, 12.1% and 9.0% for ages 7, 10 and 13 respectively. The authors suggest that the increase in hearing loss for boys with age is due to noisy leisure pastimes and/or hereditary effects. Serious Otitis Media is suggested as the least likely cause of this hearing loss. It was found that the subject's ability to conduct the test at the age of 10 and 13 mean that the measured hearing is better.

The authors state the benefit of longitudinal studies over transectional studies due to the increased control and therefore more reliable method.

### **B.2 (Axelsson A, Rosenhall U and Zachau G, 1994; 113)**

Pure tone audiometry was used to measure the hearing levels of 500 randomly selected conscripts. For the purposes of the study hearing loss was defined as thresholds greater than 20 dB at one or more frequencies in one or both ears. In addition a social questionnaire was used to assess the historical noise exposure of the subjects. 18 year old subjects were chosen for the study due to their small amount of exposure to occupational noise and therefore any hearing loss can be attributed to hereditary factors, otitis media or nonoccupational activities. From the results it was found that the mean hearing was mostly well within that expected by international standards. Individually 14% of the subjects has some hearing loss. The author reported that this was considerably lower than that reported in comparable studies in the UK and Norway (Borchgrevink, 1988; 103). 79% of the subjects reported listening to pop music often or very often, 17% had attended more than 10 pop/rock concerts and 21% played a musical instrument.

No correlation between musical activities and the state of hearing were found. The authors state that in several previous studies they had not been able to demonstrate any correlation between attendance at rock concerts or clubs and hearing loss. However, they do express caution due to the fact that normal pure tone audiometry is by no means a guarantee for a complete assessment of sensory hair cells.

The high frequency hearing loss seen in the study were attributed to medical conditions in youth, noisy toys and guns. Differences in test conditions and testers are suggested as a possible reason for the lack of agreement between studies of music noise and hearing loss.

### **B.3 (Axelsson A, Eliasson A and Israelsson B, 1995; 79)**

This paper presents a comparison of pure tone audiometry data from an initial series of tests, performed on a number of rock/pop musicians, in 1975 (n = 83) and re-tests of the same subjects in 1991 and 1992 (n = 53) to see if their hearing had changed over the intervening period.

On an individual basis the data from the re-examination shows that 63% could be said to have 'normal hearing' with hearing losses less than 20 dB at frequencies 3, 4, 6, and 8 kHz in both ears. In addition another 15% of the subjects who had a mean pure tone average of 25 dB hearing loss at 3, 4, 6, and 8 kHz could also be considered 'normal'.

In the 1975 study the conclusion was made that the hearing sensitivity of rock/pop musicians was surprisingly well-preserved after an average of 10 years exposure 18 hours a week to levels of between 95 to 105 dB(A). In addition, the authors were surprised that rock/pop musicians, after performing for 26 years, had such well posed hearing. It was hypothesised that this could be attributed to "a protective effect by the generally positive attitude from the musicians towards their performance and their audience". However, 27 out of 40 musicians did complain about hearing loss, tinnitus and hyperacusis.

The authors were surprised by the apparent resistance of musicians to high sound levels but are careful not to advocate performances of loud rock/pop music at sound levels above 100 dB(A). In addition the authors state that pure tone thresholds are a fairly crude method of reflecting the condition of sensory cells and therefore may hide an underlying problem with the ear.

The authors conclude, there is "no satisfactory answer to the question of who makes the decision of sound levels during performances -the audience, the musicians or the sound engineer. We feel that the sound engineer is the key person who should also be responsible for how high sound levels could be emitted to the audience".

This study is well defined and controlled. In addition the authors clearly state their reservations in over emphasising the results.

### **B.4 (Becher S, Struwe F and Weber K, 1996; 30)**

(The paper is written in German with only the abstract in English. Therefore it is difficult to assess the quality of the work and derive any specific conclusions.)

Pupils aged 16 to 25 years of age (n = 277) were questioned about their hearing and instructed about the consequences of hearing impairment resulting from listening to loud music. Over 75% of the pupils knew that loud music can cause damage to their hearing and after the instruction 75% of the pupils were willing to protect their hearing in future.

In addition audiometer assessments were offered. Eight out of the 89 pupils measured had a hearing reduction of up to 40 dB.

### **B.5 (Borchgrevink, 1988; 103) and (Borchgrevink, 1992; 137)**

Both these papers use data collected from screening audiograms of 18 year old males conducted before starting military service between 1981 and 1987 ( $n \sim 35000$ ). The procedure for the screening started by testing whether the subject's hearing was sufficiently good to hear the level representing a 20 dB hearing loss at the standard test frequencies (250 Hz to 8 kHz). In the case where the hearing loss was greater than 20 dB at any frequency a pure tone audiogram for all the test frequencies was carried out.

The results showed that during this period the incidence of high frequency hearing loss doubled from 18% to 35%. The incidence of low frequency and mid frequency hearing loss were unaltered in this period.

The author states that, since the measurement conditions were the same for all the measurements, the results reflect a true and reasonably view. The author attributes the increased prevalence of hearing loss to greater exposure to music noise. This statement is based on the fact that exposure to occupational noise is unlikely at this age and consequently the increase in hearing loss is caused by increased exposure to leisure noise. However, no scientific data is presented to support this argument.

### **B.6 (Brookhouser PE, 1992; 133)**

Only the abstract is presented so it is not possible to establish the techniques used. This report focuses on children aged below 19 years who were diagnosed as having probable noise induced hearing damage on the basis of clinical history and audiometric configuration. 42% of the children had unilateral losses while 72% has sensorineural losses of varying degrees. As a result of this study the author calls for more longitudinal studies of noise induced hearing loss in children and adolescents. No indication of the percentage of the population this sample of subjects represents is given.

### **B.7 (Carter N, Murray N and Bulteau V, 1985; 87)**

In this work pure tone audiometry was carried out on subjects aged 16 to 21 years old ( $n = 117$ ) and a second group aged 28 to 33 years old ( $n = 136$ ). Two age groups were chosen because the lower age group have been tested a great deal and there is a risk that they are not old enough to have been exposed to enough noise to damage their hearing. In addition to the measurements a questionnaire was completed to identify the level of exposure to loud music. Subjects who had had a history of ear disorders were rejected. For the purposes of the study loud music was defined as music which made it difficult to understand speech (raised voice) at a distance of 1 metre. The results indicate that, while hearing acuity declines measurably at higher test frequencies between the ages of about 18 to 30, there is no evidence of the effect of amplified music during this time. Also the results, which are not presented in the paper, indicate no change in the shape of the average audiogram and no deterioration in hearing acuity between tests conducted on 16 to 21 year olds in 1977 and 1984.



### **B.8 (Clark WW, Bohne BA, 1986, 117)**

The hearing thresholds of six volunteers were tested before and after a rock concert. In addition dosimeters were used on two subjects to assess their noise exposure. The average exposure was 100 dB(A) during the 4 hour concert and five subjects had threshold shifts greater than 50 dB predominantly in the 4 kHz region. The hearing of all the subjects had returned to normal after 16 hours. The author concludes that “although no PTS was observed, comparison of these data with studies of hearing loss and cochlea damage in animal models suggests that these subjects may have sustained some sensory cell loss from this exposure”. Only the abstract is presented so the details of this comparison and the severity of the impairment is not presented.

### **B.9 (Danenberg MA, Loos-Cosgrove M, and Lo Verde M, 1987; 118)**

This paper presents the results of a study of 20 students (12 to 17 years old) and 7 adults prior to and after exposure to a school dance. All but one student and one adult experienced at least a 5 dB shift at one frequency or more. Alarming, of the four students and two adults randomly selected for a re-test 3 days post-exposure, only two students displayed complete recovery. The authors conclude that “ although the exact relationship between TTS and PTS has not yet been established, we believe that the results of this study should arouse concern among adolescents, their parents and school administrators”.

### **B.10 (Davis AC, Lovell EA, Smith PA and Ferguson MA, 1998; 44)**

This work was split into a number of phases:

1. A questionnaire was distributed to several thousand households asking about hearing, tinnitus and social and occupational noise. The results from this phase demonstrated that hearing problems and tinnitus were more likely to be reported by those people who had higher exposure to social noise sources.
2. The hearing of as larger population as possible (n = 341) were tested using a number of different test methods to establish the effect of the reported threefold increase of social noise greater than 97 dB NIL over the last decade. These subjects had varying social noise exposures. Individuals who reported tinnitus were selected for further study (n = 32) to investigate any differences due to social noise exposure.
3. The aims of the third phase, which consisted of subjects identified in phase 2, were:
  - to compare the nature of the tinnitus reported by those who have social noise exposure of greater than 97 dB NIL and those who do not exceed this criterion,
  - to compare the auditory function of those subjects who complain of tinnitus and who have social noise exposure of greater than 97 dB NIL with:
    - a) those subjects with tinnitus and no social noise,
    - b) those subjects with no tinnitus but have substantial social noise exposure.

The conclusions drawn from the incomplete study suggests that:

- the auditory function of young people who report tinnitus differs depending on the level of social noise exposure.
- there is some evidence to suggest that the auditory function of young people who report tinnitus and have significant social noise exposure differ from those who do not report tinnitus and those who have not experienced similar leisure noise.

The authors conclude that “Much larger collaborative studies are needed to investigate this important area and make definitive and generalisable statements about the effects of leisure noise -especially tinnitus”.

At the time of reporting the study was not complete. However, the sample sizes for phase three were small at 32. Although the methodology adopted by the authors seems rigorous it is difficult to gain an overall understanding of the depth and quality of the work due to the presentation of the results and incomplete descriptions of the methods adopted.

#### **B.11 DeLay S, Hiscock S, Koopmans T and Lenser S, 1991; 9)**

This study examined the relationship between hearing loss and loud music levels in 15 bars in Canada. Sound pressure levels were measured and a questionnaire completed by patrons, bar staff and management to gauge awareness of the effects of loud music and determine the prevalence of hearing conditions.

The average sound level measured is reported as 101.8 dB(A). It is not clear from the paper if this is a peak measurement of an  $L_{eq}$ . The survey data showed that 60% of patrons admitted that they experienced ringing in their ears after leaving the bar. 70% of bar employees experienced ringing in their ears after completing a shift. 70% of patrons did not believe that loud music could have a permanent effect upon hearing. 60% of bar staff responded positively to the introduction of more stringent noise regulations. However, the majority of patrons and bar owners were not in favour of any new regulation.

The authors conclude that the measured data and the prevalence of ringing in the ears following attendance in a bar suggested a potential hazard and that there is a general lack of awareness of the risks.

It is unclear from the paper what was measured in the bars, but the data on opinions clearly show the difference between bar staff who want to protect their hearing and bar owners who may not be conducive to reducing the levels because of commercial implications.

#### **B.12 (Drake-Lee AB, 1992; 81)**

In this small scale study of members of a rock band ( $n = 4$  one of which wore hearing protection) audiograms were taken before and after a concert. All unprotected ears showed a temporary threshold shift which was maximum at low frequencies. The mean thresholds are presented but there is no individual analysis presented. The author concludes that “there is a small but definite risk of developing noise damage with sensorinural hearing loss and tinnitus in rock musician”. However, this conclusion is based on a very small sample. The influence of the relationship between TTS and PTS is not discussed in the paper.

#### **B.13 (Fearn published data between 1986 and 1993)**

Following on from work conducted in the early 1980s, Fearn presents a series of letters and articles which analyse the methods used to assess the data from audiograms from young people and new data to establish the link between hearing loss and attendance of clubs. Throughout this work the results are normalised by adjusting the pure tone audiometry

thresholds at different frequencies to those at 2 kHz which helps to the audiometric variations introduced by background noise and calibration. The analysis methods are modified through the progression of the work but essentially the methods are the same throughout. During the series of papers it is not always obvious whether new data is being presented or additional data is being added to a database of existing data.

(Fearn, 1986; 105) found that better results could be obtained if the results of each ear were not averaged and the percentage of subjects with hearing loss of 10 dB or more in either ear were plotted against the number of attendances. This approach identifies the 5 to 10% of the population that suffers the greatest hearing damage. In addition, the relaxation of the rejection of audiograms from otologically abnormal subjects makes no statistically significant differences to the results. The results from the re-analysis of the data were found to be a lot clearer and showed that at 4 kHz there is a reasonable relationship with the number of attendances and the percentage of subjects with greater than 10 dB (15 dB or more at 6 kHz) hearing loss in one or both ears.

(Fearn, 1989; 107) extends the age range of the subjects included in the previous study and carries out a more rigorous analysis of the data. The results of this show that there is no justification for the rejection of audiograms where a family history of hearing difficulties is obtained, subjects have undergone adeno-tonsillectomy, subjects have recently had a catarrhal illness or where only a single audiogram is obtained. All these relaxations greatly increase the number of available results and thus improve the accuracy of the results. The results were found to be consistent with the hypothesis of increasing threshold shift at 3 kHz and 4 kHz with increasing exposure to amplified pop music.

(Fearn, 1989; 31) compares hearing threshold of student musicians ( $n = 92$ ) with the results from a control group ( $n = 255$ ). Both groups included non-attenders to amplified music performances and subjects with a total of 99 such performances which is associated with little or no elevation of thresholds. Included in this study is the investigation of older musicians to allow for possible presbycusis effects. The percentage of subjects with hearing thresholds greater than 15 dB (20 dB or more at 6 kHz) in one or both ears were determined. The results show that overall, musicians aged between 18 and 25 years old have no significant difference in their hearing thresholds when compared to the control group. However, differences were seen when comparing the data with older musicians. Indications are that hearing thresholds are worse for amplified music professionals than orchestra professionals but the authors state that the sample sizes are small. The hypothesis was confirmed by splitting the subjects into amplified and classical music groups where those who play regularly in amplified music groups show elevated thresholds.

(Fearn, 1990; 106) presents the percentage of a tested sample of school children aged between 11 and 17 ( $n = 1126$ ) whose normalised hearing threshold are greater than 15 dB at 3 or 4 kHz or 20 dB at 6 kHz in either ear and identifies the most likely reason for the high tone dips in their hearing. A similar analysis of a group of students aged 18 to 25 years old is also shown ( $n = 929$ ). The percentage of subjects with elevated thresholds is significantly higher for a group with attendances between 1 and 99 than for a control group of non-attenders. Similarly a significant increase of subjects with elevated thresholds is seen in a group with attendances of 250 or more when compared with the group who have attended between 1 and 99 events. The author concludes that amplified music accounts for 14% of the subjects with hearing

thresholds of 15 dB or more at 3 kHz or 4 kHz or 20 dB at 6 kHz. The risk to the hearing of young people from amplified pop music performances is under no restriction and hearing damage from this source will continue.

(Fearn, 1991; 86) aims to show the relationship between serial audiometry (the measurement of hearing thresholds of a subject at successive intervals of time) and retrospective audiometry (the measurement of hearing thresholds at a point in time and establishing the history through the use of questionnaires). The results obtained show the same trends but serial studies have less measurement variation and give a much surer measure of hearing loss but it is harder to achieve.

(Fearn, 1993; 89) a survey of typical sound levels ( $L_{eq}$ ), taken at various positions in orchestras and bands and at practice lessons of solo instruments, was conducted. The highest levels arose from playing amplified pop music in particular the drums. Due to the frequency of noise exposure through regular practice sessions it was thought that studies of the permanent threshold shift in musicians may be influenced by temporary threshold shifts. Data from this study suggests that, to ensure measurements of hearing thresholds are not elevated by temporary shifts, an overnight freedom from exposure to sound of percussion, brass instruments, orchestra and amplified music and one hour freedom from sound of other instrumental practice is required. Hearing threshold tests were conducted on student musicians aged between 16 and 30 years old ( $n = 220$ ) and musicians aged 31 years or over ( $n = 30$ ). Substantial numbers of young musicians exhibit normalised hearing thresholds of greater than 15 dB at 3 or 4 kHz or 20 dB at 6 kHz in either ear. About 31% of these play in orchestras and up to 50% play in amplified music groups. Much of the hearing loss occurs at 6 kHz in one ear. These findings are in line with those of young people exposed to amplified pop music. However, the author states that there is a major difference as professional musicians are employed in the industry and therefore the Noise at Work Regulations 1989 apply. The author believes that routine audiometry has a major role to play in hearing conservation and should be preferred over measurements using sound level meters.

All of Fearn's work is based on the assumption that normalised hearing thresholds of greater than 15 dB at 3 or 4 kHz or 20 dB at 6 kHz in either ear are a true reflection of a damaged ear. This analysis approach may explain why, in general, Fearn reports greater incidences of music induced hearing loss than other authors. On the other hand Fearn's analysis of the data without averaging the results may give a truer reflection of the real incidences of music induced loss.

#### **B.14 (Gunderson E, Moline J and Catalano P, 1997; 12)**

The noise exposure to bartenders and waiters in eight music clubs in New York were studied. All the clubs feature live bands. The average of the noise levels, measured during three or four visits to each club between the hours of 21:00 and 02:00, were made. A dose meter was worn by an investigator standing near the midpoint of the bar. Measurements were taken for 30 minutes during the performance and 10 minutes in either the interval or before the band started their act. In addition a questionnaire was completed by 97% of the bartenders.

All averaged levels exceeded 90 dB(A) with the averaged performance levels ranging from 95 dB(A) to 107 dB(A). A relationship between distance from the noise source and noise levels was not found.

The findings for the questionnaire survey were:

- Employees who worked in the louder clubs were found to experience more symptoms of noise exposure after work and were more likely to perceive hearing deficiency after work,
- Recent employees perceived more hearing loss after work than did employees of longer service,
- The relationship between tinnitus after work and employment duration approaches significance,
- 55% of those questioned felt that they could not hear as well since becoming employed at the clubs,
- Hearing difficulty was associated with the noise level, duration of employment and the use of hearing protectors,
- 55% never or rarely used hearing protection, 29% used hearing protection occasionally, 16% used hearing protection often or always. No employees were observed wearing hearing protection during the data collection.

The authors conclude that hearing conservation programmes need to be developed for the employees of music clubs. Providing education about the risks of noise induced hearing loss and the necessity of regular use of hearing protection is essential for the prevention of hearing loss in this range of workers.

#### **B.15 Henoeh MA and Chesky K, 1999; 73)**

Data on musicians obtained through voluntarily responding on the Internet about their age and reported hearing loss (n = 3292). The data was then compared to data provided by the National Center for Health Statistics (Jekel JF, 1996; 63). The results of this comparison suggest that musicians may have a higher incidence of reporting hearing loss up to the age of 40.

No details of the questionnaire are presented and the validity of the study is not discussed in the paper. The lack of any statistical analysis of the data with respect to the sample size differences and differences in the nature in which the two surveys were conducted calls into question the validity of the conclusions from this study. In addition, an analysis of the differences in the questions posed in the two surveys and its impact on the results is not discussed. These factors are thought to be critical in this sort of study.

#### **B.16 (Hoffmann E, Fleischer G; Muller R and Lang R, 1997; 85)**

(The paper is written in German with a summary in English. Therefore it is difficult to assess the quality of the work.)

Pure tone audiometry (up to 16 kHz) was used to assess the auditory acuity of military recruits prior to the start of their training (n = 424). In addition, a questionnaire was completed to approximate their noise exposure related to occupation, sport, hobbies and music and it also covered incidences of tinnitus and medical problems with the ears.

The authors identify hearing damage where subjects have a greater than 20 dB hearing loss in one or both ears at at least one test frequency. 60% of the subject were found to have hearing

damage in one form or another. This is a higher than normal incidence of hearing loss due to the extension of the test frequency range. Different damage patterns were seen in the data. 23% of the subjects had a hearing damage within the range 250 Hz to 8 kHz. This hearing loss was in most cases connected with a hearing loss in the extended frequency range. 38% of the subjects' hearing affected only the high frequency range 9 kHz to 16 kHz. In 60% of all cases the maximum point of dip was at 6 or 8 kHz with only 7% of all dips occurring at 4 kHz. 81% of the high frequency dips occurred in one ear only implying a primary cause from a massive single event.

79% of the subjects habitually went to clubs. On average these were visited once a week for approximately 4 hours. Measurements in clubs recorded noise levels of 103 dB. Analysis of recreational activities gave no statistical significant evidence of auditory effects due to exposure to loud music. In addition, analysis of the data using an ISO1999 approach showed that this method overestimated the risk. However, the authors state that these results should not be taken as a sweeping statement of the harmlessness of loud music.

#### **B.17 (Hohmann BW, Mercier V and Felchlin I, 1999; 149)**

The aims of this study were to assess the extent of hearing damage of young people in Switzerland. To achieve this young people aged 15 to 26 years old completed a questionnaire and had their hearing thresholds measured using pure tone audiometry (n = 347). In addition each subject configured a personal cassette player (PCP) to the level they normally use. The data from the questionnaire was used to estimate the noise exposure levels over the previous five years with levels of 93 dB(A) for clubs and 100 dB(A) for concerts assumed. These figures were assumed because since 1996 Switzerland has had a regulation which sets the A-weighted levels of clubs and concerts to 93 dB(A) and 100 dB(A) respectively. The results from the questionnaire show that 64% of the subjects suffered tinnitus at least once after attending a loud music event. 13% were musicians of which 28% had a high frequency hearing loss of greater than 15 dB. 58% of the subjects had a weekly sound exposure of 85 dB(A) or greater.

The results from the audiograms showed that 33% suffered hearing loss of at least 15 dB in the frequencies between 3 and 6 kHz. Which the authors considered high considering the relevant ISO standard states that less than 10% of the population at this age should have such a hearing loss.

The study showed that concert and clubs are responsible for the most important part of sound exposure in this age group. However, no allowance for other noise exposure sources are given other than PCPs. In addition it appears from the paper that the PCP level was set in an environment with little or no background noise present which may influence the results and make this form of noise exposure more significant.

The following conclusions were drawn from the work:

- hearing loss caused by music listening is a real and potentially costly problem,
- sound level limits for public events are more important than regulations for PCPs,
- a public awareness campaign, especially in schools, is justified.

### **B.18 Ising H, Babisch W, Gandert J and Scheuermann B, 1988; 62)**

(The paper is written in German with only the abstract in English. Therefore it is difficult to assess the quality of the work.)

Approximately 4000 hearing test results from examinations for employment together with a questionnaire provided data to assess the state of hearing and also identify important sources of noise exposure

Roughly 2% of the subjects, who were not subjected to occupation noise, were found to have inner ear hearing losses of 30 dB or greater at one or more frequencies (this figure does not include hearing defects with known hearing history such as diseases or congenital disorders). Approximately 12% of the whole group experienced longer lasting ringing after exposure to intense sound.

The most frequent causes of inner ear hearing loss, as established through the history data given in the questionnaire, was impulsive noise trauma from firecrackers or pyropistols. The authors state that Music-induced hearing losses are more difficult to prove because normally they will aggravate slowly with advancing age.

The authors conclude “if the music listening habits found are representative and persist for 5 years, 2 to 3 % of young people in large cities will develop a hearing loss of 30 dB on average”.

### **B.19 (Ising H, Babisch W and Hanee J, 1997; 33) and (Ising H, Babisch W, Hanel J and Kruppa B, 1995; 35)**

In these studies the level of noise exposure from clubs was estimated using data from a questionnaire of subjects aged between 10 and 17 (n = 569). 15% of the subjects attended clubs at least once a week. As the music levels in the clubs were not known, the total music exposure relating to a 40 hour week was calculated for various sound pressure levels from 95 dB(A) to 110 dB(A) in 5 dB steps. The data is then compared to percentages of the population with hearing damage following exposure to noise based on ISO 1999 and show that for clubs levels of 95 dB(A) 0.6% and 5.1% of the population will have a hearing loss greater or equal to 10 dB at 3 kHz after 5 and 10 years respectively. These percentages increase to 1.8% and 14.7% respectively at club levels at 110 dB(A).

The authors conclude that urgent action is needed to take preventative measures against hearing loss caused by loud music. It is also suggested that a limit of 95 dB(A) should be introduced in clubs. They state that this limit would reduce the incidences of hearing loss greater than 10 dB from 10 to 20% to 1%.

### **B.20 (Jaroszewski A and Rakowski A, 1994; 90)**

The aim of this work was to study the distribution of sound pressure levels at a rock music performance in Poland and measure the TTS of the musicians after the concert and one year later.

Very large differences in the estimated  $TTS_2$  values were found between subjects. The values of PTS measured 48 hours after noise exposure revealed moderate permanent hearing loss in all the musicians and in one case this was severe.

The authors discuss the results from this study using work carried out in the 1960's by Botsford, Kryter and Nixon that showed that if an noise exposure leading to a given threshold shift  $TTS_2$  is repeated 5 times a week for about 10 years it results in a permanent hearing loss equal to the observed  $TTS_2$ . From this analysis the authors conclude that hazards of listening to music through high powered electronic equipment may be large to specific individuals and that in any case these hazards are substantial.

These conclusions are drawn from a very small sample of 4.

### **B.21 (Jokitulppo JS, Bjork EA and Akaan-Penttila E, 1997; 36)**

The aim of this study was to estimate the potential personal weekly noise exposure of young adults and the possible influence of different leisure time activities.

The data for the study was collected from a questionnaire ( $n = 405$ ) used to establish the amount of time subjects participated in various leisure activities and the instances of tinnitus, pain in the ear and temporary threshold shifts. From this data the percentage time for each activity was determined across each subject. The noise exposure levels used in the study were taken from the literature.

The average time of exposure at clubs and pop concerts was 3.3 hours per week. From this an estimate of the weekly noise exposure was made based on a numerical identification of the loudness of the activity indicated by the subjects in the questionnaire from 1 to 5. To estimate the noise exposure the following levels were assigned to each numerical value  $5 = 105 \text{ dB } L_{Aeq}$ ,  $4 = 95 \text{ dB } L_{Aeq}$ ,  $3 = 85 \text{ dB } L_{Aeq}$ ,  $2 = 75 \text{ dB } L_{Aeq}$ ,  $1 = 65 \text{ dB } L_{Aeq}$ . 50% of teenagers were estimated to be exposed to leisure noise at a level which the authors state could be detrimental to their hearing (i.e.  $85 \text{ dB } L_{Aeq}$ ). 70% of subjects reported tinnitus, 45% said that they experienced a temporary hearing loss. The authors state that it was not possible to identify a correlation between hearing symptoms and leisure activities and they conclude that leisure noise may be a very significant source of noise pollution in teenagers.

There are a number of assumptions and simplifications taken in this study which indicate that there is a large possibility of errors in the approximation of the noise exposure levels.

### **B.22 (Jaroszewski A, Fidecki T, Rogowski P and Moniak R, 1997; 109)**

This paper reports data on sound pressure levels and the level of TTS in patrons and performers.

Only moderate PTS was found in the patrons while the performers has PTS over middle and high frequencies of the order of 40 dB. The  $TTS_2$  values reached 40 dB in young attendants and 70 to 80 dB in performers. There is no statistical analysis of the TTS and PTS data performed. Also it is not possible to extract the number of subjects who exceeded a certain threshold from the paper.



The authors conclude “the data indicate very high risk of hearing damage in the clubs” but there is no scientific justification for this in relation to the patrons and it is difficult to assess the severity, in terms of numbers affected, for performers.

### **B.23 (Jaroszewski A, Fidecki T, Rogowski P, 1998; 84)**

The paper studies the effects of noise exposure, in the form of permanent and temporary threshold shifts, in a sample of clubs attendants and music students. It is recognised that the abundance of published data on the hearing damage from amplified music show very large variance with reference to the sound levels and their distribution in frequency and time. Audiometric testing of a sample of music students ( $n = 214$ ) showed that 68% had a permanent threshold shift of at least 10 dB in one ear at 6 kHz. In most of the literature the amount of hearing loss, used to define impairment, is usually 20 dB. Therefore one would expect there to be many more individuals who show a permanent threshold shift of at least 10 dB. From interviews, the authors established that all the notch shaped audiograms were from attendants to clubs, PCP users or those who used home audio equipment at very high levels. The authors state that the data indicates that the hazard of listening to very loud music may be substantially larger than it is generally assumed.

The paper discusses the effects on hearing as a consequence of overexposure to music in terms of the frequency discrimination, frequency resolution, the perception of loudness and the perception of time and the impact of these on professional musicians with varying degrees of hearing loss.

This paper places the current work in context with previous work conducted by other authors. There is very little description of both the methods used during this study and discussion of the limitations of the methods adopted.

### **B.24 (Jekel JF, 1996; 63)**

Questions regarding listening to loud popular music were included in a survey performed by the National Center for Health Statistics in the US. These questions were carefully worded to enable the exposure to loud music to be differentiated from exposure to other sources such as chain saws, aircraft, guns etc.. The questions was aimed to substantiate the hypothesis that there is an increased incidence of partial hearing loss due to extensive listening to loud popular music over the last three decades.

The questions were:

- can you understand whispering in a quiet room.
- does your hearing trouble come from another noise source (i.e. machinery, aircraft, power tools, loud music, appliances, walkman personal stereos, hairdryers etc.).

The age adjusted prevalence of hearing trouble of any kind, per 1000, increased from 75.5 in 1971 to 86.1 in 1991. Also, between 1971 and 1991 there was a doubling of severe hearing loss in the 18 to 44 year age group and the 45 to 64 year age group.

The author states that the questions were inadequate to be able to extract enough data but the indicators are that the prevalence of hearing disease is on the increase.

### **B.25 Lavender DA, 1993; 177)**

The aims of this work were to determine the noise exposure levels of employees in pubs and clubs and to assess the risks attributed to these levels. To do this dose meters were used on a number of staff in these premises and also hearing levels were measured prior to and after a shift.

Noise levels ranged from 89 to 97 dB(A) $L_{eq, 5mins}$  and personal doses ranged from 84 to 98 dB $L_{EP,d}$  (based on an 8 hour day). One employee was found to be below the first action level, 5 employees were between the first and second action level and 45 employees were found to be over the second action level. However, it was suggested that shocks to the dose meters may have influenced the results.

The audiometric data was analysed on the basis of the extent of TTS and compared to the CHABA Damage Risk Criterion. It was recognised that the extent of TTS depended on the subject as well as noise exposure and that it occurred at 125 Hz and 250 Hz whereas a previous study had indicated that frequencies of 1 to 6 kHz were worse effected. This difference was attributed to changes in the spectra of the music in the intervening period. The author states that overall employees are potentially at risk of noise induced hearing loss. But if the Noise at Work Regulations 1989 were enforced rigorously and a hearing conservation programme implemented then it is possible to ensure that all employees are protected.

### **B.26 (Lees R, Roberts J and Wald Z, 1985; 130)**

Subjects were randomly selected from two high schools and their hearing thresholds measured using pure tone audiometry ( $n = 60$ ). In addition a questionnaire was completed to provide information on family history of hearing loss, previous occupational noise exposure, duration and subjective level of non occupational noise (i.e. music, shooting, machinery). The audiometric data was measured at 5 dB intervals and the prevalence of a notch in the audiograms at 6 kHz was identified as an indication of a positive case of noise induced hearing loss. A 6 kHz check was chosen on the basis of previous studies identifying this frequency as an indicator of first signs of noise induced hearing loss. From the paper it is not clear if the 10 dB notch is defined as an absolute value of threshold or normalised to the data at other frequencies.

40% of the subjects were found to have evidence of noise induced hearing loss as defined by the 10 dB notch criterion. The authors state that none of the subjects examined had a hearing loss severe enough to cause disability but they do say that the 6 kHz notch may (or may not) be an indication of a greater sensitivity to noise by the subject. Also a high correlation between impairment and exposure to leisure noise was found. The frequency most often involved in noise induced hearing loss in young people was 6 kHz.

This percentage of subjects with hearing loss indicated in this study is high due to the low threshold used for the definition of hearing loss. No discussion of other possible explanations for the hearing loss other than noise exposure is given. The authors recognise the need to increase the sample size.

### **B.27 (Lindeman H, van der Klaauw MM and Platenberg-Gits FA, 1987, 112)**

This paper describes a longitudinal study of 163 males from two types of school (one general secondary school and the other a technical school) with possibly different types of noise exposure. The tests were conducted in 1977, 1980 and 1983 with the subjects' ages being approximately 17, 20 and 23 years respectively. 163 of the original 201 boys tested in 1977 were also tested in 1980 and in 1983. Bekèsy audiometry was used in conjunction with a questionnaire to evaluate the type of noise exposure.

The data was analysed by forming the average threshold for each ear, each survey and each school. The results of the study show that there is no presence of hearing damage among normal boys aged 17 who are still in full time education. Also, on the whole, there is no reduction of the hearing acuity observed among males over the study period. However, there are some indications that possible slight hearing damage will occur among adolescents between 17 and 23 years old at the frequencies 1 and 2 kHz for both the left and right ear.

The authors conclude that the failure of a significant correlation to appear between noise exposure and hearing level indicates that this has not yet been reached in the group tested. However a significant proportion of students are risking some, perhaps minor, hearing loss from their recreational pursuits though this may not appear until their mid-twenties.

The study seems very well structured and the consistency of the number of subjects through the study period is very good. Therefore it would seem that the results obtained from this study probably reflect the situation as well as can be achieved. However, as the authors recognise, it is very probable that this age range is too young to show any significant hearing loss especially since the data has been averaged rather than the identification of the number of subjects with hearing loss over a set threshold.

### **B.28 (Lundeen C, 1991; 167)**

This paper reports the results of a survey of the hearing of 38000 school children conducted in 1968 and 1969 throughout the US.. Pure tone audiometry was used at 500, 1000, 2000, 3000 and 4000 Hz. The data is analysed by determining the percentage of subjects' with hearing loss defined at the average of the pure tone thresholds at 500, 1000 and 2000 exceeding 25 dB.

2.6% of the subjects were found to have a hearing loss. This figure is lower than other researchers report due to the high criterion used for the definition of hearing loss and the lack of high frequency data used in the analysis. No reasons are given for the hearing loss.

### **B.29 (Marttila TI, 1986; 174)**

The purpose of this study was to determine the extent of undiscovered hearing losses and various types of hearing impairments in school aged children. The hearing thresholds of 40824 children were measured with screening audiology at a level of 20 dB hearing loss. All children were screened at the age of 7, 9, 13 and 17 years old. It was found that the number of pathological findings diminished significantly from repeat screening showing the significance of the training effect. 2.5% of the population were found to have impaired hearing. Of these

only 8% had sensorinual hearing impairment affecting speech frequencies and the incidences were not related to age. 6% of the subjects who were found to have impaired hearing could be identified at having a 4 kHz dip. This result prompted the author to state “the results of the study clearly show the significance of noise exposure for schoolchildren”. However, this group, with suspected noise induced hearing loss, represents 0.2 percentage of the overall population. This figure does not seem significant considering the sample population contains 17 year old subjects who have been shown to have greater incidences of hearing loss by other researchers.

### **B.30 (Mawhinny CH McCullagh GC, 1992; 136)**

The authors state that it is the view of some researchers that musical sounds at high levels do not seem to result in deafness. Other researchers following extensive studies have found that whilst hearing loss due to exposure to high levels of music is less than that of similarly exposed workers in industry, there is nevertheless a definite risk.

The research was split into a number of activities and was based on the data provided by 153 musicians of which 87 were professional.

The sound levels and  $L_{(EP, d)}$  to which musicians and patrons were exposed to were measured using fixed microphones and dosimeters. Normally performances lasted approximately 2 hours with breaks during this period. The loudest ambient noise between sets was 89.8 dB(A). Maximum value of sound pressure for individual musicians were in the range 93.5 to 117.2 dB(A).  $L_{eq, 10s}$  .  $L_{EP, d}$  values ranged from 84.6 to 104.5 dB(A) with the mean 96.2 dB(A).

Audiometric testing was carried out on the premises prior to any noise exposure from practice or performance. Data was compared with a control group with a similar average age. The means of the hearing loss of the musicians show increases at all frequencies for both ears with the left ear showing the largest increase. The authors state that “it would appear that the mean hearing losses are relatively small for musicians and overall musicians exposed to loud music do not appear to have as great a hearing loss as expected”.

The authors suggest that the maximum  $L_{eq, 1min}$  measured at the personal address system should not exceed 106 dB(A) which could result in an on stage level of 96 dB(A).

This research seems well structured and focused.

### **B.31 (Meecham EA and Hume KI, 1998; 139)**

This study was aimed at investigating the association between the attendance at night clubs and the incidence and duration of tinnitus. The study was based on a questionnaire (n = 494) designed to establish the extent and cause of tinnitus. Noise exposure levels were determined using the attendance rates indicated in the questionnaire and level data provided by the Local Authority and literature. The study showed that the attendance of university students in noisy night clubs is high and that there is a significant association between the attendance at night clubs and the duration of tinnitus. The authors state that this may indicate that although night club attendance does not cause tinnitus it may enhance tinnitus in susceptible ears.

There is no discussion of the limitations of the exercise which may have influenced the results specifically the calculation of the noise exposure. Also there is no justification presented for the argument that the listening to loud music does not cause tinnitus.

### **B.32 (Mercier V, Wursch P and Hohmann B, 1998; 53)**

(The paper is written in German with only the abstract in English. Therefore it is difficult to assess the quality of the work.)

A group of young people attending a school (n = 347) completed a questionnaire about their habits regarding the listening to music and possible hearing damage. In addition audiometry was used to measure their hearing thresholds.

In this group 64% suffered tinnitus after a loud event and 58% had an estimated weekly exposure level of 85 dB(A) or greater. The percentage of subjects suffering hearing losses of more than 15 dB at test frequencies between 3 kHz and 6 kHz was 33% with the data showing a dose-response relationship between hearing problems and increased noise exposure level.

The authors state “that the results demonstrate that too high exposure to sounds may damage the hearing of young people”.

### **B.33 (Merluzzi F, Arpini A, Camerino D, Barducci M and Marazzi P, 1997; 55)**

(The paper is written in Italian with only the abstract in English. Therefore it is difficult to assess the quality of the work.)

The hearing thresholds were measured, using semiclinical pure tone audiometry, during an initial medical examination for military service (n = 315). In addition a questionnaire was completed to assess the attitude of young people to music, their listening habits and knowledge of noise induced hearing loss. 63% of the subjects said that they attended clubs 1-4 times a week and 3% said that they listened to music with earphones at the maximum level.

When comparing the hearing thresholds with the least exposed group a significant difference was observed only for the right ear, while for the left ear the difference was not significant. The authors conclude that the hearing of young people today is worse than in the past. Prevention programmes for noise-induced hearing loss is required, at all levels, irrespective of the cause of the hearing disorders.

### **B.34 (Mori T, 1985; 121)**

Hearing thresholds of shipyard workers were measured and the exposure to recorded music assessed to establish the influence of this source of nonoccupational noise on the hearing acuity of the workers (n = 175). The subjects were split into two groups - those who listened to recorded music regularly (n = 120) and those who did not (n = 55). These groups were further divided to determine the influence of the length of noise exposure, the use of headphones and the type of music. The analysis of the data was conducted in terms of the prevalence of hearing loss greater than 20 dB.

The results show that the prevalence of hearing loss greater than 20 dB was significantly larger among listeners to recorded music than among non listeners.

The author concludes by saying that individuals who receive significant exposure to occupational noise should take care to regulate nonoccupational exposure.

In this study there is no analyses of the relative levels of occupational noise exposure of the two groups and therefore the influence of the degree of occupational noise exposure is not taken into account. In addition the sample size of the study is small and only one work environment was studied. However the study does illustrate the importance of nonoccupational noise especially to those who are subjected to high noise levels at the work place.

### **B.35 (Meyer-Bisch C, 1996; 4)**

According to MRC 6000 people are exposed to music greater than 95 dB(A) for between 150 to 230 hours every year (#97). Also 4 million adolescents suffer from hearing loss due to listening to amplified music (#97).

The aim of this study was to quantify the hearing loss with an epidemiological survey of 1500 subjects. To achieve this they defined a pure exposed group and a control group giving average results likely to give a profile of the risk associated with different tasks. The control group was defined as young people (14 to 18 years old) who were just discovering loud music (n = 358).

A questionnaire was completed by all the subjects to assess the exposure to noise at work, exposure to extra-professional activities, approximate total exposure to music, signs of auditory suffering (hearing fatigue and tinnitus) and otological antecedents not attributed to noise.

The results from the questionnaire were used to identify subjects who could be categorised into one of the following exposed groups:

- The club attenders group were identified as attending clubs and never or only occasionally attend pop/rock concerts and never or only occasionally use a PCP (n = 211),
- The concert attenders group were identified as attending concerts at least once a month and only occasionally using PCPs or attending clubs (n = 136).

The exposed groups were made up of the following individuals:

- The age range of these group was from 14 to 40 years old although the majority of subjects were in the 16 to 25 age range,
- amateur and professional musicians,
- music teachers,
- sound and stage technicians,
- concert organisers and venue managers.

Subjects who used guns or were subjected to noise in the workplace were rejected from the study.

High definition audiometry was used and was situated in the same environment for the complete study. The background noise levels in the booths were between 29 and 32 dB(A) depending on the time of day.

The results from this study indicated that risk to hearing from club attendance is limited to those who go regularly, even intensively, but do not work in them. Sound levels measured in a previous report by the author reported levels of 105 dB(A) and even 110 dB(A) and off the dance floor levels hardly go below 95 dB(A). However, a significant difference does exist between the hearing thresholds of the control group and people who frequently attend rock/pop concerts. The group who attend rock/pop concerts only regularly show intermediate results.

As control measures, the author suggests technical protective devices be used to limit the sound level to 100 dB(A) on the dance floor and less than 90 dB(A) off the dance floor. To implement this the author suggests that the labour laws would need to be conformed with and the workers access to the dance floor restricted. In addition a young persons hearing conservation programme, based on preventative measures, is required in order to limit the noise levels in places where amplified music is listened to. Training for concert and club staff responsible for sound levels is also required to give them a basic understanding of the hearing risks and means of preventing them.

The author states “what has been said about the relative harmlessness of exposure to discotheque ‘noise’ for customers is not true for staff ..especially DJs”.

The methodology of the study is well designed and planned. The author has been rigorous in verifying the test method in terms of the validity of the audiogram data.

### **B.36 (Panter CH, 1987; 116)**

The hearing level of students aged between 18 and 25 was measured together with a questionnaire detailing their estimated history of disco and pop attendances (there is no definition of these terms in the paper so it is taken that pop attendance is attendance of a pop music concert). Two types of audiometer were used during the study. No details of the comparison of the results from these devices and/or differences in calibration between them are presented.

The sample population were divided into three categories based on their attendance history. These were pop (ignoring disco), disco only, pop and disco together. The data was analysed in the form of the percentage of attenders having a mean loss of  $\geq 10$  dB at 4 kHz and 8 kHz and a mean loss of  $\geq 15$  dB at 6 kHz for both ears. These data were also corrected to the total attendance time but the details of how this was achieved are not presented. An approach similar to (Fearn, 1986) was adopted which normalises the threshold values to the data at 2 kHz.

The author compares the data to that published by (Fearn, 1986) and (Fearn and Hanson, 1984) and states that the data shows a marked difference to Fearn et al's work but the differences are not specified. Changes in the spectra of the music over time was specified as a possible cause of the differences however no data was presented to justify this. In addition all

the subjects were volunteers and therefore not a random sample may have influenced the results. No conclusions are drawn from the work but it is implied that at 6 kHz and 8 kHz there is an increase in hearing loss with attendance but it is far from conclusive.

### **B.37 (Persson BO, Svedberg A and Gothe CJ, 1993; 60)**

This study reports the results from hearing tests performed on conscripts prior to the commencement of service through the period 1969 to 1977 (n = 37381). The prevalence of hearing loss is identified as a function of year by categorising the severity of hearing loss in bands. The data shows that the percentage of subjects with hearing loss that does not exceed 20 dB in either ear at any frequency increased during this period. Conversely the percentage of subjects with hearing loss greater than 30 dB in at least one ear at one or more frequencies has reduced during the same period. This improvement in the hearing over this period was attributed to improved medical treatment over this period.

The authors attempt to compare the results of this study with more contemporary data from Norway and the hypothesis that the improvement of the hearing of the general population would cease at approximately 1980 and start to decline. However, no data was presented to substantiate this argument and there is no justification for attributing the hypothetical decline of hearing to amplified music. In addition the authors do not state the limitations of their arguments in the light of the incomplete nature of the work.

### **B.38 (Rosenhall U, Axelsson A and Svedberg A, 1993; 127)**

A comparison of the prevalence of hearing loss in conscripts measured using audiometry screening in between 1970 and 1977 (n = 37000) with conscripts of the same age measured using pure tone audiometry in 1992 (n = 500) is presented.

The prevalence of hearing loss, effecting the 3, 4 and 6 kHz region exceeding 20 dB, from the 1970 to 1977 group at one or more frequencies was 7.8% for the left ear and 6.2% for the right ear. From a similar analysis of the 1992 data the prevalence of hearing loss was 6.4 % for the left ear and 5.8% for the right. These data show that there are no indications in the present material that hearing loss affecting noise sensitive frequencies has become more common in recent years.

The authors discuss the differences between reported incidences of hearing loss from similar studies and suggest that the methodology used can strongly influence the results. In addition the method of analysing the results by establishing the prevalence of hearing loss above a specified threshold is very sensitive to slight differences very close to that threshold. Therefore it is possible to get very different results as a consequence of a slight elevation of the hearing level due to differences in measurement methodologies.

### **B.39 (Smith PA and Davis AC, 1999; 39)**

The history of noise exposure, including concerts, nightclubs, PCP and other noisy leisure pursuits, of a randomly selected sample of 18-25 year olds (n = 346) was determined and audiograms taken from all subjects. The information from the noise exposure data was



converted into an equivalent continuous dose. No details of the noise exposure levels and exposure times are presented.

65% of the subjects were thought to have significant noise exposure levels mainly from nightclubs and personal stereos. Dullness of hearing and/or tinnitus was reported by 66% of the subjects following the attendance of nightclubs and 73% following attendance of a rock concert.

No effect of significant social noise exposure on hearing thresholds was seen even in those with a history of otitis media. However an effect of this noise on the rate of reported tinnitus was seen.

#### **B.40 (Standaert B, Mertens J, Nelen V and Truyen C, 1993; 132)**

This project looked at a number of issues to determine the effect of club music on the hearing of young people. The approaches taken were; a questionnaire, a study of the general state of hearing, assessment of noise levels in clubs, the extent of TTS following noise exposure and the incidences of PPT as a function of attendance rate.

A questionnaire was sent to school pupils aged 16 to 22 ( $n = 682$ ) to establish information about their hearing relating to diseases, noise exposure and free time activities. Also an estimate of the number of hours of exposure and the noise intensity was requested on a scale form 1 to 5. The questionnaire revealed that 41.4% of vocational students spend more than 8 hours per week in clubs compared with 25.8% of students from general secondary schools and 6.8% of students from technical schools.

The authors analyse the results from the audiograms ( $n = 3519$ ), collected from students aged 16 to 22, in terms of the prevalence of hearing abnormalities as a function of the days of the week. It is not obvious why this approach was taken and there is not discussion regarding the results.

Ten minute  $L_{eq}$  and peak levels were measured in 23 clubs at a distance of 2 metres from a loudspeaker. The authors state that it was found that “only 1 club conformed to the legally permitted level of 90 dB(A)” but also “that in 7 clubs the average noise level was under 90  $dB_{L(A)eq}$ ”. It does not state what the legal requirement is in Belgium, where the survey was carried out, but it is thought that any legal requirement would be based on an exposure basis rather than a ten minute  $L_{eq}$ . The highest level was 121.2 dB(A) which seems very high for a ten minute  $L_{eq}$ . However, the sound level meter was carried in a hand bag with the microphone positioned on the outside which would not seem to be the best mounting method considering the environment in which it was being used.

Two groups were exposed to 90  $dB_{L(A)eq}$  ( $n = 12$ ) and 100  $dB_{L(A)eq}$  ( $n = 18$ ) for 1.5 hours. The hearing threshold of the subjects were measured before, immediately after and 12 hours after the exposure. The group exposed to 100  $dB_{L(A)eq}$  showed the temporary effect of disco music at frequencies of 4 kHz and 500 Hz. The tests conducted 12 hours later showed that the hearing recovered more rapidly at 4 kHz than 500 Hz.

Two exposure groups, of 25 subjects, were specified using the results from the questionnaire. These groups were characterised by the level of noise exposure based on the number of times they “went out”. The term “went out” is not defined in the paper so there is some doubt on the level or type of noise exposure these subjects were exposed to. It was found that the group who went out at least 8 times per month had statistically poorer hearing at 125, 250 and 500 Hz.

The authors conclude that “young people hear less well at lower frequencies. The possible explanation is the nature of present day disco music and its distinctively louder bass tones”. The authors suggest the following to control the levels:

- legal noise limits laid down in average  $L_{(A)eq}$ ,
- provision of quiet areas in clubs,
- monitoring systems in pubs and clubs for actual noise measurements,
- responsible placing of loudspeakers,
- health information,
- noise limiters.

This work covers many aspects which have been shown to influence the hearing in young people. However, there is no indication of the limitations of the study presented. For example the lack of discussion of the very high level measured in one nightclub and the measurement method used questions the thoroughness of the study.

#### **B.41 (Struwe F, Jansen G, Schwarze S and Schwenzer C, 1995; 128)**

The hearing levels of a sample of 1814 men aged 16 to 24 were tested using screening audiometry (1 kHz to 12.5 kHz). In addition a questionnaire was completed to allow the subject to evaluate their own hearing and give details of exposure to leisure noise.

90% of the subjects had attended clubs or live music concerts during the last 12 months. 68% of the subjects visited clubs and the average attendance time was 7.5 hours a week. 24% of the subjects showed a hearing loss of greater than 20 dB for the frequency range 3 to 6 kHz in one or both ears. 28% of the subjects showed a hearing loss of greater than 20 dB for the frequency range 8 to 12.5 kHz in one or both ears. It was found that those subjects who show a distinct auditory impairment for the frequency range 3 to 6 kHz state also reported a significantly higher number of visits to clubs or live music concerts during the last 12 months. The authors state that conspicuous audiometric results increase by 1.3 times from subjects visiting events more than once a week over those who attend such events rarely.

The authors conclude that young people have to be protected effectively from a permanent hearing loss induced by leisure noise. Information campaigns are suggested to draw more attention to the potential health hazards.

No details of the subject selection process was presented.

#### **B.42 (Swanson SJ, Dengerink HA, Kondrick P and Miller CL, 1987; 40)**

The purpose of this study was to replicate earlier work which suggested that greater TTS occurs after acoustic stimuli if the listener finds the music aversive. The subjects were split into two equally sized groups (those that liked pop music and those who did not) and exposed

to 10 minutes of pop music over headphones at a level of 106 dB(A)Leq and 10 minutes of noise with equal acoustic energy. The results indicated that persons who liked the music selection had TTS at 6 kHz after music than after the noise and visa versa for those who disliked the music. This effect was only seen at 6 kHz and was attributed to stress.

#### **B.43 Tomasevic P, Goodair G, Nicoll G and Carter P, 1998; 52)**

Incidence of TTS (10 dB or greater shift) and Distortion Product Otoacoustic Emissions ( at least 6 dB or greater shift) of 22 subjects attending a club for 2 hours was compared to a control group of 3 subjects.

59% of the subjects had TTS at 4 kHz and 36% showed a significant reduction in DPOAE. Threshold had returned to the baseline after 1 day. Tinnitus was present in 10 subjects with 80% of those showing TTS and 55% showing reduced DPOAE.

The authors state that “those subjects with tinnitus had a greater chance of having a threshold shift than those without tinnitus and this suggests greater noise induced damage in those with tinnitus”. However it is difficult to see any scientific justification for this statement due to the lack of evidence presented and the use of non defined acronyms. They conclude “it seems likely, but not yet proven, that ears showing TTS and reduced DPOAE are more susceptible to noise injury and go on to permanent noise induced hearing loss with repeated or protracted exposure”.

#### **B.44 (West PD and Evans EF, 1990; 42)**

The author states that pure tone audiometry is not a good indicator for detection of hair cell damage hearing loss. The study was designed to determine whether early evidence of damage was present in young listeners whose listening habits would seem to place them in a very high risk category and to discover whether a test of complex auditory function such as frequency resolution could be used for early detection of such damage.

Subjects aged 15 to 23 (n = 60) were selected for the study on the basis of a questionnaire. The subjects were categorised into three groups to “enable the tracing of a possible progression of noise induced pathology”. Subjects with previous ear disorders or exposure to sources of noise other than amplified music were excluded.

- The control group was made up from the 20 least exposed subjects of a group of 15 to 16 year olds (n = 141).
- The young exposed group was made up from the 20 most exposed subjects of a group of 15 to 16 year olds (n = 141).
- The older exposed group was made up from the 20 most exposed subjects of a group of 19 to 23 year olds (n = 52).

The hearing of these subjects was then tested using high resolution sweep frequency Békésy audiometry and the measurement of auditory frequency resolution at 4 kHz.

It was found that the more exposed group had 10-15% wider bandwidths than the least exposed. While the most exposed groups did not show significantly greater average

thresholds. In the older range group there was a significant increase in the prevalence of notches in the audiograms in the 3.5 to 6 kHz region.

The authors conclude that exposure to music can be harmful, the earliest sign being decrease in frequency resolution. Early evaluation of the thresholds is better detected by high resolution Békésy tracking between 2 kHz and 8 kHz than using fixed frequency audiometry.

The authors conclude that many young listeners should modify their listening habits, particularly those who experience TTS or tinnitus following exposure to music. They also recognise that the number of subjects in the study were small, however the experimental procedure was well designed and sufficient for the status of pilot study which they attribute to the work.

#### **B.45 (Yassi A, Pollock N, Tran N, and Cheang M, 1993; 43)**

The study was undertaken to assess noise exposure at modern rock concerts and the nature, degree and duration of associated TTS to help determine a preventative strategy.

22 subjects were recruited for the study and their hearing was tested before and after the exposure and subjects also completed a questionnaire. In addition dosimeters were used on three subjects to monitor the level of exposure.

The results from the three dosimeters showed that the Leq over the 2.5 hour duration of the concert were 98, 99 and 101 dB(A). The authors also state the peak levels in units of dB(A) and assess these in terms of the peak action level of 140 dB (linear) which is clearly not appropriate. In addition the A-weighted peak level do seem very high but the authors attribute this to the nature of the music without ruling out the possibility of mechanical shock during the event.

The results from the audiograms showed that 17/21 of the subjects showed a TTS greater than 10 dB at 4 kHz following the concert but only 8/21 reported a transient hearing loss. The incidences of TTS varied depending on location in the auditoria. All audiograms had returned to the baseline by the next day.

The authors state that the noise exposure recorded and the extent of TTS suggest that this and similar concerts are hazardous to hearing but there is no discussion of the relationship of the temporary threshold shifts in relation to permanent damage.



## **ANNEX C - CASE STUDIES FROM DAVID WOMACK BLACKPOOL BOROUGH COUNCIL.**

### **C.1 Case Study 1 -Night-club where DJ applied for an exemption from the Noise at Work Regulations 1989.**

A letter was circulated to all nightclubs within the jurisdiction of the council asking them to conduct noise assessments since it was thought that all the noise exposure level to employees would be greater than the first action level and therefore the manager of the club should conduct a noise assessment. Following this an Improvement Notice was served on any club that did not volunteer a noise assessment on the ground that it was a breach of;

- Health and Safety at Work Act 1974 section 2(1),
- Health and Safety at Work Act 1974 section 2(2a), and,
- Noise at Work Regulations 1989, Regulation 4(1), which states that every employer shall, when any of his employees is likely to be exposed to the first action level or above or to the peak action level or above, ensure that a competent person makes a noise assessment....

Following this all the clubs provided noise assessments.

In the case of Night-club X the noise assessment established that all the staff exceeded the first action level and the DJ exceeded the second action level. It was suggested in the noise assessment that it was not possible to reduce the level of the music due to public demand and so hearing protection was suggested for all staff and made compulsory for the DJ.

An exemption to Regulation 8[2] of the Noise at Work Regulations 1989 for the DJ was applied for due to difficulties performing his job whilst wearing hearing protection. The application for exemption was applied for on the following grounds:

- that due to the irregular work pattern the noise exposure averaged over number of days would not exceed the second action level,
- the sound pressure levels varied significantly throughout the evening and therefore the noise exposure would be reduced,
- the earphones used would reduce the noise exposure,
- hearing protectors would prevent communication and make mixing levels very difficult, and,
- the DJ would not hear alarms.

This application for an exemption was rejected.

An HSE specialist inspector was called to assist and suggested the following;

- glass collectors should be supplied with ear plugs for the period when they are working near the dance floor.
- DJs should wear hearing protectors with sound restoration devices fitted. These devices are readily available and allow the audio signals to be presented to the ear whilst also providing good attenuation.
- a volume regulation device should be fitted.

The club complied with these points.

Note: Exemptions from specific requirements of the Noise at Work Regulations 1989 may be granted by HSE (full details in Regulation 13), for example an exemption to Regulation 7 may be granted in situations where the  $L_{EP,d}$  of employees varies greatly from day to day (e.g. 95 dB(A) to 60 dB(A)) and when the  $L_{EP,d}$  of employees averaged over a week is less than 90 dB(A). In the situation described in this case study the  $L_{EP,d}$  of the DJ was fairly constant and exceeded the second action level on each day.

## **C.2 Case Study 2 -Night-club fitted with volume regulation device.**

Following an initial visit to this night-club the LA Inspector suggested that a noise assessment should be carried out. The night-club carried out the assessment. During a follow up visit it was found that the measured levels were far greater than those in the noise assessment. The noise assessment was invalidated and formal action taken against the night-club.

An HSE specialist inspector was called to assist and suggested that a volume regulatory device was required. This device was configured to produce an  $L_{eq}$  of 96 dB(A) on the dance floor and at the centre of the stage. This device was found to be effective at reducing the noise levels.

## ANNEX D - GLOSSARY AND NOMENCLATURE

**A-weighted sound pressure level**, is the measured using a sound level meter and corrects the measured acoustic pressure to account for the frequency response of the human ear and is expressed in dB(A).

**BEDA**, British Entertainment and Discotheque Association.

**Club**, for the purpose of this document a club is defined as premises with both a Public Entertainment Licence and extended opening hours. These premises provide amplified music as a key part of the entertainment.

**Discotheque**, see Club.

**DJ**, Disc Jockey.

**Dosimetry**, this is a sound level meter that integrates the sound energy over a period and expresses the results in terms of the personal sound exposure.

**DPOAE**, distortion product otoacoustic emission (see section 2.3.1)

**h**, used in this report to denote hours.

**HSE**, Health and Safety Executive.

**Hyperacusis** is an increased sensitivity to sound. This condition can occur with normal hearing or with those with hearing loss. Hyperacusis most often is associated with an alteration in the central processing of sound. Individuals with this condition often experience physical pain or discomfort to everyday sounds.

**ISO 1999**. This International Standard presents, in statistical terms, the relationship between noise exposure and the noise induced permanent threshold shift in people of various ages.

**$L_{Aeq,t}$ ,  $Leq$**  A-weighted equivalent continuous sound pressure level and is used to express a time varying sound pressure level as a steady sound level with the same amount of energy for a given duration (t).

**$L_{EP,d}$** , Eight hour  $L_{Aeq}$  and is used to define the daily exposure level of an employee.

**n**, used in this report to denote the number of subjects included in a study.

**NIHL**, Noise Induced Hearing Loss quoted in dB.

**NIL**, the noise immission level, a measure of lifetime noise exposure based on total energy of the exposure and expressed in dB.

**NIPTS**, noise induced permanent threshold shift.

**OAE**, otoacoustic emission (see section 2.3.1)

**Otitis Media**, a disorder involving inflammation and/or infection of the structures of the middle ear. This inflammation may occur when there is a collection of sterile fluid in the ear and may be caused by overproduction of fluid by the structures in the middle ear. It may also be caused by blockage of the eustachian tube (the connection between the middle ear and the back of the nose/upper throat). The presence of excess fluid causes the ear to become irritated and inflamed and may result in temporary or permanent hearing loss.

**Pa**, (Pascal), the unit of pressure corresponding to a force of 1 N/m<sup>2</sup>.

**PCP**, Personal Cassette Player.

**Pub** (Public House), is defined, for the purposes of this document, as an establishment that sells alcoholic drinks for consumption on the premises. In addition these premises may provide entertainment based on amplified music. In these situations the pub is required to have a Public Entertainment Licence.

**Pure Tone Békésy Audiometry**, used to determine the hearing sensitivity at different frequencies. The subjects is presented with the stimulus via headphones and responds by pressing a button if the signal is perceived. Once perceived the level of the stimulus is reduced



until the subject no longer responds. This is repeated a number of times to gain an average of the threshold of hearing. This process is repeated at a number of frequencies (normally 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz and 6 kHz).

**PTS**, permanent threshold shift.

**RNID**, Royal National Institute of the Deaf.

**SLM**, sound level meter.

**SOAE**, spontaneous otoacoustic emission (see section 2.3.1)

**SPL**, sound pressure level expressed in dB.

**Sweep Frequency Békésy Audiometry**, similar to Pure Tone Békésy Audiometry and was used in (West PD and Evans EF, 1990; 42). In this technique a continuous frequency sweep over a range 2 kHz to 8 kHz is presented to the subject rather than the continuous frequency stimulus used in the pure tone audiometry. The intensity of the stimulus tone is changed by 1 dB with each successive presentation at a rate of 2 dB/s.

**TEOAE**, transient evoked otoacoustic emission (see section 2.3.1)

**Tinnitus**, a medical condition in which noises are heard by the individual which do not come from an acoustic signal. The noises may be described as the sound of escaping air, running water, the inside of a seashell, or as a sizzling, musical, buzzing, or humming noise. It is a symptom of almost any ear disorder including ear infections, foreign objects or wax in the ear, otosclerosis, Meniere's, acoustic trauma, and others. Tinnitus may be associated with hearing loss including occupational hearing loss.

**TTS**, temporary threshold shift.

**TTS<sub>2</sub>**, the TTS that would exist 2 minutes after the termination of the noise exposure. Two minutes is used because the maximum level of TTS occurs two minutes after the termination of noise exposure. After 2 minutes the level of TTS begins to reduce.

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