Prevention of Noise Induced Hearing Loss in New Zealand

Final Report

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Contents

List of Tables 4
List of Figures 5
Prevention of NIHL Research Team 6
Executive Summary 7
1. Study Objectives 7
2. Review of Literature 7
3. Survey of Workplaces 8
4. Development of an Intervention Strategy for the Prevention of NIHL 9
1.0 Introduction 10
1.1. Research Design 11
1.2 Research Questions 12
1.3 Timeline 14
1.4 Structure of the Report 14
2.0 Literature Review Summary 15
2.1 Introduction 15
2.1.1. Purpose of this review 15
2.2 Methods 15
2.2.1 Systematic Review Approach 15
2.2.2 Review Questions 15
2.2.3 Scope of this Review 16
2.2.4 Search Strategy 16
2.2.5 Literature Extraction 17
2.2.6 Data Extraction 18
2.2.7 Quality Assessment of Retrieved Literature: Determining the Strength of the Body of Evidence 18
2.3 Results 20
2.3.1 Summary of included articles 20
2.3.2 Introduction to Literature Analysis 21
2.4 Key strategies 28
2.4.1 Strategy One: Legislative change 28
2.4.2 Strategy Two: Championed by leaders 29
2.4.3 Strategy Three: Multifactorial approach 30
2.4.4 Strategy Four: Implement engineering 31
2.4.5 Strategy Five: One off training 32
2.4. Discussion 33
2.6 Impact on industry 44
2.7 Legislative Change 45
2.8. Leadership, Multifactorial Interventions and Workplace Safety Climate 45
2.9. Social and Organisational, Not Just Personal 46
2.10. Conclusion 47

3.0 Background 48
3.1 Noise sources and paths 48
3.2 Exposure to workplace noise 49
3.3 Noise control and management 51
3.4 Concepts of best practice in noise management 55
3.5 Interventions to prevent NIHL 59
3.6 Safety climate and attitudes to noise and exposure to noise. 69
4.0 Methodology 70
4.1 Introduction 70
4.2. Study design 70
4.3. Industry, organisation and employee selection 70
4.4. Data collection 72
4.4.1. Survey 1 - Noise at Work Survey (Evaluation of existing noise source, exposures and controls) 73
4.4.2. Survey 2 - Noise at Work Survey (Noise control conformance assessment) 74
4.4.3. Survey 3 - Noise at Work Survey- (Evaluation of workplace safety climate) .76
4.5. Ethical issues 79
5.0 Results 80
Occupational noise sources, exposures and controls 80
5.1 Noise sources and paths 80
5.2. Exposure to noise and personal sound exposure (dose) measurements 83
Noise exposure by sector 86
Daily noise exposure by sector 89
5.3. Noise controls and conformance assessment 93
5.4. Safety climate and attitudes to noise and exposure to noise 95
5.4.1 Company level noise exposure and compliance 96
5.4.2 Individual level data 98
5.5 Summary 100
6.0 Discussion 104
6.1 Workplace surveys 104
6.1.1. Noise sources and paths 104
6.1.2. Exposure to noise and dose measurements 105
6.1.3. Noise control and conformance to standards 108
6.1.4. Safety climate and noise exposure 119
6.2. Industry and Stakeholder views 123
6.3. Future areas for research 125
6.4. Limitations of the study 125
7.0 Conclusions 126
8.0 References 131

Appendix 1 – Prevention of Noise Induced Hearing Loss: Literature Review.
Appendix 2 – Noise assessment report form (Survey 1 – Noise at Work)
Appendix 3 – Noise conformance report form (Survey 2 – Nosie at Work)
Appendix 4 – Safety Climate/ Culture Questionnare (Survey 3 – Noise at Work)

List of Tables

Table 2.1: NHMRC Body of Evidence Matrix 19
Table 2.2: NH&MRC criteria (1999) for levels of evidence. 19
Table 2.3: Characteristics of included studies 24
Table 2.4: Summary of key strategies to prevent NIHL in body of evidence framework 34
Table 2.5: Six Essential Criteria of Social Marketing Approach 35
Table 2.6: Examples of NIHL interventions with a number of social marketing elements 36
Table 4.1: Industry sectors with relative risk of NIHL 71
Table 4.2: Data collection methodologies used in workplace surveys. 73
Table 4.3: Conformance elements of the Approved Code of Practice for the Management of Noise in the Workplace. 75
Table 5.1: Summary of noise sources and paths in industry sector case studies. 81
Table 5.2: Summary of sound levels and dose estimates of workplace surveys by industry sector. 84
Table 5.3: Conformance elements of the Approved Code of Practice for the Management of Noise in the Workplace. 94
Table 5.4: Noise exposure and compliance data for participating companies. 97
Table 5.5: Correlations for company level data 98
Table 5.6: Regression analysis predicting compliance scores 99
Table 5.7: Correlations for individual level data 99
Table 5.8: Predictors of self-reported HPD use. 100
Table 5.9: Perceived benefits as a mediator of HPD use. 100

List of Figures

Figure 1.1: Prevention of NIHL Research Strategy 12

Figure 2.1: Strategies identified in the prevention of NIHL 23

Figure 3.1: HSE (UK) framework for managing noise risks. 53

Figure 3.2: NOPSA risk management model for noise management 54

Figure 3.3: National Foundation for the Deaf NIHL Strategy overview. 66

Figure 5.1: Distribution of L_{Aeq8hr} for employees across all sectors 83

Figure 5.2: Distribution of L_{Cpeak} for employees across all sectors 85

Figure 5.3: Relationship between L_{Cpeak} and $L_{Aeq.}$ 85

Figure 5.4: Mean employee L_{Aeq8hr} levels by sector. 86

Figure 5.5: Median L_{Aeq8hr} levels by sector. 87

Figure 5.6: Proportion of employees with noise exposure in excess of 1 Pa^{2}hr by industry sector. 88

Figure 5.7: Percentage of work areas where noise exposure in excess of 85dB L_{Aeq} by industry sector. 89

Figure 5.8: The distribution of L_{Aeq} values for agriculture workers. 89

Figure 5.9: The distribution of L_{Aeq} values for manufacturing - bottling workers. 90

Figure 5.10: The distribution of L_{Aeq} values for manufacturing – engineering workers. 90

Figure 5.11: The distribution of L_{Aeq} values for manufacturing – textile workers. 90

Figure 5.12: The distribution of L_{Aeq} values for manufacturing – wood processing / saw mill workers. 91

Figure 5.13: The distribution of L_{Aeq} values for constructions workers. 91

Figure 5.14: The distribution of L_{Aeq} values for hospitality - cafe workers. 92

Figure 5.15: The distribution of L_{Aeq} values for education - preschool workers. 92

Figure 5.16: Total scores by conformance element. 93

Figure 5.17: Mean conformance scores by industry sector 95

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Executive Summary

1. Study Objectives

The objective of this project was to evaluate existing work-related interventions to reduce NIHL in New Zealand, to identify critical factors in the development and implementation of such strategies, and to propose strategies/interventions where current interventions are considered ineffective. In particular, this research project was to identify barriers to implementation of known approaches for addressing noise exposure, given that the association between noise and NIHL is well established. This included the perspectives of social marketing and behavioural psychology with respect to barriers to noise control and effective marketing of noise control messages to employers and workplaces. In addition, the research was to examine those aspects of workplace culture that affect decision-making around NIHL. The first objective of the project was to develop a research strategy that addressed the key objectives of the project.

2. Review of Literature

The second objective of the research strategy was the completion of an evidence based literature review relating to the effectiveness of intervention strategies to prevent NIHL. The evidence identified and collated in the review suggests that NIHL prevention is a complex issue without simple solutions. A systematic and comprehensive search of the peer-reviewed and non-peer reviewed literature identified 71 reports of relevance. Critical evaluation of the reports included assessment of study quality, impact and quality of outcome measures, consistency of study findings, and generalisability and applicability of study findings to the NZ industrial context. Overall intervention study quality was satisfactory to poor. Studies varied widely in intervention type (from legislative change to one-off interventions) but interventions to promote the use of personal hearing protection dominated. Most interventions were conducted in the USA amongst white, middle-aged male workers. A range of industries was represented with manufacturing, mining, construction and agriculture the top four. Effective interventions will require a combination approach, taking the best strategies from different types of intervention. In the intervention studies identified, the best of these approaches combined "high level" interventions (e.g. active management targeted with greater use of noise elimination, design and engineering noise controls). The least effective contained a lower level component (e.g. person-centred behavioural approaches with little management support to promote the wearing of personal hearing protection). The review identified five key strategies used in NIHL prevention interventions: **introduction of legislation and enforcement, leadership, multifactorial interventions, implementation of engineering and design controls, and training interventions.** The challenge for designing effective NIHL intervention strategies will be to integrate and build on evidence from previous international quantitative and qualitative studies, in combination with attention to optimal occupational intervention study design, and a clear understanding of the local context gained through primary research.

3. Survey of Workplaces

The third objective of the research project was the completion of a survey of workplaces. A case study design was utilised to identify, describe and evaluate noise sources, exposures and control strategies used by those "high", "moderate" and "low" risk industry sectors in relation to exposure to noise. Thirty three (33) primarily small business workplaces were assessed, which showed that generally noise sources and paths could be readily identified and that area and personal sound level exposure measurements varied considerably between the high, moderate and low risk industry sectors. It was found that of the "high risk" industry sectors surveyed, most had mean and median sound levels that were at or above $L_{Aeq.8hr}$ 85dB and mean and median noise exposures recorded in "moderate" and "low risk" industry sectors (cafes and preschools respectively) were below $L_{Aeq.8hr}$ 80dB. Saw mills, construction and engineering businesses had the greatest percentage of employees exposed to noise levels above 85dB $L_{Aeq.8hr}$ (85%, 83% and 75% respectively). For other sectors, agriculture and bottling plants had lesser percentages (40% and 30% respectively) of employees exposed to levels in excess of 1 Pa^2hr. No employees in textiles and cafes were exposed to noise above 85dB $_{LAeq.8hr}$. Two employees in preschool facilities had daily dose estimates of 1.94 and 3.16 Pa^2hr. However, these values were outliers and were excluded from the analysis.

The predominant noise control strategy used by the businesses was the use of personal hearing protection. Although many operations were complex, noise management strategies aimed at the noise source and noise paths could have been investigated further. In agriculture and construction however, prevention through either noise reduction at source or isolation of the noise, even though best practice, may not always practicable so that hearing protection could be the only control option available. Most enterprises surveyed did not conform to the specific requirements of legislative standards for noise management. Conformance values, scored from conformance values to the Approved Code of Practice, across all sectors ranged from 0 to 6 out of 10 (with 10 being total conformance - median value 2.0 and mean 1.9 (sd.1.7)). Of the "high risk" industry sectors surveyed the bottling, engineering businesses and farms were the most compliant (mean (sd) conformance scores; 4.3(2.1), 3.3(2.3) and 3(0) respectively). Mean conformance scores for the remaining industry sectors ranged from 2.3/10 to 0.33/10.

In addition, a survey of one hundred and sixty-three (163) respondents from these enterprises also provided data on hearing protection use, safety climate and attitudes to noise at work. Factor analysis identified two facets of safety climate: personal responsibility and workplace priority. Neither was related to company compliance with the Code of Practice but objective sound levels did predict compliance. There was little evidence that safety climate, conceptualised as perceptions of workplace priorities for safety, was related to noise management. Perceptions of safety as a personal responsibility predicted HPD use, and perceptions of benefits to managing noise mediated this relationship. Attempts to address safety climate by changing attitudes, beliefs and perceptions may be less effective than changing unsafe conditions and behaviours at all organisational levels.

Evidence from this study suggests that an employee's sense of personal responsibility for safety is the main motivator for protective behaviour in the workplaces surveyed rather than management initiatives or leadership. After decades of effort in trying to promote and improve health and safety management at the organisational level, this is disappointing. It is concluded that noise hazards are best managed directly rather than indirectly through attempts to change climate through marketing, training or attitude change. Safety climate is complicated. Different facets have different correlates and implications. The findings from this study suggest that perceptions of safety climate may follow, rather than lead, safety management efforts in relation to noise control within the businesses.

The background and results of this study were presented to industry and stakeholder representatives at the Symposium on Noise-Induced Hearing Loss, School of Population Health, University of Auckland. 29th November 2010. Comments and feedback was sought on the research and key issues identified included the importance of legislation and enforcement, culture change, intervention strategies, surveillance and provision of advice and information.

Finally, proposals for intervention strategies for the prevention of NIHL are described. They include establishing noise exposure and NIHL as national health and safety priorities; community wide (leisure and home) intervention strategies inter-related with workplace (occupational) initiatives; the Prevention through Design (PtD) initiative developed by NIOSH (2010) could be successfully applied to reduce the noise exposure of equipment and machinery used in "high" risk industry sectors; changes in expectations with respect to policing the requirements of noise regulations; increased enforcement activity from the Department of Labour is seen as an important part of a multilevel national strategy for the prevention of NIHL; the potential for introducing into New Zealand legislation a strata of action levels (lower and upper) similar to those recently introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards; adoption of "best" or "good" practice models for noise control, including noise control measures that actually improve productivity and reduce costs; development and maintenance of surveillance schemes for occupational hearing loss and surveillance of workplace noise exposure; adoption of interventions designed for small businesses within the "high" risk industry sectors (agriculture, construction and manufacturing) identified in this report, over 90% of enterprises within these sectors have less than 20 employees; initiatives providing technical advice and support for enterprises have been developed and trialled in Australia, UK and Europe with varying levels of success; interventions need to be cyclical and on-going, from needs assessment, intervention development, implementation and evaluation to renewed assessment of needs (Laird, et al., 2010).

4. Development of an Intervention Strategy for the Prevention of NIHL

A final and fourth outcome of the research project was the development of Recommendations for an Intervention Strategy for the Prevention of NIHL. This has been undertaken as a collaboration between the two research project teams. These recommendations are detailed in the companion document to this Report - "*Recommendations for the Development of an Intervention Strategy in the Prevention of NIHL"*.

Prevention of Noise Induced Hearing Loss (HRC/ACC/ DoL JRP OHS 08/606) Introduction and Research Strategy

1.0 Introduction

For New Zealand society, noise induced hearing loss (NIHL) is a major cost and burden and projections based on current trends suggest that predicted future costs are likely to escalate. The prevention of work-related NIHL has become a top priority for prevention and enforcement agencies. In order to address these issues, the Occupational Safety and Health Joint Research Portfolio of the Health Research Council (HRC) in New Zealand, funded a future-focused research programme comprising two separate but interrelated projects: Research Project One: Epidemiology of NIHL in New Zealand and Research Project Two: Prevention of NIHL in New Zealand.

The OHS & JRP Programme of HRC, ACC and Department of Labour awarded a contract to Massey University to undertake the second project into the Prevention of Noise-Induced Hearing Loss in New Zealand. The project was undertaken by a multidisciplinary team led by Dr Ian Laird, Centre for Ergonomics, Occupational Safety and Health, Massey University, Palmerston North.

The overall objective across the two research projects was to provide the OH&S JRP partners with a knowledge base for understanding NIHL in New Zealand, currently and in the future, in both work-related and non-work-related environments, and to provide them with the robust evidence upon which they could develop effective interventions for control of noise-at-source and hearing conservation.

Research Project One: Epidemiology of NIHL in New Zealand

This project focused on evaluating the current and future incidence and prevalence rates of NIHL in New Zealand, both in the workplace and in non-work-related environments. Specific objectives of the project were:

1. to determine the prevalence and incidence of NIHL in the New Zealand workplace and characterise the noise environments in occupational settings;
2. to identify the potential contributions of other occupational hazards and non-work related noise exposure to the incidence and prevalence of NIHL; and
3. to develop more accurate methods of monitoring hearing damage in the workplace.

The work was undertaken by a team based at the University of Auckland, with input from national and international collaborators and numerous stakeholders. The research was undertaken over a period of three years.

Expected outcomes of research project one included the identification of New Zealand occupations associated with low, medium and high-risk of NIHL, and identification of industries and groups that may benefit from targeted intervention.

Research Project Two: Prevention of NIHL in New Zealand

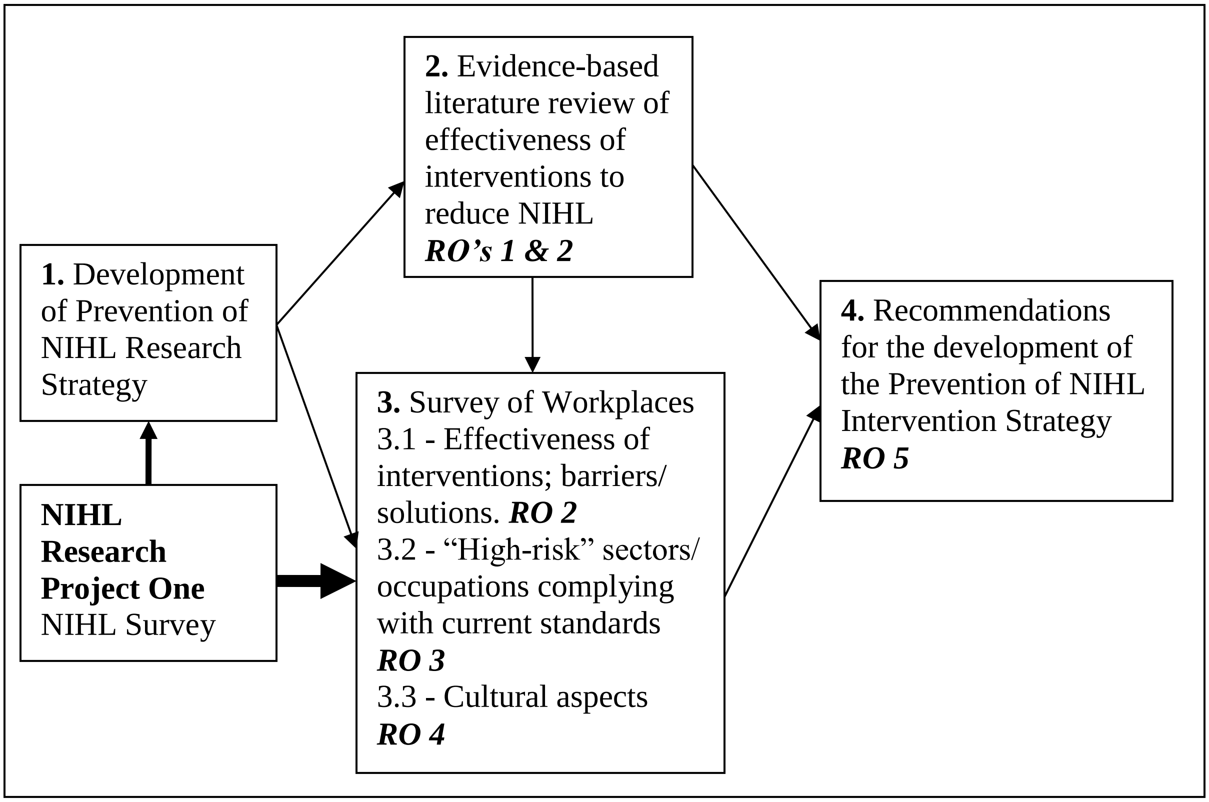
The objective of the second project was to evaluate existing work-related interventions to reduce NIHL in New Zealand, to identify critical factors in the development and implementation of such strategies, and to propose strategies/interventions where current interventions are considered ineffective. In particular, this research project was to identify barriers to implementation of known approaches for addressing noise exposure, given that the association between noise and NIHL is well established. This included the perspectives of social marketing and behavioural psychology with respect to barriers to noise control and effective marketing of noise control messages to employers and workplaces. In addition, the research was to examine those aspects of workplace culture that affect decision-making around NIHL. The specific research objectives were as follows:

1. Conduct an evidenced based literature review of effectiveness of interventions to reduce NIHL.
2. To determine the nature and effectiveness of interventions currently used in industry to reduce noise exposure and the incidence of NIHL and identify the barriers to the implementation of noise management strategies and programmes.
3. To determine whether identified "high-risk" sectors and occupations are complying with current recommendations (e.g. Codes of Practice) and legislation to prevent NIHL.
4. To determine what aspects of workplace culture and environment affect decisions around NIHL, including cultural barriers to preventive actions and what motivates individuals to prevent hearing loss.
5. Development of an intervention strategy for the prevention of NIHL.

The project was managed by a multidisciplinary Massey University and Otago University research team (Prevention of NIHL Research Team) with Dr Ian Laird as the Principal Investigator. In addition, an Expert Advisory Group was convened comprising international experts in fields that complement and enhance the skills of the research team. A Stakeholder/ Industry Advisory Group (SAG) comprising government (ACC, DoL and HRC), industry, union and research team representatives was formed to give overall direction to both research projects and ensure that they were linked into the research programmes of key government agencies.

1.1. Research Design

The research design and methods addressed each of the five research objectives (RO's 1 - 5) detailed in the research proposal (Figure 1.1) and was in four parts; Part 1 – Development of a prevention of NIHL research strategy (Project 1 – prior to commencement of the studies), Part 2 – Evidenced-based review of the effectiveness of interventions to reduce NIHL (Project 2), Part 3 – Survey of Workplaces (Project 3.1 Survey of interventions used by industry to reduce noise exposure and prevent NIHL; Project 3.2 Survey of identified "high-risk" sectors and occupations; Project 3.3 Survey of workplace cultural aspects of noise management and prevention of NIHL, Part 4 - Recommendations for the development of the Prevention of NIHL Intervention Strategy (Project 4). The methodology involved cross sectional and case study designs of noise exposure and the effectiveness of interventions to reduce noise exposure and prevent NIHL.



RQ – Research Question identified in RFP, Prevention of NIHL,

Figure 1.1: Prevention of NIHL Research Strategy

The survey of workplaces was divided into three component parts;

Survey 1 described the nature and effectiveness of interventions currently used in industry to reduce noise exposure and the incidence of NIHL and identify the barriers to the implementation of noise management strategies and programmes.

Survey 2 determined whether identified "high-risk" sectors and occupations were conforming to with current recommendations (e.g. Codes of Practice) and standards to prevent NIHL?

Survey 3 determined what aspects of workplace culture affected decisions around NIHL. In particular what were the cultural barriers to the development of a proactive, preventive workplace stance regarding NIHL?

1.2 Research Questions

The research questions identified in the Request for Proposal document are detailed below and linked to the specific sections in the Report as follows;

Research Questions

<table>
<tr><th>Research Questions from RFP</th><th>Section in the Report</th></tr>
<tr><td>1. From a review of the literature, what is the evidence base for the effectiveness of existing work-related interventions/programmes to reduce NIHL?
What are the elements of successful programmes especially from the perspectives of social marketing and behavioural psychology?
Why did programmes fail?
Which interventions are most likely to be effective in New Zealand?
What does the literature suggest is the potential to control noise at source?</td><td>Section 2 – Literature Review
Effectiveness of interventions</td></tr>
<tr><td>2. From the perspectives of social marketing and behavioural psychology what will be the likely features of a successful NIHL intervention?</td><td>Section 2 – Literature Review
Social marketing and behavioural psychology perspectives on effective interventions</td></tr>
<tr><td>3. Which interventions are currently in place in high-risk New Zealand industrial/service sector(s)?
How effective are these interventions?
What do social marketers and behavioural psychologists have to say about these programmes?
What are the barriers to their implementation and to achieving quiet workplaces?
What else could be done applying the statutory control hierarchy (eliminate, minimise, isolate)?
What are the barriers to quiet workplaces, and, if quiet workplaces are not possible, what are the barriers to use of Personal Protective Equipment?</td><td>Section 5 – Workplace Surveys
Noise sources, exposures and noise controls
Effectiveness of interventions in industry
Barriers to control and management of noise
Section 6 - Discussion</td></tr>
<tr><td>4. Are key ACC “target” industries and other high-risk sectors/occupations complying with current recommendations (e.g. Codes of Practice) and legislation to prevent NIHL?</td><td>Section 5 – Workplace Surveys
Conformance Assessment
Section 6 - Discussion</td></tr>
<tr><td>5. What aspects of workplace culture affect decisions around NIHL?</td><td>Section 5 – Workplace Surveys
Safety climate and attitudes to noise</td></tr>
</table>

• *In particular what are the cultural barriers to the development of a proactive, preventive workplace stance regarding NIHL?* • *What motivates employers and employees to prevent hearing loss?*	Section 6 - Discussion

Development of an Intervention Strategy

Based on the results of research and literature reviews, and with reference to the results of Research Project One as they become available, the researchers are to develop **Recommendations** for an intervention strategy focused on the higher risk industries and technologies. This should outline:

1. the highest areas of priority for immediate intervention (note: this will also be informed by Research Project One);

2. the most effective intervention options within those sectors, using the control hierarchy; and

3. the most effective means by which these interventions can be implemented and sustained within the sectors (particularly when dealing with isolate or minimise strategies).

1.3 Timeline

The project timeline was from July 2008 to June 2010, with subsequent extensions until 31st March 2011.

1.4 Structure of the Report

The first section of the Report (Section 1), **The Introduction**, provides and **Executive Summary** and reviews the background, research questions and objectives and the design of the research project. The second section (Section 2) is a summary of the background, methodology and results of the evidence based **Literature Review** (RO 1 & 2). The full Review Johnston et al (2011) is appended as Appendix 1. The third section (Section 3) presents the **Background**, which reviews research related to noise sources, exposures and controls; noise management strategies; concepts of "best practice" and surveillance; concepts of safety climate in relation to NIHL. The fourth section (Section 4) presents the **Methodology** including research design; industry selection; data collection techniques; data collection templates and questionnaires. The limitations of the research design and methodological approaches are also discussed. The fifth section (Section 5) presents the **Results** of the workplace surveys. The sixth section (Section 6) the **Discussion** addresses the specific questions posed in the original RFP and integrates material from the literature review and workplace surveys. The section also includes feedback and recommendations on the research from the participants of the NIHL Symposium held at School of Population Health, University of Auckland, 29 November 2010. The final section (Section 7) outlines the research **Conclusions.**

2.0 Literature Review Summary

The Effectiveness of Strategies in the Prevention of Noise Induced Hearing Loss - Key features of the Literature Review

2.1 Introduction

A structured systematic review of recent evidence (1999 to 2008) for the effectiveness of strategies to prevent occupational noise induced hearing loss (NIHL) was undertaken (Johnston, 2009). The complete report is appended as Appendix 1. This section presents the key features of this review, and relates the findings to the specific research questions (RQ's) identified in the RFP and detailed in the Research Strategy (Section 1).

2.1.1. Purpose of this review

The purpose of the review was to determine the evidence for effective workplace interventions to prevent NIHL. Of interest to this review were the elements associated with effective strategies to prevent NIHL, particularly with regard to behavioural psychology and social marketing. Evidence for key barriers to effectiveness of NIHL prevention strategies, particularly at higher levels of control (ie. engineering or administrative controls compared with personal noise protection devices) was also reviewed.

2.2 Methods

2.2.1 Systematic Review Approach

The systematic review was undertaken using an iterative, step-by-step approach to ensure transparency and rigour in the review process. This process also provided opportunities for project stakeholders to guide the direction of the project, and add valuable insights from their perspective. The systematic review was conducted in five discrete, conjoined stages.

- Defining the search questions
- Setting the search parameters
- Literature extraction
- Literature synthesis
- Production of final report

2.2.2 Review Questions

Question one

How effective are strategies implemented in workplaces to prevent NIHL or noise exposure?

What are the barriers to implementation of effective interventions to prevent NIHL or noise exposure? In particular what barriers are identified which relate to strategies at higher levels of control (eg. engineering and design controls)?

Question two

What factors are associated with effective workplace interventions to prevent NIHL or noise exposure? In particular, what factors are identified which relate to:

- behavioural psychology?
- social marketing?

2.2.3 Scope of this Review

The search process identified articles which met the following study characteristics for inclusion:

Study types: Qualitative and quantitative research.

Participants: Adult workers exposed to and/or workplaces with high noise levels (i.e. more than 80 dB (A) as a time-weighted average (TWA) over a period of an entire work shift or working day or part of the work shift).

Interventions: Interventions intended to prevent noise-induced hearing loss in the workplace which may consist of one or more of the following elements:

- Engineering controls: reducing or eliminating the source of the noise, changing equipment, materials, processes or workplace layout
- Administrative controls: changing work organization, practices, management policies or worker behaviour
- Use of personal protective equipment or personal noise protection devices

Comparators: No intervention.

Outcomes: Including but not limited to:

- Noise exposure (sound level meter or a noise dosimeter)
- Noise induced hearing loss (audiometer)
- Worker/employer perceptions and acceptability of intervention

The search was limited by the following characteristics:

Language: Only English language publications were selected

Year of publication: Publications in the last 10 years were included

Type

- Scientific literature: Peer reviewed publications were accessed and relevant publications selected
- Grey literature: Relevant websites were accessed to seek quality evidence for NIHL prevention programs from industry or regulatory bodies. Opinion or editorial pieces were excluded

Human: Animal studies were not selected

2.2.4 Search Strategy

Keywords related to four relevant concepts (below) were used in the literature search. Combinations of keywords were searched within columns using “OR” and between columns using “AND”. This strategy used search terms and search strings found to have sensitivity and specificity in locating occupational health intervention studies (Verbeek, Salmi et al. 2005), keywords to locate studies on reduction of noise exposure and hearing loss prevention, and additional concepts of specific interest to this literature review.

Concept one: noise induced hearing loss, noise exposure, hearing loss
Concept two: work, occupation
Concept three: prevention, reduction, isolation, management program, engineering controls, administrative controls, personal hearing protective equipment, hearing protection device, hearing conservation, hearing surveillance, program, strategy, intervention, effect, control, evaluation

Databases searched: Peer reviewed literature
From the peer reviewed literature, databases searched included OVID (EMBASE,MEDLINE, AMED, ICONDA), EBSCO (Academic search, Australia/New Zealand Reference Centre, CINAHL, HealthSource, PsychINFO, Health business full text elite, Business SourceElite), PubMed, The Cochrane Library, Web of Science, Libraries Australia, ScienceDirect, Scopus, Ergonomics abstracts online, OSH-ROM (Occupational Safety and Health-Read Only Memory). Additional publications were identified following citation searching.

Databases searched: Non peer reviewed literature
Searching the non-peer reviewed literature included keyword searches of the National Institute of Occupational Safety and Health database (NIOSHTIC-2) and website. In addition, search engines Google Scholar and MetaCrawler were used to identify government, academic and industrial websites of potential relevance, which were then searched for reports for inclusion in the review. Where relevant projects were identified but no publications were available, personal communication was made with researchers to attempt to any obtain recent reports or publications.

A full listing of all websites accessed in provided in the complete report (Appendix 1, p.10, 11)

2.2.5 Literature Extraction

The initial search of the scientific and grey literature according to the processes above captured 403 titles of potential relevance to the review questions. Screening this list of titles, 323 abstracts were identified for further investigation (270 peer reviewed, 53 non-peer reviewed).

Following examination of these abstracts (and full article text when required) according to direct relevance to review questions and inclusion/exclusion criteria, 71 articles were identified for inclusion in this report (61 peer reviewed, 10 from “grey” literature sources). At least one third of the included articles were listed on the NIOSH website (which included peer reviewed and non-peer reviewed articles) and related to projects that were at least partially funded by NIOSH.

Although a large number of indexed titles and web-based resources were identified from database and website searching, relatively few of them (22%) were found to provide data which would directly address the review questions. Many of the excluded reports were editorial or opinion pieces, or provided information about noise exposures or prevalence of NIHL, or suggested strategies to prevent NIHL in the workplace without providing further evidence. Similarly, studies examining non-work related NIHL in child or adolescent populations did not meet the inclusion criteria. These have been retained in a list of excluded studies, which is available on request. However, one recently published controlled trial of an intervention to address NIHL in children has been included (Griest, Folmer et al. 2007), in order to examine any factors which may be transferable to the study population and questions of this review.

Noise engineering control list examples

A number of web-based resources were identified which listed engineering-based strategies for noise control. These lists provided single case study-type solutions for a range of industrial applications. In some instances these problem solving strategies were accompanied by a figure for noise emission before and after application of the strategy, but this evidence was not supplied in all cases. These websites (listed in Appendix 1, p.12,13) may be of interest to industries seeking solutions to specific noise engineering problems, but in most instances could not be considered "evidence based practice". It would not be feasible to summarise the case studies in a way which would make a meaningful contribution to this review. However, the six articles and reports on engineering controls which have been included in this systematic review either summarise a number of interventions in one area, or provide a higher quality of evidence for intervention effectiveness.

2.2.6 Data Extraction

A standard form was used to extract the following information from each report: characteristics of the study (design, methods of randomisation); setting; participants; interventions and outcomes (types of outcome measures, timing of outcomes, adverse events). Intervention content and setting were described. Information related to the body of evidence matrix (NHMRC, 2008) about the level of evidence, workplace impact, generalisability and applicability of each study was also extracted. A completed example of the data extraction template is included in Appendix 1, p.92. Thematic data extraction from the identified literature was then conducted in order to address the key questions of the review.

2.2.7 Quality Assessment of Retrieved Literature: Determining the Strength of the Body of Evidence

Critical appraisal and evaluation of the retrieved literature was undertaken to identify the quality and strength of the literature evidence. The range of programs and interventions identified to prevent NIHL was heterogeneous in study design, geographical locations and industry type. Whilst the international literature was surveyed in this review, in order to best answer the review questions in relation to NIHL prevention in New Zealand, a matrix (Table 2.1, NHMRC 2008) which examines the body of evidence in relation to the evidence base, study consistency, impact (size of the effect of the intervention), generalisability and applicability to the New Zealand environment was employed.

Table 2.1: NHMRC Body of Evidence Matrix (modified for review questions)

Component	A	B	C	D
	Excellent	**Good**	**Satisfactory**	**Poor**
Evidence base	several level I or II studies with low risk of bias	one or two level II studies with low risk of bias or a SR/multiple level III studies with low risk of bias	level III studies with low risk of bias, or level I or II studies with moderate risk of bias	level IV studies, or level I to III studies with high risk of bias
Consistency	all studies consistent	most studies consistent and inconsistency may be explained	some inconsistency reflecting genuine uncertainty around clinical question	evidence is inconsistent
Impact	very large	substantial	moderate	slight or restricted
Generalisability	population/s studied in body of evidence are the same as the target population	population/s studied in the body of evidence are similar to the target population	population/s studied in body of evidence differ to target population but it is clinically sensible to apply this evidence to target population	population/s studied in body of evidence differ to target population and hard to judge whether it is sensible to generalise to target population
Applicability	directly applicable to local industrial context	applicable to local industrial context with few caveats	probably applicable to local industrial context with some caveats	not applicable to local industrial context

The first component of this matrix (evidence base) was assessed using the following NH&MRC criteria (1999) for levels of evidence (Table 2.2).

Table 2.2: NH&MRC criteria (1999) for levels of evidence.

Level of evidence	Research designs
I	Evidence obtained from a systematic review of all relevant randomised controlled trials
II	Evidence obtained from at least one properly-designed randomised controlled trial
III-1	Evidence obtained from well-designed pseudo-randomised controlled trials (alternate allocation or some other method)
III-2	Evidence obtained from comparative studies (including systematic reviews of such studies) with concurrent controls and allocation not randomised, cohort studies, case-control studies, or interrupted time series with a control group
III-3	Evidence obtained from comparative studies with historical controls, two or more single arm studies, or interrupted time series without a parallel control group
IV	Evidence obtained from case series, either post-test or pre-test/post-test

In addition to the body of evidence information, a recommendation rating was made for each key finding from the literature review. A maximum of 5 stars were awarded, one for each of the following categories:

- Quality of the evidence base
- Position in the hierarchy of noise control
- Impact and quality of outcomes
- Sufficient detail provided (could this strategy be easily replicated?)
- Is it ready to use? (could this strategy be easily applied?)

2.3 Results

2.3.1 Summary of included articles

The initial search of the scientific and grey literature according to the processes above captured 403 titles of potential relevance to the review questions. Following screening of titles, 323 abstracts were identified for further investigation (270 peer reviewed, 53 non-peer-reviewed). Examination of these abstracts (and full article text when required) identified 71 articles (61 peer reviewed, 10 from "grey" literature sources) that evaluated NIHL prevention interventions (31 studies) or addressed barriers/enablers to NIHL prevention (40 studies). The 31 articles (27 peer reviewed, four non-peer reviewed reports) that evaluated NIHL prevention interventions were included in this review.

Most of these studies were undertaken in the United States (71%), with five studies (16%) from Australia, two from the United Kingdom, and one each from Canada and India. The identified studies showed a range of industries where NIHL prevention was being addressed, with manufacturing and mining each representing 19% of all included studies. Programs in agriculture (16%), construction (13%) and music industries (10%) were represented, along with programs in mixed (10%) or other workplaces (13% including military, hospital, school and local government). Two studies that did not meet the participant inclusion criteria were also reviewed to examine any factors that may be transferable to the study population and aims of this review. These included a recent controlled trial of a NIHL intervention in school students, and a study in a hospital where noise was troublesome but <80dB.

Studies relating to Review Question One: NIHL intervention effectiveness

The first part of Review Question one is concerned with the effectiveness of strategies implemented in workplaces to prevent NIHL or noise exposure. A total of 39 reports of NIHL interventions which provided data to directly address this question were identified. These can be broadly categorized into:

16 reports on effectiveness of multiple strategies to prevent NIHL: including introduction of legislative rule (6 studies), approaches which focus on leadership and management (4 studies), and multifactorial interventions (6 studies)

6 reports on effectiveness of engineering controls to prevent NIHL

2 reports on effectiveness of administrative controls to prevent NIHL

15 reports on effectiveness of one-off training interventions, or other single factorial interventions involving the use of hearing protection.

Most of the research provided data from case studies or series (level IV evidence), with a few examples of controlled trials and one systematic review (comprised of 2 studies on personal protective equipment). The articles were very heterogeneous, ranging from evaluation of 17 years of hearing conservation programs in Canada sawmill industry (Davis, Marion et al. 2008), to evaluation of a single noise awareness raising intervention with local government workers in Sydney, Australia (Williams, Purdy et al. 2007).

Studies relating to review question one: Barriers to NIHL interventions

The second part of Review Question One concerns the barriers to implementation of effective interventions to prevent NIHL or noise exposure. A total of 19 studies were included which specifically focused on barriers to NIHL prevention. Most of the research conducted in this area has examined barriers to the wearing of personal protective equipment (11 included studies), although 8 studies addressing barriers to hearing conservation programs in general were also identified. Additional data about barriers to NIHL strategies was found within the intervention studies themselves, and there was significant cross-over with articles listed in answer to Review Question Two. Reports which are non-peer reviewed (i.e. grey literature) are listed in italics in Appendix 1 (p.18-21).

Studies relating to review question two

This literature review also sought to discuss evidence for factors associated with effective workplace interventions to address NIHL, and in particular, factors associated with behavioural psychology or social marketing. All above studies identified in response to Review Question One were examined for evidence of these factors. In addition, thirteen further studies were identified which described factors associated with effective NIHL prevention, many of which included elements of behavioural psychology or social marketing frameworks. Reports which are non-peer reviewed (i.e. grey literature) are listed in italics in Appendix 1 (p.22)

2.3.2 Introduction to Literature Analysis

This report is the first systematic review to examine prevention strategies in workplaces to prevent NIHL or noise exposure, in literature and reports published between 1999 and 2008. A protocol for a Cochrane review of this subject has been published (Kateman, Verbeek et al. 2007), and preliminary results (Kateman and Verbeek 2007) indicated that 20 studies were being reviewed. Of these, twelve were published prior to 1998, so not included in this review, four have been included (Adera, Amir et al. 2000; Brink, Talbot et al. 2002; Horie 2002; Neitzel and Seixas 2005) and four were excluded as they were technical reports comparing attenuation of different HP devices(3 studies) or a specific engineering control (1 study). The Cochrane review specified it sought studies where the outcomes were noise levels and hearing loss. The current review also includes studies where outcomes were preventive behaviours (such as introduction of noise controls, reported or observed use of HP).

A previous systematic review has examined the effectiveness of programs to promote use of personal hearing protection (El Dib, Verbeek et al. 2006) which included 2 studies. As these studies were very different from each other (Knobloch and Broste 1998; Lusk, Ronis et al. 2003), they have been each been addressed separately in this review.

Review question one has been addressed by identifying 5 key strategies used in NIHL prevention interventions: introduction of legislation, leadership, multifactorial interventions, implementation of engineering and design controls, and one-off training interventions. Barriers to NIHL prevention, particularly barriers to the use of hearing protection (HP) (overwhelmingly the subject of study in the literature) have been addressed in detail in the quantitative and qualitative literature. While the hierarchy of noise control is an important overarching occupational health framework used for control and management, NIHL intervention effectiveness did not correspond in a simple direct way with this framework alone. For example, an intervention to promote the use of HP which used a comprehensive, multi-factorial strategy led by management (Hughson, Mulholland et al. 2002) was more effective than an intervention to promote the use of HP which consisted of a single training session (Lusk, Ronis et al. 2003).

Review question two was addressed by summarising the factors associated with effective NIHL interventions, and also identifying factors associated with preventive behaviours in qualitative, non-intervention studies. While qualitative studies do not provide evidence for effectiveness as intervention studies do, they are vital preliminary work for intervention development, and reflect the more current thinking and practice in NIHL prevention. They provide insights which add to the body of knowledge from which new intervention studies can be designed. NIHL prevention interventions that used behavioural psychology or social marketing models were identified and examined for effectiveness of these frameworks. This comprehensive review has enabled some clear recommendations to be extracted regarding effective strategies for NIHL prevention, proven barriers and enablers for NIHL prevention, and the role that behaviour change strategies and social marketing may have in future intervention development.

Identification of five key NIHL prevention strategies

The range of programs and interventions identified to prevent NIHL was heterogeneous in study design, outcome measures, geographical locations and industry types thus precluding any statistical meta-analysis. Interventions that reported positive effects on NIHL ranged from large scale legislative change, to one-off workplace training sessions.

Thematic synthesis of the intervention studies identified the following five key strategies for NIHL prevention: introduction of legislation, leadership, multifactorial interventions, implementation of engineering and design controls, and one-off training interventions (Figure 2.1). While the hierarchy of noise control is an important overarching occupational health framework used for control and management, NIHL intervention effectiveness did not correspond in a simple direct way with this framework alone. For example, an intervention to promote the use of hearing protection (HP) using a comprehensive, multi-factorial strategy led by management (Hughson, Mulholland & Cowie, 2002) was more effective than an intervention that consisted of a single training session (Lusk et al., 2003).

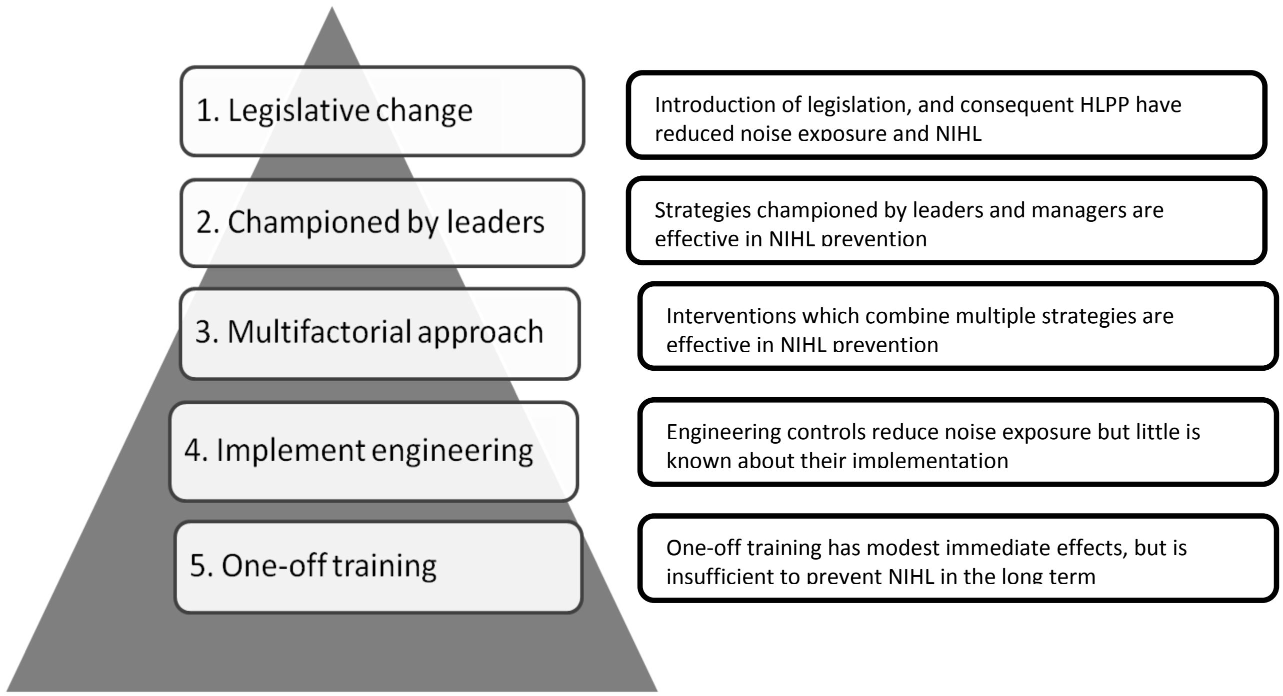


Figure 2.1: Strategies identified in the prevention of NIHL

Articles corresponding to each key strategy are described (Table 2.3) according to study type, intervention characteristics, outcome measures, main results and study limitations.

The evidence identified from this systematic review has been presented in the NHMRC body of evidence framework for each key strategy in Table 2.4. Grading of study generalisability and applicability (other components of the body of evidence matrix) have not been included, as these require understanding of local target populations and industrial contexts to be meaningful.

Table 2.3: Characteristics of included studies

Intervention features	Study type/intervention	Outcome measures	Main results	Study limitations
Legislative/regulatory change				
Davies et al., 2008	Interrupted time series with a control group (III-2) HLPP in sawmill workers	Self-reported use of hearing protection Risk of STS	Increased self-reported HP use from 71.6% in 1979 to 91.1% in 1996. 30% reduction in risk of STS Entering program later in time associated with further 30% reduced risk of STS	No detail provided regarding components of HLPP; some additional information gained from other sources (Roberts 2000)
Joy & Middendorf, 2007	Interrupted time series without a parallel control group HLPP in US mining industry	Noise exposure	Reduced annual mean noise exposure from 62.2% of PEL dose in 1998 to 34% of the PEL dose in 2004. Reported hearing protection use increased from 61% in 1987 to 89% in 2004.	Changes in sampling methodology resulted in more data post 2000 being collected from workers with lower noise exposure. Non-random sampling of miners for dosimetry Detail of the HLPP not described
Adera et al., 2000	Interrupted time series without a parallel control group HLPP in US manufacturing and production workers	Incidence rate of hearing loss (STS) over time Hazard ratio[a] over time	Rate of hearing loss declined over time since the mid-1980s.	Change to method of audiometric testing in 1987 may have influenced results. Detail of HLPP not described
Brink et al., 2002	Historical control study HLPP in automotive manufacturing workers	Hearing loss (STS) Self-reported HP use	% of workers using HP increased over time (4.5% in year 1 to 100% in year 17) Inverse correlations between % of time HP worn, and hearing loss.	HP yearly use based on self-reported point estimate Detail of HLPP over time not described.
Daniell et al., 2006	Cross sectional study Introduction of OSHA requirements for HLPP	Noise exposure Compliance with OSHA requirements for HLPP	Full-shift average exposures were >85 dBA for 50% of monitored employees (OSHA standards). Most HLPP incomplete	Volunteer bias in recruitment of companies and individuals. Measured program completeness, not effectiveness.
Humes et al., 2005	Review HLPP in the military	Noise exposure Hearing loss (STS) Use of HP Compliance with noise control requirements	HLPP insufficient at time of review and since WWII (e.g. average compliance with annual audiograms 1988-2003 was 45%, use and effectiveness of HP insufficient, high workforce mobility, extreme and unpredictable noise exposure)	Retrospective review, based on information made available to the review committee. Large amounts of missing data
Championed by leaders				
Groothof, 1999	Case study Intervention with facility owners in music entertainment venues	Implementation of noise control measures Availability of HP Noise exposure	Improved implementation of noise control measure (in 8/14 venues vs. none at baseline), availability of HP(12/14 venues vs. none at baseline)	Only 14 of original 30 venues assessed at 2 year follow-up. No change in measured noise levels (but study methodology and size

			and training of employees(4 venues vs. none at baseline)	lacked power to detect this)
LaMontagne et al., 2004	RCT of 16 month OSH management intervention	Management and employee survey re: Compliance with OSHA legislative requirements	Improved subscale score in "management commitment and employee participation"	Study evaluated general OSH program, so not specifically applicable to NIHL
Pingle & Shanbag 2006	Case study Manager led/staff participated in intervention in manufacturing plants	Implementation of noise control measures Cost Noise exposure Attitude of workers to HP use	Improvements reported descriptively in all outcomes e.g. noise levels "reduced by more than 9dB in each of the top ten high noise locations"; "reduction in LP steam saved >US$60 000 per year"	No statistical analysis of described improvements
Dube et al., 2008	Case study Manager led/staff participated in intervention in hospital wards.	Implementation of noise control measures Employee and consumer noise ratings Noise exposure	Reduction in employee and consumer noise ratings	Noise dosimeter results increased in post intervention period, but extraneous variables not controlled for
Multifactorial approach				
Curk & Cunningham, 2006	Case series Hearing test, education, free musician quality earplugs in percussionists n=172	Self-reported use of HP and consultation with audiologist	Survey responses 6 months later 77% reported increased use of HP 27% reported earplug purchase 13% reported audiology consult	49% survey return rate, respondent bias likely
Voaklander et al., 2006	Case series NSW rural hearing conservation project. Hearing questionnaire and screening, individualized results and recommendations. At agricultural farm days. N=5013	Self-reported use of HP, noise control, seek further advice re hearing Satisfaction with service	Survey sent to a randomized stratified sample (n=1000) of participants, 64% response 67% started or increased HP use 41% instigated noise control strategies 25% of those recommended to seek further assistance had done so 98% felt screening should continue at field days	Differences between responders and non-responders with regard to age, farming experience and hearing loss, may have contributed to bias
Gates & Jones, 2007	Pilot controlled study in farmers n=25 Seminar, individualized site assessments and strategies for change, free HP vs. control	Self-report HP use	Very small improvement in reported HP use vs. control at 2 months post intervention, not sustained at 3 months	37% drop out Sample too small to interpret results.
Hughson et al., 2002	Case studies Tailored multifactorial interventions: manager and employee training (some behavior change training), individualized HP provision	Self-report HP use Observed use of HP	Observed use of HP increased by up to 75% Reported use of HP increased by up to 85%	Intervention not fully described (frequency/duration of settings). Post intervention responses from low numbers of participants? responder bias Descriptive analysis only
Knobloch & Broste, 1998 [b]	RCT in agricultural youth 4 year intervention free HP, classroom instruction, noise exposure monitoring at	HP use (at least sometimes)	Intervention group 48% more likely to report HP use "at least sometimes" vs. control.	Not clear if outcome translates into NIHL prevention. Intervention in school attenders, so not

	home, mail outs			generalisable to other groups.
Implement engineering				
Kovalchik et al., 2007	Case study. Dual sprocket chain for coal conveyor on continuous mining machine	Noise exposure (operator dosimeter)	Average 27% reduction in noise exposure in 1 shift field test.	Improvement insufficient alone to reduce noise exposure over a 9 hour shift to MSHA limits
Kovalchik et al., 2008	Case study. Coated flight bars on conveyor belt of continuous mining machine	Noise exposure and cost analysis	Field tests demonstrated 3dB reduction in noise exposure 20% more expensive but increase product durability x3	Highly specific
Yantek et al., 2007	Case study: partial cab for drilling rig	Noise exposure	Field tests demonstrated 2-9 dB reductions in noise exposure	No information about cost, acceptability, durability
Presbury & Williams, 2000	Case study: use of acoustic shield by orchestra members	Noise exposure	Reduced noise exposure by 3-5dB	One off test in rehearsal and performance, no information about acceptability
Evans et al., 2004	Case studies (7) in agricultural settings Farm site visits and implementation of selected noise control measures	Noise exposure	Improvements of 3-16dB reported Farm staff reportedly "pleased" with changes not formally assessed	Repeatability, sustainability of changes unknown
Gunn, 2007	Case studies (8) from construction/metal manufacture industries. Government regulatory body met with industries to implement strategies including new equipment/substitution, elimination, noise control and training	Noise exposure	Noise exposure reduced to <85dB	Unknown if changes were sustained
One off training				
Neitzel et al., 2008	Case series: Face-to-face training HPM based, new types of HP introduced. Construction workers	Self-reported HP use	Reported use of HP improved from 29% to 57% at 8 weeks post intervention	30% missing data
Smith et al., 2008	Case series: Brochure based on EPPM in farmers and landscapers	Self-reported intention to wear HP	Increased intention to wear HP immediately after training	Short and long term effects not assessed
Barrett & Calhoun, 2007	Case series: Written quiz and slideshow on handheld device in miners	Knowledge of HP use	Improved knowledge immediately after training	Short and long term effects not assessed
Griest et al., 2007	Controlled trial: classroom session in adolescents	Knowledge, attitude and intended behaviour	Knowledge, attitude and intended behaviour improved immediately post training	Improvements not sustained at 3 months after training
Kerr et al., 2007 [b]	Experimental trial: computer based audiology and training in carpenters/labourers/roofers	% of time in noise that HP were worn	At 1 year, median % of time in noise that HP were worn was 8% greater (from 42-50% of time), not effective to prevent NIHL	
Williams et al., 2007	Controlled trial: Face-to-face informal interactive session local	Perceived susceptibility to NIHL	Slight improvements in training group for perceived susceptibility and self-	

	council workers	Attitude Self-rated noise exposure Self-report use of HP	reported noise exposure, no change HP use	
Hong et al., 2006 [b]	RCT; computer based audiology and training in construction workers	Self-report HP use	Slight improvements in reported HP use, but ineffective in magnitude to prevent NIHL E.g. immediate improvement of 8-11% from a baseline of 51% At 12 months, improvement of 6-7% from baseline of 51%	34% drop out rate
Stephenson et al., 2005	Case series: postcard mail out with messages about wearing HP in miners	Intention to use HP (Likert scale 1-7)	Slight immediate effect for positive and neutral messages (<1 on seven point Likert scale)	
Lusk et al., 2003[b]	Controlled trial: computer based session tailored and non-tailored information manufacturing workers	Self-report % of time HP worn in noise	At 12 months, self-reported time in noise HP worn increased 3% from a baseline of 79%. Insignificant change.	47% drop out rate
Lusk et al., 1999 [b]	Case series: video and guided practice with HP in construction workers		At 12 months, self-reported frequency of HP use increased from 44-53%, insufficient to prevent NIHL	

[a] Hazard ratio: describes relationship between exposure variable (noise exposure) and outcome variable (STS/hearing loss) after accounting for potential confounding variables of baseline hearing threshold, gender, race, and age (Adera)
[b]Studies included in review by El Dib and Mathew, 2009.

(HP=hearing protection; HPM=Health Promotion Model, EPPM=Extended Parallel Process Model, HLPP=Hearing Loss Prevention Program,STS=standard threshold shift, PEL=permissible exposure level)

2.4 Key strategies

This report presents a systematic review of workplace NIHL and noise exposure prevention strategies in literature and reports published between 1999 and 2008. This review identified five key strategies used in NIHL prevention interventions: introduction of legislation, leadership, multifactorial interventions, implementation of engineering and design controls, and one-off training interventions.

2.4.1 Strategy One: Legislative change

Occupational noise control regulation was introduced in the USA/Canada in the 1970s, and was modified and updated in the 1980s with changes to regulations made as recently as 2000 (Joy & Middendorf, 2007). Six studies were identified that analysed occupational records to determine the effectiveness of these regulations, and associated hearing loss prevention interventions. Four studies supported the effectiveness of legislative change (Adera, Amir & Anderson, 2000; Brink, Talbot, Burks et al., 2002; Joy & Middendorf, 2007; Davies, Marion & Teschke, 2008), while two studies (Daniell, Swan, McDaniel et al., 2006; Humes, Joellenbeck & Durch, 2005) refuted its effectiveness.

The workplace impact in studies that described positive outcomes as a result of NIHL prevention programs was substantial, with changes over time in hearing protector use of at least 20 percentage points (Davies, Marion & Teschke, 2008; Adera, Amir & Anderson, 2000; Brink, Talbot, Burks et al., 2002). In most cases this change took the estimated adherence in hearing protector use to over 90%, although due to the use of a point estimate based on self-report, this finding must be interpreted with caution. A number of features were common to this group of studies:

1. They interpreted data collected over a long time period, from as early as 1979-1996 Davies, Marion & Teschke, 2008) to 1986-2004 (Joy & Middendorf, 2007), with a significant delay between end of data collection and publication. Completeness of noise exposure and audiology data, facilitated by regulation and a centralized database, helped to demonstrate positive changes.

2. Statistical expertise in appropriately interpreting long-term data with multiple confounding factors is required to interpret data. A variety of analytical methods have been employed, all of which have their respective limitations.

3. Little detail was provided about the nature of the HLPPs implemented.

In reports where legislative change had been ineffective to prevent NIHL, key barriers to this strategy included

1. Low use of data collected to provide feedback to employees, inform practice, effect and evaluate change (Daniell, Swan, McDaniel et al., 2006).

2. Incomplete implementation of key features of hearing loss prevention programs (Daniell, Swan, McDaniel et al., 2006).

3. Limited or no use of noise controls (engineering/ administrative) (Daniell, Swan, McDaniel et al., 2006).

4. Incomplete collection of audiology or noise exposure data in mobile and high-risk workforce, resulting in inadequate NIHL prevention (Humes, Joellenbeck & Durch, 2005)

In this group of studies, four comparative studies with or without concurrent controls provide satisfactory and consistent evidence that legislative change has a substantial impact on NIHL prevention. The review and cross-sectional study in this group support these results, leading to the first key finding:

Key finding 1: Introduction of legislative rule and consequent introduction of Hearing Loss Prevention Programs (HLPP) have reduced noise exposure, incidence of NIHL and increased the use of control measures, including the use of hearing protectors.

2.4.2 Strategy Two: Championed by leaders

The role of leadership in effective occupational NIHL prevention has consistent support. The four studies in this category each implemented an intervention directed at workplace leaders and managers, and evaluated the response on NIHL prevention (or, in the case of LaMontagne, Barbeau and Youngstrom, 2004, occupational safety and health in general). However, the quality of this evidence is poor due to the predominance of case reports and studies, and sources of bias found in the published reports (e.g. drop-outs, lack of control groups). The impact of management and leadership in NIHL prevention has been demonstrated in outcomes such as improved perceptions (Dube, Barth, Cmiel et al., 2008; Pingle &Shanbhag, 2006) and greater use of prevention strategies (Groothoff, 1999), but limited results in terms of reduced noise exposure (Pingle & Shanbhag, 2006) and none in actual cases of hearing loss. Conversely, perceived lack of management prioritization of NIHL prevention practices made staff less likely to adopt them (Hughson, Mulholland & Cowie, 2002; Prince, Colligan, Stephenson et al., 2004; Daniell, Swan, McDaniel et al., 2002)

Three features promoting the success of leadership and management strategies in NIHL prevention included an external driver for the process, the use of needs assessment data, and demonstration of cost-benefit.

External driver for the process

In these studies, an external leader or strong management was vital to the success of the intervention. Interventions were initiated and sustained by government regulators (Groothoff, 1999; Gunn, 2007), study or project staff (LaMontagne, Barbeau et al. 2004; Pingle and Shanbhag 2006). Workplace management was often then actively engaged to promote and implement the process (LaMontagne, Barbeau, Youngstrom et al., 2004; Pingle & Shanbhag, 2006).

Leadership formulated intervention in response to needs assessment data

Qualitative data from Dube, Barth, Cmiel et al. (2008) indicated that their program effectiveness was enhanced by managers' ability to synthesize information from multiple sources (i.e. their staff, consumers, information resources about noise), develop local solutions, put them into action and evaluate the results.

Demonstrate cost benefit to managers

The process of engaging management in prioritising NIHL prevention often came down to an appeal to cost-benefit, usually made by an external body such as a legislator, regulator or insurance provider (Bertsche, Mensah & Stevens, 2006; Gunn, 2007; Kovalchik, Matetic, Smith et al., 2008).

For example, in relation to engineering noise controls, Gunn (2007) reported that "..what solutions were available, were normally perceived by industry as being too complicated or too expensive for an average workplace to implement.." although no direct evidence was provided to support this statement. Gunn's intervention attempted to refute this perception by providing examples from industry where low cost noise control measures had been implemented. Kovalchik, Matetic, Smith and co-authors (2008) described a marketing imperative: if industry partners manufactured low noise equipment they were guaranteed that the mining industry would buy it. The cost of providing hearing surveillance alone to employees was calculated by Bertsche, Mensah & Stevens (2004) at around $50 per employee per year, compared with the average cost of a single NIHL claim which could range from $44 to $20 157(claims sustained by the same company in other facilities in recent years).

In summary, while the evidence base was poor (one randomized controlled trial, three uncontrolled case studies), studies were highly consistent, indicating a moderate impact of management-driven strategies on outcomes relating to NIHL prevention. Thus the second key finding of this review is as follows:

Key finding 2: Strategies championed by leaders and managers promote effective NIHL prevention.

2.4.3 Strategy Three: Multifactorial approach

Interventions to address NIHL generally involve multiple strategies, due to the complex array of elements involved in the occupational safety and health process (Franks, Stephenson & Merry, 1996). Studies in this section, where the multifactorial aspect was a key strategy, are especially relevant to industries where legislation (Strategy 1) and management (Strategy2) are less likely to exert an effect (e.g. agriculture). Although this group of 5 studies included one randomised controlled trial (where participants were school students, and not in the target population of occupational NIHL (Knobloch & Broste 1998), most were case reports with post intervention data only (Voaklander, Franklin, Depczynski et al., 2006; Curk & Cunningham, 2006; Hughson, Mulholland & Cowie, 2002), or involved a highly selected population resulting in significant bias (Gates & Jones, 2007). While two studies based findings on outcome measures 8-12 weeks after the intervention(Hughson, Mulholland & Cowie, 2002; Gates & Jones, 2007), others reported persistent changes in self-reported hearing protection use at 6 months (Voaklander, Franklin, Depczynski et al., 2006; Curk & Cunningham, 2006), and 3-4 years (Voaklander, Franklin, Depczynski et al., 2006) after implementation.

While a number of these interventions appear well developed, theory based, and labour intensive it is difficult to be conclusive about their benefits because of the limitations of study design and significant bias in outcome measurement. Workplace impact of study findings was significant in relation to self-reported and observed wearing of hearing protectors, with increased use in 60-90% of participants. In one study (Voaklander, Franklin, Depczynski et al., 2006) increased use of noise control measures was also described, though not in a majority of participants.

Consistency of study results was reduced due to the very heterogeneous nature of intervention type, duration, context and target participants. Generally interventions were not described in sufficient detail for them to be replicated, even in the longer reports (Hughson, Mulholland & Cowie, 2002). Longer or repeated interventions (Knobloch & Broste, 1998; Voaklander, Franklin, Depczynski et al., 2006) and an external enthusiastic team (Voaklander, Franklin, Depczynski et al., 2006) or leader (Hughson, Mulholland & Cowie, 2002) to drive the process, were associated with more positive results.

In summary, interventions utilizing a multifactorial approach to NIHL prevention were described in uncontrolled case studies and one randomized controlled trial. A wide range of subjects and interventions were described, limiting consistency, but a number of studies demonstrated substantial impact on self-reported use of HP, leading to the third key finding:

Key finding 3: Interventions which combine multiple strategies are effective in NIHL prevention.

2.4.4 Strategy Four: Implement engineering

The range of possible engineering and administrative noise control strategies to prevent NIHL is very wide. In an effort to share knowledge and promote NIHL prevention, these solutions have been presented in the industrial literature as long lists of specific solutions (e.g. Sound Solutions, Health and Safety Executive, UK Government; Noise Reduction Ideas Bank, Washington State Department of Labor and Industries). However, trying to match these solutions to a unique workplace noise situation is problematic, and the need for general methodologies to assist application of engineering noise control is gaining attention (Canetto, 2007).

Of the six reports discussed in this review only two are from the peer-reviewed literature, so the quality of scientific evidence in this area is not strong. In the reports by Evans, Whyte, Price et al. (2004) and Gunn (2007) the authors point out that interventions were undertaken in companies who were already engaged in change toward NIHL prevention. Only workplaces that chose to participate were evaluated, so results were more likely to be positive than if the intervention was evaluated with a controlled trial. To the extent that they were able to be evaluated, the engineering controls mostly demonstrated good effectiveness, although in a couple of cases were insufficient to reduce noise to below acceptable levels on their own. The two studies that dealt with administrative controls (Bauer & Babich, 2004, Tharmmaphornphilas, Green, Carnahan et al., 2003) were theoretical only, and as no implementation had occurred these could not be evaluated for this review.

Workplace impact was moderate because only immediate effects were reported: medium or long term impacts were not described. Evans, Whyte, Price et al. (2004) report participant satisfaction with an individualized, collaborative problem solving approach to engineering control in agriculture. However, most studies did not discuss the degree of acceptance of change by management and employees, or the long term sustainability of noise reductions. In theory, engineering controls have potential for a substantial impact, but at the moment this is not reflected in the available evidence.

The role of demonstrating cost-benefit of engineering noise control to leaders and managers has been previously described. The development of links between regulators, researchers, industry and suppliers may also facilitate NIHL prevention through the development of policies, collaborations and joint initiatives. However, the multidisciplinary nature of the implementation could also be a barrier, requiring a high level of expertise in several professions. Effective engineering noise control may be a lengthy and costly process in industries where solutions are not simple (e.g. longstanding work by NIOSH Pittsburgh Research Group in underground coal mining (Kovalchik, Smith, Matetic et al. 2007; Kovalchik, Matetic, Smith et al. 2008).

In summary, most of these studies were reported in the non-peer-reviewed literature. Generally engineering approaches demonstrated a consistent reduction in noise exposure, but due to a lack of information about sustainability or long term outcomes, had a moderate impact on NIHL prevention. Thus the fourth key finding of this review is:

Key finding 4: Engineering controls reduce noise exposure but little is known about the logistics and economics of their implementation.

2.4.5 Strategy Five: One off training

One-off training sessions were a frequently evaluated strategy to promote NIHL prevention, albeit a largely ineffective one. Ten studies evaluated the immediate (up to 6 weeks), short term (2-3 months) or longer term (10-12 months) effects of a single training session with workers. In most cases the goal of the training was to promote the hearing protection use, with the exception of Williams, Purdy, Storey et al. (2007) where the training session addressed other strategies for noise control including noise elimination, substitution, and engineering control. Presentations varied from computer-based sessions that combined audiometry with hearing protection advice (Hong, Ronis Lusk & Kee, 2006), to slide shows through a hand held device (Barrett & Calhoun, 2007)and face-to-face sessions with hands-on practice in hearing protector use (Neitzel, Meischke, Daniell et al., 2008).

Compared to studies evaluating more complex interventions, designs of these studies were more likely to include a control group and subject randomisation. However, undescribed or high dropout rates of around 30% (Lusk, Hong, Ronis et al. 1999; Hong, Ronis, Lusk & Kee, 2006; Neitzel, Meischke, Daniell et al., 2008) reduced the quality of the evidence. The main outcome described was self-reported current or intended use of hearing protection with data on observed hearing protection use in one instance only (Neitzel, Meischke, Daniell et al. 2008). Due to questions about the validity of this measure, particularly when compared with more objective methods (e.g. observed hearing protection use), and the underlying inadequacies of personal hearing protection (Williams, 2006), this is not a strong indicator of effective NIHL prevention.

Many of the training sessions were developed using the tenets of the Health Promotion Model as a framework to promote behaviour change (Lusk, Ronis, Kazanis et al. 2003; Hong, Ronis, Lusk & Kee, 2006; Neitzel, Meischke, Daniell et al., 2008). Briefly, this model describes the effect on the desired behaviour (i.e. wearing hearing protectors) of workers' beliefs about the barriers and benefits of using hearing protection; workers' perceived susceptibility to NIHL and perceived severity of NIHL; the workers' confidence that they can address the problems of NIHL (self-efficacy), other interpersonal or situational factors, and knowledge about NIHL. Neitzel, Meischke, Daniell et al. (2008) evaluated the effect of their intervention on aspects of this model, for example, they examined whether perceived barriers to wearing hearing protection had changed post-intervention.

Five studies reported an immediate positive effect on intended/reported hearing protection use. Improvements were found in knowledge about hearing protector use and attitudes and intentions to use HP. Two studies described medium term effects, one effective and one ineffective. The six studies that evaluated long term effectiveness (10-12months post training session) all reported very slight or insignificant effects (Table 3). Where intention to use HP did improve, increases were of insufficient magnitude to prevent NIHL (e.g. increased intention to wear HP to 62% of time in noise (Hong, Ronis Lusk & Kee, 2006), compared with the recommended requirement for wearing HP 100% of time. Where workers' perceptions improved (benefits, barriers, self-efficacy etc.), these did not correlate with changes in HP use (Neitzel, Meischke, Daniell et al., 2008).

While more robust study designs were employed to examine the effectiveness of training sessions, high drop-out rates in these studies limited the overall quality of the evidence base. The included studies consistently described slight improvements in reported HP use but had no significant impact on workplace NIHL prevention. The final key finding of this study is:

Key finding 5: One-off training has modest immediate effects, but is insufficient to prevent NIHL in the long term.

2.4. Discussion

1. From a review of the literature, what is the evidence base for the effectiveness of existing work-related interventions/programmes to reduce NIHL?

Effective strategies in workplaces to prevent NIHL and noise exposure vary widely in scope and reported outcomes. Interventions which have reported positive effects on NIHL range from large scale legislative change, to one-off workplace training sessions, and have been implemented in a diverse array of industries. The effective strategies identified in this review have been described according to five key areas, which correspond to five key findings regarding NIHL intervention effectiveness. The "evidence base" presented in the review of literature for the effectiveness of existing work-related interventions/programmes to reduce NIHL was identified as poor or satisfactory. Table 2.4 summarises the body of evidence for the effectiveness of interventions in the prevention of NIHL.

Table 2.4: Summary of key strategies to prevent NIHL in body of evidence framework

Key strategy 1: Legislative change		
	Body of evidence grade	Comments
Evidence base	C-Satisfactory Level III studies with low risk of bias, or level I or II studies with moderate risk of bias	Three level III studies, two with low risk of bias, others level IV
Consistency	B-Good Most studies consistent and inconsistency may be explained	4 comparative studies with or without concurrent controls provide consistent evidence supporting legislative change. Review and cross-sectional study concur with these findings
Workplace impact	B-Good Substantial workplace impact	Clinically significant outcomes in risk of STS (1 study), self-reported use of HP (2 studies) and noise exposure (1 study)
Key strategy 2: Championed by leaders		
Evidence base	D-poor Level IV studies, or level I to III studies with high risk of bias	Three level IV studies and one RCT (indirect influence on NIHL)
Consistency	A-excellent All studies consistent	All studies linked leadership and management support to positive outcomes
Workplace impact	C-satisfactory Moderate workplace impact	More noise controls implemented/improved staff perceptions but not reflected in noise exposure (2 studies). Good improvements in all outcomes (1 study). Improved management commitment and employee participation (1 study)
Key strategy 3: Multifactorial approach		
Evidence base	D-poor Level IV studies, or level I to III studies with high risk of bias	One level II study (in students) One level III study with high bias Three level IV studies
Consistency	C-satisfactory Some inconsistency reflecting genuine uncertainty around clinical question	Some common elements to interventions (assessment, individualized results, strategies for change, follow-up) but many inconsistencies and insufficient information to determine best approach
Workplace impact	B-Good Substantial workplace impact	Moderate-large increases in HP use in 4 studies
Key strategy 4: Implement engineering		
Evidence base	D-poor Level IV studies, or level I to III studies with high risk of bias	All level IV studies
Consistency	A-Excellent Most studies consistent and inconsistency may be explained	Consistent reductions in noise exposure, but acceptance (to workers and managers) and sustainability unknown
Workplace impact	C-satisfactory Moderate workplace impact	Only immediate effects on noise exposure reported
Key strategy 5: One-off training		
Evidence base	D-poor Level IV studies, or level I to III studies with high risk of bias	Three level II studies Two level II studies with high bias (drop-outs 34-47%) and five level IV studies
Consistency	B-Good Most studies consistent and inconsistency may be explained	Most studies reported immediate effects but these were unreported or not sustained in short-longer term
Workplace impact	D-Poor Slight or restricted workplace impact	Size of effects on reported or intended HP use insufficient to prevent NIHL

- ***What are the elements of successful programmes especially from the perspectives of social marketing and behavioural psychology? Why did programmes fail?***

Social marketing describes a framework in which strategies are drawn from diverse fields including psychology, communications theory, anthropology and sociology to effect change for the good of the individual and society. Andreasen defined social marketing as;

> “the application of commercial marketing technologies to the analysis, planning, execution, and evaluation of programs designed to influence the voluntary behaviour of target audiences in order to improve their personal welfare and that of their society” (Andreasen, 1995, p.7).

Understanding of the concepts of social marketing, by health educators and marketers has been cited as poor (McDermott 2000), with most confusion centred around the systematic and comprehensive nature of the social marketing approach (Lindenberger 2001). Neiger and co-authors (2003) felt that the common failure to view social marketing as a multi-phased, systematic planning approach jeopardised the potential quality and impact of related interventions. Social marketing differs from health education programs as its fundamental principle is the awareness of and responsiveness to, the needs, preferences, and lifestyles of the consumer (Leveton, Mrazek et al. 1996). The tendency in health education programs to rely on demographic and epidemiological data to create “top-down” (practitioner-driven) interventions, with relatively little or no input from prospective consumers (Thackeray and Neiger 2000) is insufficient to facilitate change in the community.

Six essential benchmarks of a social marketing approach (Table 2.5) were described by Andreason (1995), and these elements are reasonably consistent across the main social marketing frameworks (Lefebvre and Flora 1988; Walsh, Rudd et al. 1993; Weinreich 1999; Bryant, Forthofer et al. 2000). These elements have previously been used as a checklist to identify intervention studies which adopted a social marketing approach (Gordon, McDermott et al. 2006).

Table 2.5: Six Essential Criteria of Social Marketing Approach (Gordon 2006, after Andreason, 1995)

1	Behaviour change	Intervention seeks to change behaviour and has specific measurable behavioural objectives
2	Consumer research	Intervention is based on an understanding of consumer experience, values and needs. Formative research is conducted to identify these Intervention elements are pre-tested with the target group
3	Segmentation and targeting	Different Segmentation variables are considered when selecting the intervention target group intervention strategy tailored for the selected segment(s)
4	Marketing mix	Intervention considers best strategic application of the “marketing mix”. This consists of the 4 Ps product: tangible and

		intangible price: barriers and costs place: make product available to consumer promotion: strategies used to communicate.
5	Exchange	The intervention considers what will motivate people to engage voluntarily with the intervention and offers them
6	Competition	Competing forces to behaviour change are analysed. Intervention considers the appeal of competing behaviours and uses strategies that seek to remove or minimize this competition.

The social marketing approach also requires an on-going process, from pre-marketing (formative research) through pilot testing and marketing, to evaluation, where outcomes may be used to improve the intervention effectiveness.

While a few studies in this review have discussed social marketing in relation to NIHL (Williams, Purdy et al. 2007), none of the intervention studies reviewed in this report were developed based explicitly on social marketing principles. Some studies did not describe any of the six key elements of this framework (e.g. Groothof 1999) relying on providing more detailed information about legislative requirements. However, several studies included a number of the essential features of social marketing (Table 9), in particular promoting behavioural change, and the use of formative research (Pingle and Shanbhag 2006; Voaklander, Franklin et al. 2006; Kovalchik, Matetic et al. 2008; Overman Dube, Barth et al. 2008).

Table 2.6: Examples of NIHL interventions with a number of social marketing elements

	Pingle 2006 Single case study	**Overman Dube 2008 Single Case study**	**Voaklander 2006 Post evaluation**	**Kovalchik 2008 Single case study**	**Hughson 2002 Case Study series**
Promotes Behaviour change	✔	✔	✔		✔
Based on formative research	✔	✔	½		✔
Tailored for selected segment	✔	✔	✔	✔	✔
Marketing mix applied					
product	✔	✔	✔	✔	
price	✔		✔	✔	
place	✔	✔	✔	✔	✔
promotion	✔	✔	✔	✔	
Exchange offered	✔		✔	✔	
Competing forces addressed			✔	✔	

Nine of the intervention studies included in this review used (or in one case, implied) a theoretical behavioural psychology framework in the development of the intervention.

Workplace behavioural safety training for management was included in one of the four interventions evaluated by Hughson and colleagues (2002). No theoretical model for this intervention was described, and it involved briefly training managers in providing immediate positive feedback/reinforcement for desired behaviours. Managers reported they would require further training in this form of coaching, and authors agreed that more intervention would be required to implement this approach in the existing authoritarian work culture.

In contrast, the comprehensive OSH intervention described by LaMontagne and co-authors (2004) was based on a social ecological framework, with interventions to promote change in the worker, organisation and the physical environment. Here the intervention with management involved multiple occasions of contact during the 16 month intervention period, and resulted in significant improvement (in a controlled trial) in "Management commitment and employee and participation" (scoring based on OSHA essential requirements).

The most common behavioural theory described in NIHL prevention intervention studies has been a modification of the Health Promotion Model (HPM) (described in box below). Either the HPM or the Extended Parallel Process Model (EPPM) were used to develop interventions in seven studies in this review. These interventions were based on increasing workers knowledge; changing their beliefs about susceptibility to, and severity of NIHL; facilitating interpersonal support; addressing barriers to NIHL prevention and promoting self-efficacy.

The interventions developed from these models were all designed to promote the wearing of hearing protection, and their findings cannot be generalised to more holistic approaches which target higher stages of the hierarchy of noise control. While models such as the HPM do acknowledge the influence of social and organisational factors, these aspects were not generally addressed in the interventions, which focussed more on addressing individual's beliefs and attitudes. These person-centred behavioural models do not address many of the organisational, social and environmental factors known to influence workplace safety, and specifically NIHL prevention behaviour (NIOSH, 1999). While they are important as part of the wider behavioural change approach, it is unsurprising that interventions based on this theoretical framework alone were largely ineffective (Appendix, Table 6, pp.72-73).

A more recent study (Neitzel, Meischke et al. 2008) combined elements of the HPM (benefits, barriers) and the EPPM (severity and susceptibility) as well as emphasizing the more social and environmental factors components of the HPM (interpersonal and situational influences, Appendix 1, Figure 11, pp.71). However, in this study the cognitive/perceptual mediating factors (benefits of HP, barriers to HP, self-efficacy, susceptibility) did not change, although use of HP improved. This could have been related to small sample size and/or insensitivity of the evaluation questionnaire to detect change.

A large number of non-intervention studies were also reviewed which used behavioural models to explore the relationship of various personal, social and organisational factors on hearing protector use (Appendix 1, Table 7, pp. 74-75). Some of these studies (Cheung 2004; Williams and Purdy 2005; Brady and Hong 2006) employed models which extended beyond personal behaviour to examine social and organisational influences on NIHL prevention (although limited to hearing protector use). Positive relationships were demonstrated between safety climate and HP use (Cheung 2004; Brady and Hong 2006), and between safety climate factors and self-efficacy for NIHL prevention (Williams and Purdy 2005; Brady and Hong 2006).

The transtheoretical model of behaviour change has also been proposed as a good fit for NIHL prevention interventions (Williams and Purdy 2005; Raymond and Lusk 2006). This model, (Prochaska and DiClemente 1987) which utilised different interventions for people at different stages in the process of change (pre-contemplation, contemplation, preparation, action and maintenance) has been suggested in relation to occupational safety interventions, but not yet evaluated in NIHL prevention.

Conclusions

There is currently limited evidence for the effectiveness of interventions developed from behavioural psychology models to prevent NIHL. However, this may be explained due to;

1. **Limitations of the models utilised**. To date most of the interventions used models which focused on personal attitudes and motivations alone (i.e. HPM and EPPM). More promising models are ecological in scope, and recognise the social, organisational and environmental influences on worker behaviour (e.g. LaMontagne et al 2004), and (possibly) the different stages of the change process at all levels.
2. **Nature of the intervention developed**. The behavioural models were almost always utilised to develop one-off training interventions, or brief written interventions.
3. **The desired outcome of the intervention** in all cases was to increase use of personal hearing protection. The underlying problems associated with this low ranking approach to noise management (wear time, attenuation, worker attitude) may confound efforts to achieve change, thus making the model appear ineffective.

- ***Which interventions are most likely to be effective in New Zealand?***

Of the five key intervention strategies identified, four of the strategies have ratings of “good” in relation to generalizability and applicability to NZ industrial context. The strategy rated highest (“excellent”) for generalizability and applicability to NZ, was implementation of engineering controls.

When a NIHL prevention intervention has been effective, it is still not always clear why. Very few studies have identified the mediating factors by which the intervention may have effected behaviour change. When mediating factors have been identified, they have not always appeared responsive to the measures used (Neitzel, Meischke et al. 2008). In most cases the enabling factors identified with each of the key intervention strategies from Review Question 1 have been identified by the authors of each study; in some cases a statistical correlation was demonstrated between the enabling factor and the preventive behaviour, but not often.

In addition to the intervention studies described, many non-intervention, qualitative studies have sought to identify positive factors associated with NIHL prevention. Most of these concentrated on enablers for the use of personal hearing protection. As in literature on the barriers to NIHL, studies examining the influence of workplace safety climate, social, organisational and environmental factors are becoming more prominent, although as yet mostly in the qualitative rather than qualitative literature.

The factors associated with effective NIHL (including factors associated with HP use from qualitative studies) can be considered in terms of regulation, management, workplace culture, characteristics of the intervention, and individual qualities (Appendix 1, Figure 10, p.59) with detail regarding references and evidence quality in Appendix 1, Table 4.p.60 and Table 5.p.65).

Regulation
Motivated and enforced by legislative requirement. Noise exposure measurement, technical support and project initiation from government agency.

Management
Target senior management. Develop close interactions between management, OSH staff. Demonstrate benefits of program to management to engage active participation and commitment. Awareness, attitudes and practices of management will be mirrored by staff.

Workplace culture
A comprehensive, high quality safety program which is enforced has positive effect on worker safety. Positive peer support for safe behaviour. Training in behaviour change strategies required. Situational/ environmental support for NIHL. Leadership formulated intervention in response to needs assessment and implemented local solutions. Cultivate senior employees as role models. Strong role of social modelling and organisational support for safety.

Intervention
Multidisciplinary teams involved throughout intervention. Regular and sustained follow-up by project coordinator. Extensive needs assessment. Targeted to assessment findings. Individualised information and interpretation of hearing tests and their implications. Most change through engineering controls.

Individual
More likely to use HP if male, already have NIHL, free HP provided and annual hearing test. Increase response and self-efficacy, awareness of susceptibility, severity. Positive messages and humour more motivating than fear.

- ***What does the literature suggest is the potential to control noise at source?***

Of the six reports identified in the literature, noise control at source by engineering and design strategies demonstrated good effectiveness, although in a couple of cases were insufficient to reduce noise below acceptable levels on their own. Workplace impact was moderate because of this partial or unproved effect on noise exposure levels, and the lack of information about long term effect or persistence of these changes. Potentially, engineering controls of noise at source have a very substantial impact, but at the moment this is not reflected in the available evidence. However, both the generalizability and applicability of this strategy to the NZ industrial context in the prevention of NIHL are high. The following enablers to implement engineering controls at noise source are summarised below.

Implement engineering: Key enablers for this strategy
1. Links between regulators, researchers, industry and suppliers, where policies, collaborations and initiatives work together to facilitate NIHL prevention
2. Financial incentive for suppliers, supported by effective regulators enforcing lower noise practices
3. Regulators worked with companies who had expressed interest in changing practices, or had already started to implement some noise control measures
4. Low cost interventions ready to go, but long term sustainability and effectiveness of these approaches unknown
5. Different approaches for new workplaces (i.e. more emphasis on buy quiet, design) compared with established workplaces (train management regarding hierarchy of noise control).
6. Bauer and Babich (2004) suggested that the cost of administrative noise control may be an advantage compared with engineering controls, but no data was provided to support this opinion.

2. From the perspectives of social marketing and behavioural psychology what will be the likely features of a successful NIHL intervention?

Of the effective interventions identified in this review, most were not described as being based on behaviour change or social marketing principles. However many of the interventions contained one or more elements of these frameworks. For instance, the use of surveys, interviews and site visits to determine the needs of workers and employers, before designing the detail of the intervention (Hughson, Mulholland et al. 2002) is an example of formative research (an important part of the social marketing framework).

Formative research
A key feature of the social marketing approach is the use of formative research (Bryant 1998) to plan, design and refine the proposed intervention. Formative research involves the process of collecting data, both qualitative and quantitative, on the wants and needs of the proposed target audience, factors that influence its behaviour, including benefits, barriers, and readiness to change.

Interventions to prevent NIHL are well placed in this regard, as much work described in this review has identified these features. A number of interventions have carried out formative research prior to developing their interventions (Hughson, Mulholland et al. 2002; Evans, Whyte et al. 2004) by visiting workplaces, performing noise surveys, conducting interviews and surveys with workers and employees.

Qualitative research about NIHL has identified important aspects to address through interventions. For example, focus groups conducted in 3 US manufacturing plants (Prince, Colligan et al. 2004) allowed authors to make the following recommendations

1. Use small group or 1 on 1 training to address workers stated needs in relation to HP fit and clear explanations of audiometric results and noise monitoring
2. Cultivate senior employees as role models
3. A quality audiometric program, conducted on schedule is perceived to correspond with positive company attitudes about worker safety
4. While engineering controls must be first, don't neglect HP use until noise monitoring ensures the absence of hazardous noise.

Addressing these expressed worker needs and concerns would be vital for any NIHL intervention planned with this target audience.

Targeting

Efforts at targeting ranged in effectiveness. While many interventions aimed to relate information given in training to the specific industry, in other cases approaches were not sufficiently modified to address the complex requirements of the specific industry. For example, a single computer-based session including audiology and training was evaluated in construction workers (Hong, Ronis et al. 2006), a modification of an earlier video/hearing protector practice intervention (Lusk, Hong et al. 1999). Neither of these interventions produced significant improvements in NIHL prevention practices or noise exposure. More targeted approaches could take into consideration the specific safety challenges in the construction industry; workforce mobility and independence (Wadick 2007), the role of workplace safety climate including peer and supervisor use of HP, availability of HP, accountability for safety(Brady and Hong 2006). Hughson and colleagues (2002) describe regulations in the UK construction industry that promote accountability for safety amongst subcontractors:

> "There were additional, external supervisory pressures on the drillers which reinforced the use of the hearing protection. This is an effect that has been most noticeable since the introduction of the Construction Design and Management (CDM) Regulations whereby the principal contractor on such sites now takes a more proactive role in controlling the activities of subcontractors. In these cases the workers are required to comply with local site rules which usually require some form of site-specific induction training. There is also a high level of supervision and an understanding that workers will be expelled from the site if they do not follow the required safety procedures."

This approach seems well placed to address the difficulty of promoting NIHL prevention in industry with a largely sub-contracted workforce.

Exchange

The CASH intervention in India's Reliance Group (Pingle and Shanbhag 2006) did not cite any theoretical behavioural or social marketing model, but did involve an intensive intervention with management, leading to engagement with workers, and a number of the elements of social marketing were present in its approach. In particular the element of exchange was acknowledged, in terms of the financial and employee health gains presented to management. Over time the establishment of awards for the best OSH project were instituted, providing another avenue of exchange, where the employees may see an incentive in continuing safety endeavours.

Introduction of a quieter design in continuous mining machinery was achieved by engaging machinery suppliers, the regulatory body and the mining industry in a process where there were benefits to be gained for each partner (Kovalchik, Matetic et al. 2008). The main benefits included costs and compliance with government regulations.

In a number of intervention studies, participants listed the provision of free hearing protectors as a major factor in gaining their compliance with the intervention (Knobloch and Broste 1998; Gates and Jones 2007), so even exchange on a relatively small scale can promote behaviour change.

The inaugural "Safe in Sound" awards competition advertised by NIOSH is a current example of an "exchange" agreement, providing external recognition for companies that successfully intervene to prevent NIHL (Morata 2008). Another example relevant to NIHL is the Blue Angel Award, a German initiative labelling products which meet safe environmental standards, including requirements for low noise. Particularly in the European construction industry, this award may provide an incentive to both suppliers, to produce low noise equipment, and industry. However, no studies are available to evaluate the results of this program, although the number of construction products awarded the Blue Angel has increased since it began (Irmer and Fischer-Sheikh Ali 1999).

Conclusion

There is insufficient evidence available to determine whether a social marketing framework is effective in developing interventions to prevent NIHL, as no studies were identified that adopted this approach. However, a number of effective interventions and new initiatives demonstrate encouraging aspects of social marketing in NIHL prevention. The most promising include formative research, pre-marketing and re-evaluation, targeting, exchange, and completeness rather than piecemeal attention to the components of the social marketing approach.

The key barriers and enablers of the strategies are summarised below;

Strategy One: Legislative change

Key finding 1: Introduction of legislative rule and consequent introduction of Hearing Loss Prevention Programs (HLPP) have reduced noise exposure, incidence of NIHL and increased the use of control measures, including the use of hearing protectors.

Key barriers to this strategy
▪ Low use of data collected to provide feedback to employees, inform practice, effect and evaluate change ▪ Incomplete implementation of key features of hearing loss prevention programs ▪ No or limited use of noise controls (engineering/ administrative) ▪ Incomplete collection of audiology or noise exposure data in mobile and high-risk workforce, resulting in inadequate NIHL prevention
Key enablers to this strategy
▪ Completeness of noise exposure and audiology data, facilitated by regulation and centralized database ▪ Statistical expertise in appropriately interpreting long-term data with multiple confounding factors ▪ More complete hearing loss prevention program associated with greater use of preventive behaviours

Strategy Two: Championed by leaders

Key finding 2: Strategies championed by leaders and managers promote effective NIHL prevention.

Key barriers to this strategy
▪ Inconsistencies between management and employee responses to questions about noise at work regulations, impact of NIHL, sort of training provided, limitations of HP ▪ Management and supervisors not wearing HP ▪ Supervisors not enforcing HP usage due to perceived inability to listen to the functioning of the machines, difficulty in visually monitoring usage and proper fit of HP, reluctance to jeopardize management/union relations, lack of incentive to enforce company policy. ▪ Reduced supervisor/employee ratio associated with deterioration in enforcement ▪ Use of hearing protection advised but not enforced ▪ Direct relationship between independent responses of management and employees to questions about workplace focus on NIHL prevention ▪ Mobile workforce and management
Key enablers to this strategy
▪ Demonstrate cost benefit to managers ▪ External driver for the process ▪ Leadership formulated intervention in response to needs assessment data

Strategy Three: Multifactorial approach

Key finding 3: Interventions which combine multiple strategies are effective in NIHL prevention.

Key barriers to this strategy
▪ Requires a great deal of effort to encourage employers and employees to fulfil their statutory requirements ▪ Long term persistence of changes uncertain

Key enablers to this strategy
▪ Leaders who actively and enthusiastically encourage intervention practices
▪ Long intervention associated with improvement, but still unknown if this was sustained

Strategy Four: Implement engineering

Key finding 4: Engineering controls reduce noise exposure but little is known about the logistics and economics of their implementation.

Key barriers to this strategy
▪ Controls are situation and site specific
▪ Requires multidisciplinary collaboration: acoustic engineering, construction and industrial expertise
▪ A lengthy and costly process in tough industries where solutions are not simple
▪ No or limited use of noise controls (engineering/ administrative)
▪ Perceived gap between knowledge of the experts, and actual action taken in workplaces
Key enablers to this strategy
▪ Links between regulators, researchers, industry and suppliers, where policies, collaborations and initiatives work together to facilitate NIHL prevention
▪ Financial incentive for suppliers, supported by effective regulators enforcing lower noise practices
▪ Regulators worked with companies who had expressed interest in changing practices or had already started to implement some noise control measures
▪ Low cost interventions ready to go, but long term sustainability and effectiveness of these approaches unknown
▪ Different approaches for new workplaces compared with established workplaces
▪ Cost of administrative control may be an advantage compared to engineering controls, but no data was provided to support this onion

Strategy Five: One off training

Key finding 5: One-off training has modest immediate effects, but is insufficient to prevent NIHL in the long term.

Key barriers to this strategy
▪ Underlying difficulties when key goal of intervention is to promote hearing protection use (requirement for 100% of time use, low wearer acceptability, variability in attenuation)
▪ Changes in attitudes, perceived benefits/barriers/susceptibility not associated with more preventive behaviour, so evidence base for what to include in training is low
Key enablers to this strategy
▪ Face-to-face informal training sessions appear more effective
▪ Practical participation involving selection and use of devices important
▪ Messages focussing on the positive aspects of NIHL prevention more effective than those emphasizing the negative results of no prevention

Barriers identified with each of the key intervention strategies have already been highlighted. In addition to the intervention studies described, many non-intervention, qualitative studies have sought to determine barriers to NIHL prevention. Most of these have involved surveys, interviews or focus groups with workers and have concentrated on barriers to the use of personal hearing protection.

2.6 Impact on industry

From a systematic review and critical evaluation of the recent literature this study has identified five key features associated with more effective NIHL prevention. Reviewed studies varied widely in intervention type (from legislative change to one-off interventions) but interventions to promote the use of personal hearing protection dominated. Most interventions were conducted in the USA amongst white, middle-aged male workers, so the evidence may not be directly applicable to women or indigenous workers. A range of industries was represented with manufacturing, mining, construction and agriculture the top four. In agreement with previous reviews (Verbeek, Kateman, Morata, Dreschler et al., 2009), the overall methodological quality of studies was weak. However, findings were sufficient to make recommendations for future prevention studies in NIHL.

2.7 Legislative Change

Clearly, legislation and regulation is the essential foundation for NIHL prevention. Although detail about the nature of the hearing loss prevention programmes was lacking, there is evidence for a greater effect on behavior from comprehensive, high quality interventions where employees were well informed about the program requirements, including the testing regime, and the test results along with their implications.

Recommendations:

- Fundamental requirements are up to date, relevant legislation with good regulation/enforcement.
- In contrast to programs showing a bare minimum of compliance, comprehensive programs that strive to address the spirit of the legislation do better.
- A clearly defined program where employees understand the process, reasons for and implications of a testing and compliance regime is more effective.

2.8. Leadership, Multifactorial Interventions and Workplace Safety Climate

The importance of managerial leadership for improving safety outcomes is well established, so the evidence for the crucial role of leadership and management in effective NIHL prevention strategies provided in this review seems axiomatic. Successful interventions result where management are empowered to strive for a positive NIHL prevention culture, and work as a team to achieve this aim through multilevel strategies. The qualities of management behaviour associated with NIHL prevention include:

- Demonstrating by their own example that a high priority given to NIHL prevention.
- Working with staff in needs assessment and creative solutions to address the needs identified.
- Enthusiasm and persistence.

These are some of the features associated with transformational leadership, a style that focuses on leading by example and motivating employees, and has a positive impact on workplace safety (Zacharartos, Barling & Iverson, 2005; Clarke & Flitcroft, 2008).

Several studies in this review, and other recent industry surveys (Williams, Kyaw-Myint, Crea & Hogan, 2008) have highlighted the association between larger organisations and better NIHL prevention. Smaller businesses, subcontracted workforces, and more independently organised industries (agriculture and aquaculture) may have less clear leadership/management structures. Effective NIHL prevention strategies in these industries require creative approaches, and a number of examples are included in this review. Possibilities supported in the literature include:

- Leadership from within that supports safety but understands workplace culture (e.g. “principal” contractors in construction that champion safety (Hughson, Mulholland & Cowie, 2002).
- A social marketing approach that values needs assessment and targeting (Voaklander, Franklin, Depczynski et al., 2006) for individual situations, demonstrating a positive exchange in return for preventive action.
- Generate peer support for NIHL prevention amongst isolated workers: eg interpersonal influence (whether other farmers encouraged them to use HP, whether they felt other farmers used HP the strongest predictor of HP use in farmers, but very infrequently occurred (McCullagh, Lusk & Ronis, 2002)

Recommendations

- Targeting management is a key strategy in NIHL prevention as it leads to the participation of other staff, establishes of a positive safety climate, is associated with use of higher levels of control, and facilitates a multifactorial approach to NIHL prevention.
- Target industries with non-traditional management structures creatively, through peer support, establishing safety role models, and social marketing approaches.

2.9. Social and Organisational, Not Just Personal

The most common outcome evaluated in association with NIHL prevention has been the use (and usually, the self-reported use) of hearing protectors. All studies of behavioural models applied to NIHL prevention identified in this review were evaluated in this way, also many of the barriers and enabling factors.

It is clear that there are very real problems with the use of hearing protectors in the attempt to prevent NIHL, and this is a major reason why other methods of noise reduction are highlighted in all legislation and guidelines. For these reasons further intervention studies to promote hearing protector use alone will have little utility.

There is also evidence that personal motivation factors (perceived benefits, barriers, susceptibility to and severity of effects) are not as important as the structural, organizational managerial and peer-based aspects of workplace safety with regard to NIHL prevention.

Recommendations

- Apply effort to intervention strategies based on management promotion of safety culture through social and organizational supports, shared values around safety in general and NIHL in particular.

- Recognise that personal factors that motivate individuals need to be supported by social, organizational, environmental and legislative structure.

- Use theoretical and psychological frameworks that include social, organisational and environmental influences on behaviour, not solely personal ones.

2.10. Conclusion

The evidence identified and collated in this review suggests that NIHL prevention is a complex issue without simple solutions. Effective interventions will require a combination approach, taking the best strategies from different types of intervention. In the intervention studies identified, the best of these approaches combined “high level” interventions (e.g. active management targeted with greater use of noise elimination, design and engineering noise controls). The least effective contained a lower level component (e.g. person-centred behavioural approaches with little management support to promote the wearing of personal hearing protection).

The challenge for designing effective NIHL intervention strategies will be to integrate and build on evidence from previous international quantitative and qualitative studies, in combination with attention to optimal occupational intervention study design, and a clear understanding of the local context gained through primary research.

3.0 Background

3.1 Noise sources and paths

There is little published data on noise sources related to occupational exposures. Most published sound level surveys focus more on exposures and controls and provide little detailed evaluation of noise sources and transmission paths. Sound level surveys that have identified noise sources are industry specific and include data from agriculture (Nieuwenhuijsen et al, 1996; McBride et al, 2003); construction (Hattis, 1998; Neitzel et al, 1999); manufacturing (Lee and Smith, 1971; Reilly et al, 1998), saw mills (Schmidek, et al, 1974; Davies et al, 2009); mining (McBride, 2004) and energy (Gardner, 2003).

Farming activities involving machinery used for prolonged periods present significant risks to farmers' hearing health. Noise sources in agricultural work (and noise exposure levels) have been identified primarily by their operational and task characteristics and usually linked to specific equipment and tasks (Nieuwenhuijsen et al, 1996; McBride et al, 2003; Depczynski et al, 2005).

Noise sources in the manufacturing sector are extremely varied and very much dependent on the manufacturing process and equipment and machinery used in the process. Sound fields in the workplace are usually complex, due to the participation of many sources: propagation through air (air-borne noise), propagation through solids (structure-borne noise), diffraction at the machinery boundaries, reflection from the floor, wall, ceiling and machinery surface, absorption on the surfaces, etc. Therefore any noise control measure should be carried out after a source ranking study, using identification and quantification techniques. The basic mechanism of noise generation can be due to mechanical noise, impact noise, fluid noise and/or electromagnetic noise. Kock et al (2004) surveyed in excess of 800 companies in high risk (predominantly manufacturing) industries in Denmark and identified noise exposures related to the activities within the industry sector rather than specific noise sources. Similarly, in the US an extensive survey undertaken by Tak et al (2009) characterized noise exposure by industry sector and occupational group rather than identifying the source of the exposure.

Hattis (1998) identified categories of noise sources in the construction industry and defined three broad types of equipment according to the kind of process that was thought most likely to be responsible for generating most of the noise. Equipment that makes noise by the action of a part of the machine on material outside the machine (*e.g.,* a saw or other cutting device) was distinguished from equipment where much of the energy producing the noise originates from events entirely outside of the machine (*e.g.,* abrasive hitting an external surface, as in abrasive blasting), and equipment where the predominant noise source appears likely to be an engine.

The noise sources in the cafés consist of impact noise due to the banging of cutlery and crockery, mechanical/equipment noise from the operation of appliances such as food processors and the coffee machine and the till and fan and extractor noise. Other important sources of noise include traffic, patron generated and radio/music background noise. In their survey of restaurants, bars and cafes, Christie and Bell-

Booth (2004) found that sounds from other occupants were rated as the most predominant noise sources in all three environments. This provides evidence for the suggestion that major source of annoyance to social interaction, is in fact others conversations. However overall, cafes were not the worst performing in terms of background sound levels. It is possible that as background noise in cafes increase the degree of effort to converse increases and thus the acceptability of the environment falls.

Sound level surveys undertaken by McLaren and Dickinson (2005) and (2009) in preschools, found that some activities and equipment were especially noisy, indicating that controls on the level of noise for these were needed. Personal sound exposures were measured on 73 teachers in early childhood education centres and compared to the prescribed levels for workers in the health and safety in employment legislation. Twenty eight teachers in part-time (sessional) centres and 45 teachers in all day centres were tested over one working day. One staff member of a sessional centre and five of those in all day centres received noise exposures well in excess of the 100% maximum daily sound exposure permitted in the workplace. A similar study by Grebenikov (2006) in Sydney of 25 full-time teaching staff using similar equipment and the same criteria as adopted by the New Zealand legislation, had one staff member with a daily sound exposure in excess of 100% and three staff members close to the maximum.

3.2 Exposure to workplace noise

Occupational exposure to elevated sound levels is dependent on a variety of factors, including: (a) occupation and industry, and (b) workplace-specific factors, such as type of facility and process, raw materials, machinery, tools, the existence of engineering and work practice controls, and the existence, condition, and use of personal protective devices (Nelson et al, 2005).

The most recent European data collected during the period 1990 to 2000 showed that over a quarter of the European workforce (29%) was exposed at least a quarter of the working time to high sound pressure levels; approximately 20% of workers were exposed half or more of their working time to noise loud enough that they had to raise their voice to talk to other people; and around 10% of the workers were exposed almost continuous high-level noise. Many countries in the survey reported an increasing number or percentage of people exposed to noise in the workplace over this period or beyond although there was a 10% decline in the percentage of the workforce in Germany that reported being exposed to noise between 1992 and 1999 (European Agency on Safety and Health at Work, 2005).

Paoli and Merllié (2001), found in the European Survey on Working Conditions, the proportion of workers experiencing loud noise in the workplace had increased and workers in all occupations showed more hearing problems in 2000 (7%) than in 1995 (6%), except the professionals, clerks, skilled agriculture workers and armed forces, which reported a decrease. However, the situation does differ between countries (European Agency on Safety and Health at Work, 2005) but overall workers report more hearing problems due to their work since 1995. Noise exposure rates were regarded as a significant problem and were higher for workers in manufacturing, construction and agriculture. Interestingly (Paoli and Merllié, 2001), reported an increasing trend for notifications of hearing loss to enforcement agencies in the European Survey among schoolteachers and day care workers.

According to the Health and Safety Executive (HSE, 2005) over 2 million workers in the United Kingdom are regularly exposed to loud noise at work and about 1.7 million workers are exposed above levels that are considered safe. In 2001, approximately a third of men and 11% of women had worked in a noisy job for a year or longer, with 16% of men and 3% of women reporting more than 10 years of such exposure (Palmer et al, 2001). Six (6%) of men and 3% of women reported that work tasks left them with ringing in their ears or a temporary feeling of deafness at least every week, and 3% of men and 2% of women said this sensation was daily (Palmer et al, 2001). Despite the apparent decline in claims hearing loss caused by work-related noise exposure to noise at work continues to be a significant occupational problem in the UK.

Tak et al (2009) estimated that one in six US workers (17%) is exposed to workplace noise that is loud enough that they had to raise their voice to be heard. The five industries with the highest proportion of workers reporting exposure to workplace noise at their current job were: mining (75.8%); lumber and wood product manufacturing (55.4%); rubber, plastics, and leather products (48.0%); utilities (46.1%); and repair and maintenance (45.1%). The prevalence of exposure to hazardous sound levels among workers in each of the manufacturing industry sub-sectors was higher than the national average proportion (17.2%) and ranged from 21% (electrical machinery, equipment, and supplies) to 55% (lumber and wood products including furniture). The manufacturing industry had the greatest number of workers exposed to hazardous sound levels (estimated number of exposed workers, 5.7 million, or 25% of all US workers), followed by construction (4.5 million) and retail trade (2.1 million) (Tak et al, 2009).

In New Zealand it is difficult to identify exactly how many people are affected by noise-induced hearing loss, how many are exposed to excessive noise and how many are at risk (Driscoll et al, 2004). It is estimated that currently around a quarter of the New Zealand workforce of 1.47 million workers are affected to some degree by harmful noise at work (McBride, 2003). The 2003 New Zealand Accident Compensation Annual Report states that despite knowledge of effective controls and guidelines the prevalence of noise-induced hearing loss shows no sign of decrease. As Throne et al (2008) suggest however, in the absence of better knowledge regarding the underlying determinants, it is also difficult to reliably project future trends in the burden of NIHL. In addition, it could be argued that as the number of people working in traditionally noisy industries in New Zealand declines, the number of individuals developing hearing loss from noise exposure should, at least theoretically, diminish. This possibility requires more detailed examination, particularly as noise levels may be increasing in “non-traditional” industries (e.g. hospitality and education environments) and the decline in worker numbers may not be occurring equally across industries with high NIHL incidence rates.

3.3 Noise control and management

There has been a growing body of research into noise control strategies and initiatives (Murphy, 1966; Erskine, 1967; Ford, 1967; Lee and Smith, 1971; Pell, 1972; Hager et al, 1982; Melnick, 1984; Harrison, 1989; Leinster et al, 1994; Daniell et al, 2006; Malchaire, 2000; McBride et al, 2003; Kock et al, 2004; Williams et al, 2008; Tak et al, 2009). There is also an abundance of manuals, texts and practical guides on noise control and management and most national OHS enforcement agencies and institutions have published detailed codes and guidelines on noise control.

The international legislative requirements for control of exposure to noise tend to be similar. Generic requirements include employers need to assess the risks to employees from noise at work; take action to reduce the noise exposure that produces those risks; provide employees with hearing protection if the employer cannot reduce the noise exposure enough by using other methods; make sure the legal limits on noise exposure are not exceeded; provide employees with information, instruction and training; carry out health surveillance where there is a risk to health.

Similarly, in New Zealand, the Health and Safety in Employment Act (1992) requires employers to take all practicable steps to ensure the safety of employees at work, and to provide a safe working environment. The Act stipulates that it is the employer's responsibility to identify hazards, assess whether they are significant and control any significant hazards via elimination, isolation or harm minimisation. Furthermore the employer is also required to monitor the health of employees who have been exposed to a significant hazard, and to provide information and training supervision for staff in relation to hazards in the workplace.

The New Zealand Health and Safety in Employment Regulations (1995), require employers to take all practicable steps to prevent employees from being exposed to excessive noise, which is set as a time average level (L_{Aeq}) of 85 dB for an eight hour working day - a daily noise dose (DND) of 100 percent, and a peak level (L_{Cpeak}) of not more than 140 dB. The DND is the percentage of the maximum daily sound exposure (an energy summation of sound level and time) permitted in industry. If a DND exceeds 100 percent then this is in excess of what is permitted in the legislation, and it is potentially harmful.

This translates into a requirement to conduct preliminary noise surveys to identify possible hazards followed by detailed sound level surveys of identified noise hazards to assess if they are a significant risk. After this, employers are required to investigate, and if practicable, control the noise at the source and isolate noise sources away from employees. Where it is considered not practicable to eliminate or isolate the hazardous noise source, employers must provide approved hearing protection. The requirement for monitoring employee health means that employers must arrange appropriate hearing test for all employees working in an area of hazardous noise, once when the employee starts work and again at intervals not more than twelve months after. In addition employers must provide information, training and supervision for workers to identify noise hazards and for the safe use of plant, equipment and hearing protectors (OSH, 1996).

However, Thorne et al, (2008) comments that - “although the law forms the basis for the current hearing conservation paradigm, the law is based upon ‘practicability’ which potentially provides a convenient “opt-out” from the more effective noise control methods, and provides a basis for a legally compliant noise management program based largely on the use of hearing protectors”.

This is particularly so as there is no strict definition of what constitutes practicability. Therefore a complete noise control program as specified in the Act can potentially be passed over on the grounds of difficulty or expense, as it is often true that the provision of hearing protectors is a lot easier and cheaper than modifying equipment, the environment or work processes to lower noise output (Thorne et al, 2008).

Generally a hearing conservation program consists of a sound level survey of the workspace to establish sound levels and ‘noise hazard areas’, the issue of personal hearing protectors and education on their correct fitment and use, and some form of engineering noise control. This is undertaken in conjunction with regular and standardised audiometry administered to all noise-exposed personnel, the results of which are monitored to identify any threshold shift to evaluate the effectiveness of the program (NOHSC, 1991; Williams, 1993b).

Noise management programs differ from hearing conservation programs in that they attempt to control noise exposure on all levels, primarily via noise elimination and exposure reduction but also secondarily via the use of hearing protection where higher level strategies are not yet implemented. This is the approach suggested in the Australia/New Zealand Standard for Occupational Noise Management (2005), which states that occupational noise-induced hearing impairment can be minimized in a cost-effective way by applying noise control measures to existing noisy equipment. The Standard also advices workplaces that the reduction of noise levels through noise management policies often takes several years of planning and budgeting, and that hearing protection programmes should only be used as an interim measure while these measures are being formulated and implemented.

Overall it would appear that there is a trend internationally to shift from a focus on ‘hearing conservation’ programs to ‘noise management’ programs in order to provide the conceptual change required to further develop the avoidance of dangerous noise exposure in the workplace (Waugh, 1993). This generally reflects the purpose and intent of legislation in most jurisdictions but a such a change of focus may place more emphasis on reducing the hazard foremost and then minimising any risk that remains rather than reducing the risk while leaving the hazard in place (Williams, 1993b).

It would seem that for a hearing conservation program to be an effective prevention method, the focus needs to shift from the individual to the organisation, and from personal exposure *protection* to general exposure *prevention.* The individual certainly has a large role to play in their own hearing safety; however they cannot be expected to shoulder the full burden of a problem that goes well beyond the control of any one worker.

This difference between conservation and prevention is also noted by the National Institute of Occupational Safety and Health in the USA. As noted in the preamble to a NIOSH (NIOSH, 1996) guide to hearing loss prevention, this change is significant both in terms of the outcomes it can achieve and the changes that must be implemented:

> "The shift from conservation to prevention is not minor. Conserving means to sustain the hearing that is present, regardless of whether it is impaired or not. Prevention means to avoid creating hearing loss" (NIOSH, 1996).

In addition, the Health and Safety Executive (HSE) in the UK have changed terminology from conserving hearing to managing noise. The flow chart provides a description of the elements of the noise management strategy the HSE recommend Fig. 3.1).

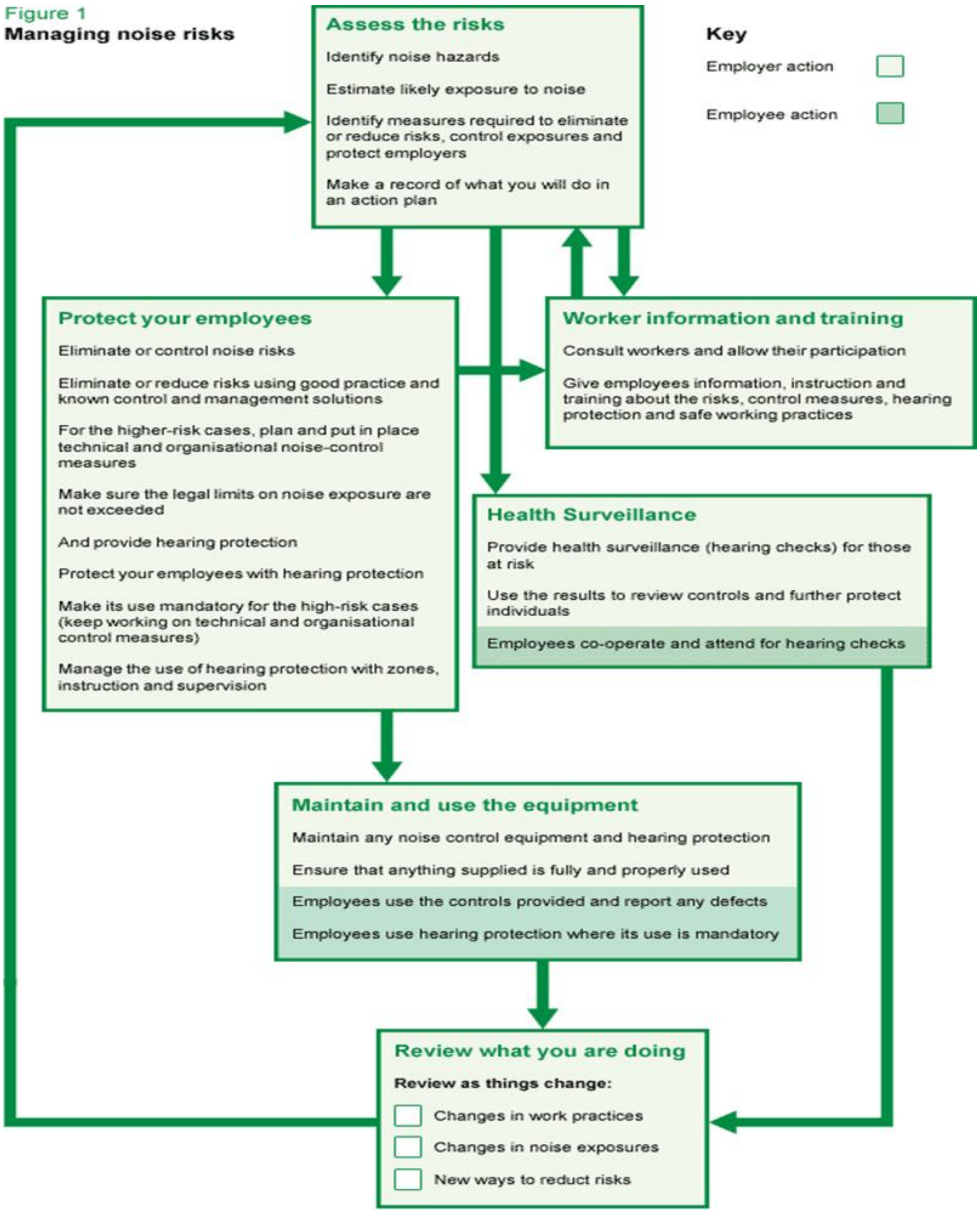


Figure 3.1: HSE (UK) framework for managing noise risks.

A risk management model for noise management has been developed by National Offshore Petroleum Safety Authority (NOPSA, 2001). The model (Fig. 3.2) has standard elements of risk identification, assessment, control and recovery. But is distinctive as it includes key management elements including leadership and commitment, policy, planning and objectives; organisation, responsibility, standards and documentation as well as implementation, monitoring and review.

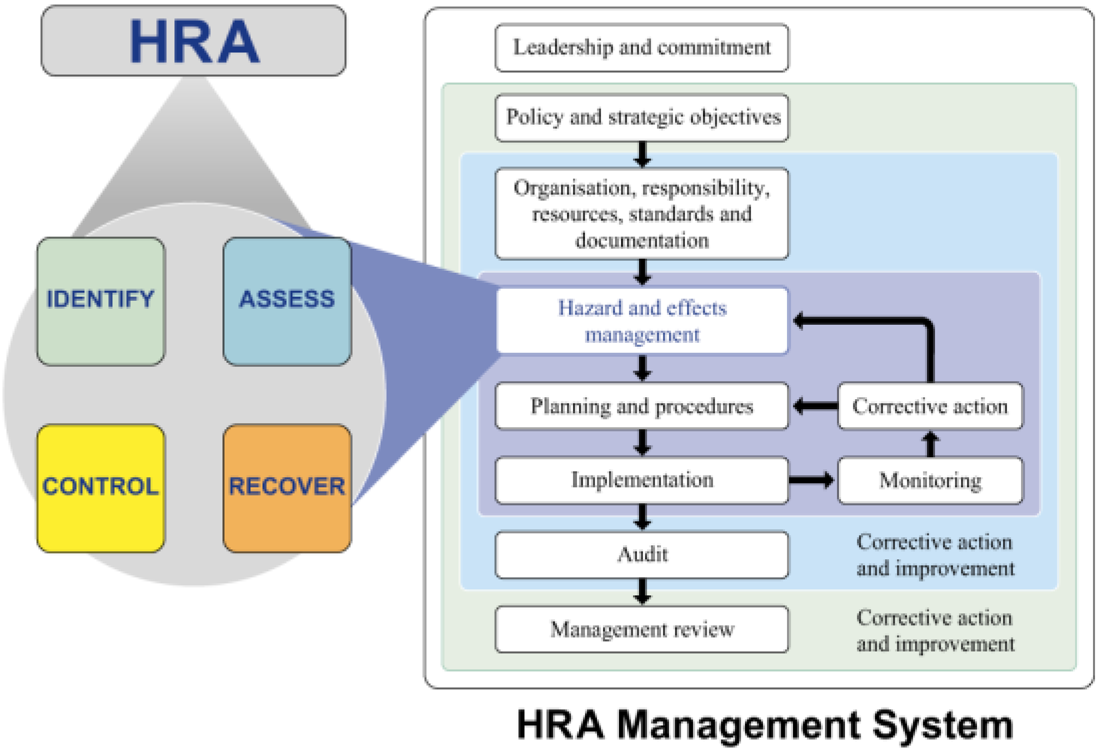


Figure 3.2: NOPSA risk management model for noise management

Leinster et al (1994) applied a risk management model to investigate managerial, organisational and psychological factors involved in managing noise exposure and preventing hearing loss in 48 UK organisations and found;

- that only 40% of the organisations carried out assessments to comply with legislation,
- that noise was taken for granted, not perceived as a serious barrier,
- there was a lack of leadership with no clear allocation of responsibilities and
- the perception by management that control measures were expensive.

Similar findings were also reported by Royster and Royster (2003) and Toivonen et al (2002).

According to Leinster, successful OHSMS and noise management requires leadership and commitment from senior managers (including policies), the ability of middle management (for example, facility line supervisors and engineers) to implement noise management practices, and specialist technical knowledge of noise and the legislation. Furthermore, the noise specialist should not only have technical knowledge, but also the interpersonal skills to influence others, such as senior and middle management (Melamed, Samuel Rabinowitz et al,1996).

Williams et al (2008) surveyed 113 South Australian businesses. Data was collected on the level of awareness of noise regulations and self-compliance; administrative, engineering and maintenance controls; exposure to ototoxic chemicals; prevalence of hazardous noise exposures. Williams et al (2008) found that noise in excess of 85bB(A) was observed in 73% workplaces; exposures exceeding national standards were in 45% sites; around 50% workplaces were aware of new noise regulations (2006); the presence of a noise control policy was predictive of the use of noise management practices; ototoxic substances observed in 19.5% sites; large and medium sized businesses showed encouraging noise management practices, but that small businesses less likely to have noise management practices. In conclusion Williams et al suggested;

> "On the face of it, it appears that there have been significant improvements in occupational noise control in Australia. However, even if significant improvements have been made, the results of this study indicate that there are still noise hazard risks in some sectors of Australian industry" (Williams et al, 2008).

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

3.4 Concepts of best practice in noise management

"Best practice" is a technique or methodology that, through experience and research, has proven to reliably lead to a desired result. A commitment to using the best practices in any field is a commitment to using all the knowledge and technology at one's disposal to ensure success. The term is used frequently in the fields of OHS, health care, government administration, the education system, project management, hardware and software product development, and elsewhere.

The concept of "Best Practice"' originated in the private sector as a tool to 'benchmark' performance against competitors and thereby stimulate improvement and has – more recently – entered popular parlance in the public sector. "Best practice" in noise management context involves a commitment to continual improvement in developing and actively enhancing current practices, equipment and procedures.

The concept of "good practice" according to the HSE in the UK is the generic term for those standards for controlling risk which have been judged and recognised by HSE as satisfying the law when applied to a particular relevant case in an appropriate manner. Recognised good practice include:
(i) HSC Approved Codes of Practice (ACoPs);

(ii) HSE Guidance; NB: ACoPs give advice on how to comply with the law; they represent good practice and have a special legal status.
(iii) Other written sources which may be recognised include:

- guidance produced by other government departments;
- Standards produced by Standards-making organisations (e.g. BS, ISO, IEC);
- guidance agreed by a body (e.g. trade federation, professional institution, sport's governing body) representing an industrial/occupational sector.

Good practice may change over time because, for example, of technological innovation which improves the degree of control (which may provide potential to increase the use of elimination and of engineering controls), cost changes (which may mean that the cost of controls decreases) or because of changes in management practices. Good practice may also change because of increased knowledge about the hazard and/or a change in the acceptability of the level of risk control achieved by the existing good practice.

In the definition of good practice, 'law' refers to that law applicable to the situation in question; such law may set absolute standards or its requirements may be qualified in some way, for example, by 'practicability' or 'reasonable practicability'. 'Good practice', as understood and used by HSE, can be distinguished from the term 'best practice' which usually means a standard of risk control above the legal minimum.

Thorne et al, (2006) undertook a review of literature for the Accident Compensation Corporation to assist in the development of immediate and long-term interventions for reducing the incidence of noise-induced hearing loss as well as directing potential future research. The review also identified the characteristics of "best practice" in noise management, questioned the efficacy of traditional approaches, reconceptualised the problem from hearing conservation to noise management and from noise induced hearing loss to sound injury. New and innovative preventative models were also described.

Timmins et al (2010) published "Occupational noise-induced hearing loss in Australia; overcoming barriers to effective noise control and hearing loss prevention". The report describes the outcomes of an investigation of the key factors ('barriers' and 'enablers') that influence the effective control of occupational noise and prevention of occupational NIHL.

Timmins et al (2010) reports that the preferred solution to excessive noise exposure is to completely eliminate the source of the loud noise. When this is not possible or practical, the legal requirement is to minimise exposure through a hierarchy of controls such as the following:

- substitute the noise source with quieter machinery or processes
- isolate the noise source from workers
- apply engineering solutions (e.g. fit mufflers, redesign the noise source, and install noise guards or enclosures)
- apply administrative solutions (e.g. schedule noisy work for when fewest workers are present,

- provide signs and quiet areas for breaks), and when none of the above are reasonably practicable
- provide personal hearing protectors (e.g. ear muffs and plugs).

This research found that increased awareness, prominence, self-efficacy, economic and regulatory incentives, and managerial commitment are the most promising enablers of the adoption of effective control. Based on these findings, several intervention strategies are proposed for overcoming barriers to effective noise control and ONIHL prevention. The major interventions are:
Provide education about;

- the dangers of exposure to loud noise,
- the risk of hearing loss,
- the effect of hearing loss on quality of life, and
- the available noise control and hearing loss prevention options.

The findings suggest that this may be achieved by visits from regulators, the influence of peers and role-models, and by other social marketing strategies. Raising the awareness of the potential benefits of effective noise control by developing easily accessible and useable noise control cost-benefit models and templates is also suggested. Business owners and managers could access these templates from government or industry websites.

The report suggests that government and industry education campaigns could be used to make employers and managers aware of the templates availability and purpose. Increase the likelihood and visibility of the enforcement of existing noise control regulations. Many participants in the current research project acknowledged a need for greater enforcement of noise control regulations by the work health and safety regulatory authorities. In addition, there was a belief that increasing the legal and economic consequences of non-compliance (i.e. raising the level of the sanctions as well as the likelihood of sanction) may increase the economic relevance of noise control and hearing loss prevention.

Noise control best practice elements identified by the Industrial Noise and Vibration Centre in the UK in 2009 included;

- Attitude
- Noise Control Audit based on detailed diagnosis and costing of the options and benefits using the best of current technology
- Implement Noise Control Programme based on the results of the audit
- Update Noise Assessment
- de-regulate areas; reduced PPE costs
- Buy Quiet purchasing policy

This approach can produce noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding.

INVC suggest that noise control is not a safety issue; noise control is an engineering problem that should be solved by engineering means, in particular through noise control at source, and that effective noise control must be based on an accurate diagnosis and not on assumptions. All the options must be considered, not just the conventional high cost palliatives of enclosures and silencers. These techniques should only be used where it can be proved that there is no engineering alternative (INVC, 2009).

Surveillance
Surveillance schemes for occupational hearing loss is identified as a key strategy in effective noise management programmes. Surveillance for occupational hearing loss is primarily about providing information to the employer to assist in their duty to manage risks to their employees. However, Ross et al. (2010) however, have suggested that current guidance for assessing audiograms for noise-induced hearing loss (NIHL) seems to be inadequate and Cheesman and Steinberg (2010) have subsequently written to say that 'further work is required to determine whether a suitable and effective method for conducting meaningful health surveillance for NIHL exists'. In addition, surveillance of workplace noise exposure is vital to prevention of NIHL because it can identify the most problematic industries and occupations, and because it can be used to evaluate the effectiveness of intervention activities.

Exposure limits
As Thorne et al (2007) identified, in comparison to international exposure limits, the New Zealand criterion, exchange rate and peak levels appear consistent with international best practice. However the potential for introducing into New Zealand legislation a strata of action levels similar to those recently introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards. For example a lower action level at 80dB(A) where training and the provision of information is required could complement the existing 85dB(A) criterion for hearing conservation. Likewise an upper action level at 85dB(A) where noise control measures become mandatory would similarly reinforce the existing standards.

The main changes incorporated in the UK Control of Noise at Work Regulations are reductions of the first/second action levels from 85/90 to 80/85dB(A). There are peak action levels of 135 dB(C) and 137 dB(C). There are also new exposure limit values of 87 dB(A) ($L_{EP,d}$) and 140 dB (peak) which must not be exceeded after taking into account wearing hearing protection. There is now a specific requirement to provide health surveillance where there is a risk to health. The guidance states that this is when there is frequent exposure at 85 dB(A).

Additionally limits on the number of permissible impacts or impulse noises, or correspondingly lower criterion levels for high impact environments, could be introduced. For specific situations of shift work and atypical work patterns in New Zealand, an alternate criterion based upon a 24 hour exposure period for applicable industries could also be investigated (Thorne et al, 2007).

3.5 Interventions to prevent NIHL

International approaches

International approaches in the prevention of exposure to noise and noise induced hearing loss have been driven by international agencies seeking to regulate and control occupational noise, community or environmental noise and consumer product noise e.g. WHO, ILO, ISO, EPA, EU agencies. In addition, national, state, provincial and local governments internationally, have developed statutes and guidelines relating to sound transmission and exposure to noise. The UK and Japan enacted national laws in 1960 and 1967 respectively. The US introduced the Noise Control Act in 1972, and in 1977 the Environmental Protection Agency (EPA) published the "Toward a National Strategy for Noise Control", which was developed;

> "..to continue the dialogue on the overall goals of the noise program, the role of government, the role of consumers, and the role of industry in noise control…", and

> "The **c**omplexity of the noise problem, **c**ombined with the large array of complementary control authorities, make possible a considerable number of alternative approaches to a national program".

The strategy recognises the essentiality of State and local programs, other Federal programs and informed consumer choice to advance the national noise control effort. The strategy sets out the general principles by which the national effort should be guided, the division of responsibilities, and the areas of emphasis. It also identified the major outstanding policy and implementation questions.

Several European countries emulated the U.S. national noise control law: Netherlands (1979), France (1985), Spain (1993), and Denmark (1994). In some cases unlegislated innovations have led to quieter products exceeding legal mandates (for example, hybrid vehicles or best available technology in washing machines). In any case, the legacy of the NCA has transformed irreversibly the way people think about noise and the intrinsic right to be protected from adverse sound levels.

In 1986 the European Union published the Council Directive on the protection of workers from the risks related to exposure to noise at work (86/188/EEC). *Official Journal of the European Communities* 1986. (No L 137/28–No L 137/34.). In 1986 a WHO Report by the Director General of Health on the Prevention of Deafness and Hearing Impairment provided the impetus for international action on noise induced hearing loss in occupational and environmental contexts. In 1997 the WHO published a Report of an Informal Consultation concerning Strategies for Prevention of Deafness and Hearing Impairment. The World Health Organizations Programme for the Prevention of Deafness and Hearing Impairment (PDH) is concerned with developing and promoting strategies for prevention of the major causes of hearing impairment and deafness which constitute public health problems. The strategies should be global in scope but should be especially applicable to developing countries, where most work of WHO is focused. The main function of WHO-PDH is to encourage and assist countries devise and implement National programmes for prevention of deafness and hearing impairment where none exists, or to strengthen an existing programme.

Clearly there is need for intensified efforts internationally to ameliorate the current situation. The costs to implement effective programs for the control of occupational noise may be, at least partially, offset by significant reductions in the continuing enormous social costs resulting from current programs. Hearing loss prevention programs instituted by some industrial enterprises, large and small, local and international, have been comprehensive and successful. Unfortunately, successful programs are the exception.

Overall, the achievements of hearing-loss prevention programs around the world have been sparse. In developed as well as developing countries, many programs have been remarkable for their failures (INCE, 2006).

It has been suggested (INCE, 2006) that payments of compensation to injured workers for occupational hearing loss are a tacit admission that a hearing loss prevention program is inadequate and has failed. The many reasons for these failures, but three are noteworthy.

First, there has been a general over-reliance on hearing protection devices for which the actual performance in the workplace is much poorer than claimed. Second, enforcement of existing regulations in many of the most-developed countries has been lax, irregular, or non-existent. Many developing countries have no applicable regulations to control noise in the workplace. Third, in many instances inadequate noise control engineering has been implemented within industry to reduce the noise produced by manufacturing machinery and equipment to levels that will not cause hearing loss after years of exposure. Public health officials, audiologists, physiologists, safety personnel, industrial hygienists, medical teams, social scientists, and others have worked on occupational noise exposures for decades. Engineers, on the other hand, who are trained to solve complex noise control problems involving machinery and equipment, have been unable to fully participate in the effort to control noise in industrial settings. Many noise control engineers are firm in their belief that if more effort were to be expended to develop and maintain quieter workplaces around the world, the result would be a remarkable improvement over the existing situation (INCE, 2006).

Employers have the primary responsibility to provide protection for the health and safety of their employees. This protection must be achieved by the design or purchase and installation of machines and devices producing noise levels that will not cause the sound exposure over the duration of a working shift to exceed a prescribed safe limit.

To be able to properly design a machine to reduce its noise emission to acceptable levels requires a clear description of the acoustical design criterion for the level of the sound that is acceptable for the intended installation and the duration of the exposure. International consensus is needed on appropriate limits on the noise emission from machines and devices accompanied by labels that describe or “declare” the noise emission level under standardized conditions. Guidelines for the measurement and assessment of exposure to noise in a working environment are available in an international standard (ISO, 1997)*. (Acoustics—Guidelines for the measurement and assessment of exposure to noise in a working environment.* International Standard ISO 9612:1997, International Organization for Standardization, Geneva, Switzerland).

INCE (2006) also make recommendations in relation to exposure to occupational noise.

- The most important element for a worldwide policy on occupational noise is the harmonization of quantities for the description of noise *immissions* and noise *emissions*, and their use in prescribing uniform limits that are accepted internationally. This result can be achieved by international agreements negotiated by the United Nations or one of its agencies.
- Engineering control of noise should be the *primary* consideration and the single, most important element in any international or national program for protection of hearing in occupational situations.
- Within a jurisdiction, the same upper limits on exposure to noise in the working environment as well as hearing conservation measures should be applied to all industries, all workers, and all employers. The jurisdiction should coincide with the geographical boundaries of a country.
- A statement of international or national noise policy should include a prefatory sentence such as: *The policy of the 'issuing authority' is to reduce the risk and magnitude of permanent hearing damage to a minimum for those individuals habitually exposed to high levels of noise in their working environments.*

Inclusion of the word 'minimum' in the declaration allows for the possibility of hearing damage to a very small fraction of the population of exposed workers, the individuals who are most susceptible to noise induced hearing loss. An upper limit on the amount of hearing damage incurred by these individuals is set by the policy on permitted noise exposure deemed by competent authorities to be acceptable for the most noise-sensitive members of the population of exposed workers (INCE, 2006).

Other related strategies

More recent international strategies of relevance to the noise management include the 2001 EU CALM network (environmental noise) initiative. The CALM network, launched in 2001 under the EU's Fifth Framework Programme (FP5) for research, set out to establish and coordinate a 'Community Noise Reduction Strategy Plan'. The first edition of this report, published in 2002 and entitled 'Research for a Quieter Europe', helped define the appropriate steps necessary to reduce noise emissions in the EU, especially in the areas of air traffic, road and rail transport, marine technologies and outdoor equipment.

The plan assembled the body of available research at the time and proposed areas where further research was still very much needed. Research in this field, according to the network, must take into consideration relevant standards, socio-economic factors, and strategies and visions for future measures aimed at reaching acceptable noise emission levels for EU citizens. CALM's vision for developing noise policy by

2020 is “to avoid harmful effects of noise exposure from all sources and to preserve quiet areas”.

In 2010 National Institute for Occupational Safety and Health (NIOSH) published “Prevention Through Design Plan for National Initiative”. NIOSH, building on a strong historical base, currently leads a nationwide initiative called Prevention through Design (PtD) (Schulte et al. 2008). PtD addresses occupational safety and health needs by eliminating hazards and minimizing risks to workers throughout the life cycle of work premises, tools, equipment, machinery, substances, and work processes, including their construction, manufacture, use, maintenance, and ultimate disposal or reuse. PtD utilizes the traditional hierarchy of controls by focusing on hazard elimination and substitution, followed by risk minimization through the application of engineering controls and warning systems applied during design, redesign, and retrofit activities.

The initiative’s goals are organized around four overarching areas: *Research; Education; Practice; and Policy. Small Business* was added as an additional focus for goal development to address the unique challenges of applying PtD methods to small business processes and environments. Each of these overarching areas, as well as the small business focus area, is supported by a strategic goal. The PtD Plan for the National Initiative includes five strategic goals, one for each of the four functional areas (*Research, Education, Practice, and Policy*) and one to address the unique business environment of *Small Business*. Each strategic goal is supported by one or more intermediate goals that organizations or individuals must undertake in support of the strategic goals (NIOSH, 2010).

To help gauge progress towards meeting the desired outcome within the specified timeframe, a performance measure is specified for each intermediate goal. Finally, activities are defined, including outputs and transfers to stakeholders. These activities include the creation of tools, controls, guidelines, training materials, recommendations, new knowledge, surveillance systems, documents, policies, and conferences. Milestones that set the timeframes for these activities are also provided when known (NIOSH, 2010).

Social marketing concepts

Social marketing can be defined as “the use of marketing principles and techniques to influence a target audience to voluntarily accept, reject, modify, or abandon a behavior for the benefit of individuals, groups, or society as a whole” (Kotler, Roberto, & Lee, 2002). Social marketing theory suggests that an exchange takes place between the consumer (i.e., the worker) and the marketer (i.e., the employer or a workplace safety organization) (Andreasen & Kotler, 2002). Within this exchange, the worker must be persuaded to give up something in order to gain something. Under the social marketing model, what is given up are the unsafe behaviours or habits that the worker has previously engaged in; what is gained by the worker is an enhanced level of safety and a greater likelihood that he/she will not be injured.

Other aspects that characterize a social marketing campaign are the use of marketing research to guide campaign development; as well, the social marketing approach may include the use of incentives, ways to facilitate the behaviour, or tools/products that make it easier for the person to engage in the behaviour (Fox & Kotler, 1980). A comprehensive social marketing campaign generally attempts to manipulate several of marketing‟s 4 Ps (product, place, price, promotion; see Figure 1). In the context of an occupational health and safety (OHS) campaign, promotion is generally the easiest of the 4 Ps to manipulate, because there is a full range of communication materials that can be developed to persuade or remind workers to adopt safer work practices. However, it is important to consider ways that the other Ps of price, product, and place can also be managed in the context of an OHS campaign. The „price‟ of adhering to a particular safety practice might be a slight reduction in the speed with which a job can be done. Alternatively the price may be looking "unmanly" by using a particular safety precaution. The price may even be financial, if the worker must buy expensive work boots, for example, rather than wearing runners. The social marketing task would be to demonstrate the value of safety, so that the „price‟ paid seems worth the safety that is being gained.

The "product‟ element of the social marketing mix can be manipulated as well. Product is a tangible object or intangible service that facilitates behaviour undertaking. The basic „product‟ of safety can be positioned as being inextricably linked with enjoyment of life (given that unsafe workplace behaviour can have drastic consequences on future health and wellness, and hence on enjoyment of life). In the context of work safety, actual tools that serve to facilitate safety, such as back braces, rubber gloves or goggles, may also serve as the "product‟. "Place‟ is another element of the social marketing mix that can be manipulated. It is the location where the product is made available and where behaviour can be carried out. The worker becomes more aware of the need for safety when safety messages are delivered at both conventional (work) and unconventional (non-work) locations. Having a variety of safety messages throughout work locations reinforces the idea that the workplace embraces a safety culture which encourages safe work practices and behaviours. If use of a particular work-safety product is being advocated, such as rubber gloves or goggles, then locating that product conveniently for worker use is a crucial element of "place‟.

Prochaska et al. (1992) demonstrated that, in order for a successful change of behaviour to occur, there are several stages that the individual must pass through. These include contemplation, preparation, action and maintenance. Ensuring that the appropriate information and support is available at the appropriate time to successfully change behaviour is a difficult task and has successfully been addressed by the concept of 'social marketing' (Andreasen, 1995). Social marketing is aimed at improving the personal welfare of the individual and their society by influencing voluntary behaviour through a marketing program centred on the targeted individual(s). Social marketing acts as a conceptual framework (Thackeray and Neiger, 2000) that can be used by health educators to better apply existing theories of health education where the focus of the education process is maintained through the use of constant feedback in a grounded approach (Jones, 1983; Strauss and Corbin, 1990). This technique can be used to constantly adjust any training that is being undertaken according to the needs of the group, the workplace and, to some extent, the needs of the individuals within the group.

Through its nature, social marketing involves what could be termed a holistic approach influencing not only the individual but also the peer group and social structures within which the individual operates (Andreasen, 1995; Rothschild, 1999). This means that a program must be undertaken not to simply raise awareness but to generate successful, ongoing behavioural change (Robinson, 2005).

Research examining social marketing campaigns on the topic of workplace safety is somewhat limited, even when the definition is extended to include more limited campaigns that focus primarily on workplace safety communication or education. Previous research includes a study on a multifaceted safety campaign to reduce workplace injury in Europe, an evaluation of a demonstration project in social marketing in northern Alberta, and the impact of marketing strategies on workers within a private company (Spangenberg et al., 2002; Guidotti, Ford, & Wheeler, 2000; Vecchio-Sadus & Griffiths, 2004). Some trade publications have discussed safety campaigns, such as a short review of the 2002 Workplace Safety and Insurance Board of Ontario social marketing campaign that appeared in *Marketing Magazine* (Turnbull, 2002). Two American studies examined the impact of safety education campaigns on Hispanic workers in the US, and teens in the State of Washington (Brunette, 2005; Linker et al., 2005). Although all of these articles discuss using educational materials or communication campaigns to improve workplace safety, less than half mention social marketing or refer to the full range of elements that would comprise a social marketing campaign. None of these previous studies have included a content analysis of social marketing campaigns relating to workplace safety.

Cowley, Else and LaMontagne (2004) examined the concepts of social marketing in relation to employee exposures to airborne isocyanates in motor vehicle body repairs in South Australia. These workplaces are typical of occupational health and safety issues facing small businesses generally. They conclude that interventions have largely focused on visits by regulators inspectors and traditional “arms-length” strategies. Neither appears to have had a significant influence due to the large number of businesses in relation to the number of inspectors and the predominantly verbal culture of the sector. They propose that social marketing may be used to improve OHS in motor vehicle body repair shop, concentrating specifically on changing the behaviour of the business operator who makes the decision whether or not to adopt OHS risk control measures (Cowley et al, 2004). They also suggest that of particular interest is the role of opinion leaders in the small business community in moving the small business operator through the stages of change (Cowley et al, 2004).

Lavack et al (2006) undertook a content analysis of English language safety communications material from Canada and the US from a social marketing perspective. Some distinct differences were found between the way Canadian and American entities approach OHS communications and social marketing. In Canada, these efforts were largely undertaken at the provincial level and were focused on using persuasive communications and social marketing tactics to encourage workplace safety. In contrast, in the US safety campaigns were largely the responsibility of federal government agencies, and mad more limited use of social marketing concepts. Efforts undertaken at the state level were focused primarily on regulatory and enforcement aspects of workplace safety. Only a few jurisdictions provided reports or studies about the effectiveness of their OHS efforts or campaigns. Of these, only one source provided evidence of increased awareness and more positive attitudes to workplace safety among the general population as a result of a provincial WorkSafe social marketing campaign (WorkSafe SK, 2006). However, even where social marketing methods are being employed, there is limited information available on the effectiveness of these campaigns in influencing the general population and workers in particular (Lavack et al, 2006).

New Zealand strategies

In New Zealand, policies and strategies relating to noise were primarily linked to the national legislation relating to working conditions generally (Factories Acts, 1946, Machinery Act 1950, Construction Act 1959), however, it was not until The Factory and Commercial Premises Act 1981, where noise was explicitly mentioned. The guide to “Planning the Workplace” (1991) specifically stated; “The occupier of any undertaking must take all possible steps to control at source noise arising from any processes or activities carried out, or to isolate or insulate them. It is easier and less costly to design premises specifically for a noisy operation than it is to modify and adapt an existing building to comply with legislation”.

In 1996 the Occupational Safety and Health Service of the Department of Labour published the Approved Code of Practice for the Management of Noise in the Workplace (1996) The purpose of the code was to provide practical guidance in meeting the requirements of the Health and Safety in Employment Act 1992 (“the Act”) and the Health and Safety in Employment Regulations 1995 (“the Regulations”). This process involved the identification and the management of noise hazards in the workplace. Regulation 11 of the Health and Safety in Employment Regulations 1995 required employers to take all practicable steps to ensure that no employee would be exposed to noise above the following levels:

(a) A noise exposure level LAeq, 8h, of 85 dB(A); and

(b) A peak noise level, Lpeak, of 140 dB,

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

Since the publication of the original *Approved Code of Practice for the Management of Noise in the Workplace* in 1996, there have been changes in the standards that underpinned the code. These standards were AS/NZS 1269-1998 *Occupational noise management*, Parts 0-4, AS/NZS 1270:2002 *Acoustics — Hearing protectors*.

The publication of these standards has included some significant changes to the “preferred work practices or arrangements” that a code of practice is intended to present. It was necessary to update the approved code to recognise these changes. The Code was subsequently revised in 2002.

The National Foundation for the Deaf (NFD) initiated a Noise Induced Hearing Loss Project in 2009. The long term goal of the strategy is to lower the incidence of NIHL in NZ. The objectives of the strategy are;

1. To increase awareness of NIHL in key groups both consumer and sector

2. To reduce exposure to noise, both intensity and duration

3. To increase hearing sector activity supporting the NIHL social marketing programme

4. To increase awareness of NIHL by key NGO, government and partner agencies

5. To increase prioritisation of NIHL by key NGO, government and partner agencies

The strategy has a social marketing perspective, linked to community engagement and includes a multi-level programme of action working across policy, setting, community and behaviour change. A range of partners from government agencies to private sector will be engaged to achieve sustainable change. The current phase of the NIHL programme is to define the strategic objectives of the programme. The next phase is to develop the social marketing strategy and implementation plan. The overview of the NIHL strategy is detailed in Figure 3.4.

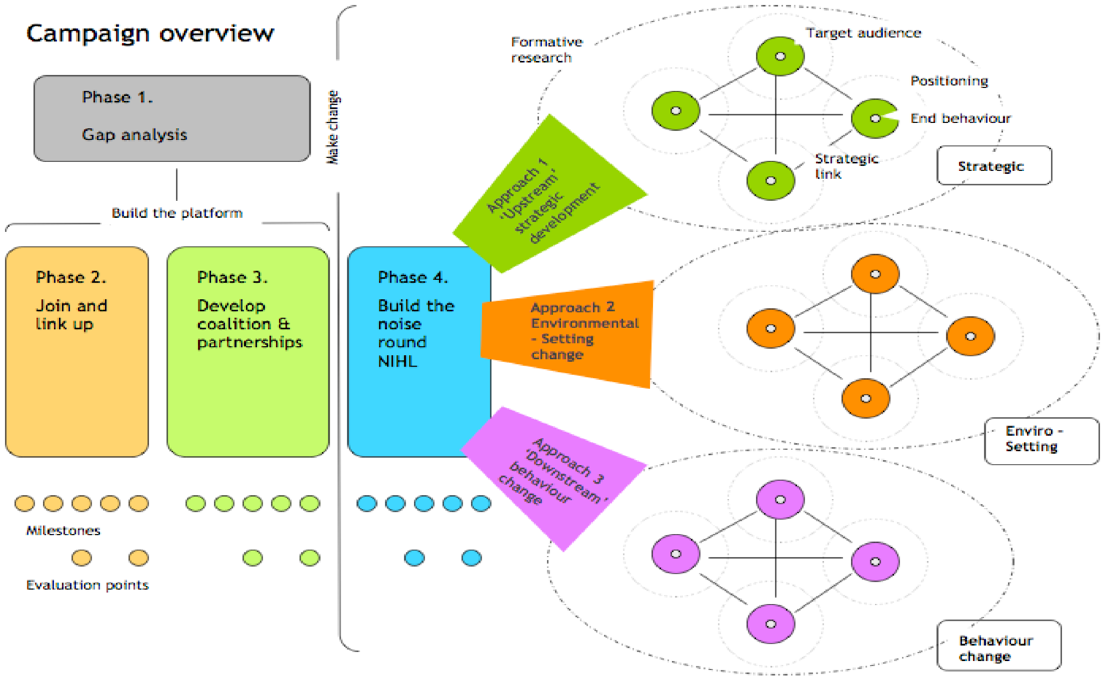


Figure 3.3: National Foundation for the Deaf NIHL Strategy overview.

The NFD strategy has many positive features. It is important that primary prevention principles (elimination/ control of noise at source) are emphasised promoted and implemented in any community/ workplace NIHL strategy. Social marketing and behavioural change strategies are useful, but need to be critically evaluated over an extended period of time.

Thorne (2010) reviewed programmes to raise public awareness of the effects of noise are critical strategies to counter the effects of noise and to develop a more sustainable approach to noise control. A number of non-government organisations (NGOs) and philanthropic organisations are focussing their efforts on schools and educational institutions in an attempt to influence child and youth behaviours around noise exposure as a long term health promotion strategy and to introduce behaviour change.

The NFD has also developed a programme to raise awareness of the impact of noise exposure, both in terms of the potential risk to hearing but also the effect of noise exposure on listening environments and communication, especially in schools. It has developed a “Safe Sound Indicator”, which will indicate safe to dangerous levels of noise in preschool classrooms using the coloured traffic lights. These are currently being trialled in classrooms as an aid to teachers to maintain safe and appropriate noise levels in classrooms (Thorne, 2010).

The Pindrop Foundation in the USA, developed the “Listen Up” programme, has been working with groups to introduce a programme of noise awareness based on the successful Dangerous Decibels programme (www.dangerousdecibels.org) developed by Professor Martin in Portland, Oregon, USA. This uses trained educators and is centred around a series of tasks and activities that teaches primary and intermediate school children about the effects of noise on hearing. Its effectiveness has been well evaluated (Thorne, 2010).

Thorne (2010) suggested that the approaches to tackle the problem of noise exposure cover both occupational and recreational environments. Furthermore by incorporating a significant public awareness approach it is intended that targeted occupational and recreational hearing loss prevention (hearing conservation) programmes will in the long term be more effective as they will operate in an environment of public understanding and acceptance of the risks to hearing of excessive noise exposure.

Thorne suggests that it is intended that these approaches will eventually be incorporated into a single national strategy for the prevention of noise induced hearing loss in New Zealand. Such a strategy and its effects will need to be monitored, evaluated and revised but such an approach is designed to reduce the extent and impact of hearing loss in the community in a sustainable way (Thorne, 2010).

Current initiatives

The Workplace Health and Safety Strategy for New Zealand to 2015 provides a framework for the workplace health and safety activities of government agencies, local government, unions, employer and industry organisations, other nongovernment organisations, and workplaces. It is aimed at significantly reducing New Zealand’s work toll, and will also raise awareness of workplace health and safety; help co-ordinate and prioritise the actions of a wide range of organisations and improve the infrastructure that supports workplace health and safety.

The Strategy is consistent with the Health and Safety in Employment Act 1992 (HSE Act), but has a wider scope. Whereas the HSE legislation places requirements on workplaces, the Strategy includes actions for all levels – national, industry and enterprise. It also seeks to encourage and achieve higher levels of workplace health and safety performance in New Zealand than we would have through compliance and enforcement alone. The Strategy identifies 8 national priorities, of which noise and the prevention of NIHL is not specifically identified. The Action Agenda

A review of the Workplace Health and Safety Strategy for New Zealand to 2015 proposed the development of a national Action Agenda to focus workplace health and safety activity over the next three years. This Action Agenda sets the framework of having priority sectors, action areas, sector based action plans and an occupational health action plan. It targets sectors with the highest rates of injury and disease in order to reduce New Zealand's work toll. The five priority sectors are construction, agriculture, manufacturing, forestry and fishing - each of the five sectors will have its own individual Sector Action Plan, developed in consultation with industry stakeholders. To date the Construction Sector Action Plan 2010 – 2013, has been published (Department of Labour, 2011).

3.6 Safety climate and attitudes to noise and exposure to noise.

A great deal of progress has been made in the management of noise at work, but technological and legislative safety solutions will only succeed if the social systems, attitudes and behaviours at work support them (Davies, Spencer, & Dooley, 1999; Grote & Kunzler, 2000; Williams & Purdy, 2005). Safety climate, or the "perceptions of policies, procedures and practices relating to safety in the workplace" (Neal & Griffin, 2007, p. 69,), is one of the factors related to effective hazard management, including management of noise. Effective management of noise at work is particularly important: "Workers are typically not motivated to do anything about noise because noise-induced hearing loss (NIHL) occurs gradually, is not visible and has an uncertain time course in individuals" (Purdy & Williams, 2002, p. 78,).

There is growing consensus that core aspects of safety climate include the role of managers and supervisors, co-worker support for safety, employee participation, work procedures and worker involvement (Davies, et al., 1999; Fernandez-Muniz, Montes-Peon, & Vazquez-Ordas, 2007; Flin, Mearns, O'Connor, & Bryden, 2000; Guldenmund, 2000; Håvold, 2005; Neal, Griffin, & Hart, 2000; Pousette, Larsson, & Torner, 2008; Seo, Torabi, Blair, & Ellis, 2004; Shannon & Norman, 2008; Vecchio-Sadus & Griffiths, 2004; Yule, 2003; Yule, O'Connor, & Flin, 2003).

Others (Hahn & Murphy, 2008; Neal & Griffin, 2007; Zohar, 2003) suggest that measures of safety climate should only include perceptions of management commitment, or the true priority given to safety rather than other beliefs, or factors such as attributions, motivation, optimism, self-esteem, risk-taking or safety behaviours which are not connected to perceptions of safety priority. Restricting safety climate to perceptions about safety priority aligns with the notion of safety climate as a group-level rather than individual-level construct (Hahn & Murphy, 2008).

A diverse range of measures of safety climate has been developed (Davies, et al., 1999; Department for Transport: London, 2004; The Keil Centre, 2002) and there is growing evidence that this concept is directly and indirectly related to safety compliance, safety participation and accident rates (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006; Hahn & Murphy, 2008; Neal & Griffin, 2006, 2007; Neal, et al., 2000; Silva, Lima, & Baptista, 2004; Williams & Purdy, 2005; Zohar, 2000). However, accident rates provide incomplete and lagging data about safety and are rarely able to provide information about risk exposure (Glendon & McKenna, 1995; Seo, et al., 2004; Yule, et al., 2003).

4.0 Methodology

4.1 Introduction

The purpose of the workplace studies was to;

1. To determine the nature and effectiveness of interventions currently used in industry to reduce noise exposure and the incidence of NIHL and identify the barriers to the implementation of noise management strategies and programmes.
2. To determine whether identified “high-risk” sectors and occupations are conforming with current industry recommendations (e.g. Codes of Practice) and standards to prevent NIHL.
3. To determine what aspects of workplace culture and environment affect decisions around NIHL, including cultural barriers to preventive actions and what motivates individuals to prevent hearing loss.

4.2. Study design

The study was designed as a multiple case study approach where the unit of analysis was the workplace. As the association between noise exposure and health outcome (NIHL) is well known and recorded, the focus of the study was primarily on what are the current noise exposures, what is currently being done to control exposures and what potentially could be done to reduce exposures. Unlike aetiological studies where typically large samples, randomization, blinding etc. are required, intervention effectiveness studies utilise case studies of different settings in which to test the programme theory for prevention effectiveness (Rogers et al, 2000; Kristensen, 2005).

A case study design was utilised to identify, describe and evaluate intervention/control strategies used by those “high risk”, “moderate risk” and “low risk” industries in relation to noise exposure and the incidence and/or severity of NIHL. “High risk” industry sectors had sound levels > LAeq.8hr 90dB; “medium risk”, ≥ LAeq.8hr 85-90dB; “low risk” < LAeq.8hr 85dB. The case studies included site visits, where existing noise control strategies/ interventions, barriers to implementation or adoption of existing controls/ interventions, and critical factors that need to be considered when designing and implementing effective noise control interventions were recorded. In addition, information was sought on employer and employee attitudes, perceptions, beliefs and behaviour in relation to noise exposure and noise induced hearing loss and how the employer managed safety generally.

4.3. Industry, organisation and employee selection

The research focussed on ACC and Department of Labour target sectors/industries. The list of high, moderate and low-risk sectors was developed by the findings of Research Project One as this information became available. Other selection criteria included identifying industry sectors where noise exposure has been traditionally regarded as low e.g. education, hospitality, health services. This was undertaken with reference to;

1. The data provided by Thorne et al (2008) that identified specific industry sectors based on their ACC claims experience for noise induced hearing loss.
2. ACC and Department of Labour target industry sectors for excessive noise exposure
3. Recommendations from the Noise Induced Hearing Loss Stakeholder Group (initiated by Project 1 – Epidemiology of NIHL project)

These industry sectors identified include the following (Table 4.1).

Table 4.1: Industry sectors with relative risk of NIHL

Risk of NIHL	Industry sector	ANZSIC
High risk	Agriculture,	A – 0149 Grain, Crop, 0161 Dairy
	Manufacturing,	C – 1211 Beverages, 1340, Knitted products, 2221 Steel fabrication
	Construction,	E – 3019 Residential building, 3101 Road construction, 3212 Demolition
Moderate risk	Hospitality	H – 4511 Cafes, restaurants and bars
Low risk	Education	P – 8010 Preschool, 8021 Primary

Like most other modern economies, New Zealand is predominantly a nation of small businesses – 68% of all businesses have no employees (i.e. they are run by a single owner-manager or by one or more working proprietors), 89% employ five or fewer people, and 97% employ 20 or fewer people. The average number of employees per enterprise is five. When non-employing firms are removed, the average number of employees per enterprise is 14. Enterprises with fewer than 20 employees constitute over 90% of enterprises in most industries.

The profiles of industry sectors selected for this study identified that 97% of enterprises in agriculture have less than 20 employees, 92% of enterprises in manufacturing, 98% enterprises in construction, 92% of hospitality enterprises and 75% of education enterprises have less than 20 employees (NZ Statistics, 2010). The enterprise recruitment strategy took these proportions into account.

An industry database for these sector groups was developed (a) with advice from the NIHL Stakeholder Group, (b) from the ACC dataset for enterprises within the selected regions, and then (c) reconciled and validated by reference to the regional telephone business directory. Companies were randomly selected from the dataset and invited to take part in the study. The Auckland, Wellington and Dunedin areas were selected for convenience and offered the potential for access to a wide range of industry sectors. Candidate companies were sent an introductory letter outlining the aims and methods of the study. This was followed by a telephone call to identify if employers were willing to participate and if so the number of at risk employees. A list of employees was provided by the company, and up to 10 were selected at random for inclusion in the research. Participation was voluntary and no incentives were provided, except with the provision of a report of findings, and specific recommendations for the company. Recruitment efforts gave priority to companies that reported between 10 and 100 FTE employees. Candidate companies were potentially eligible if they meet the size and geographic criteria.

The employee sample (personal dosimetry) for each company was as representative as possible of employees involved in noisy tasks or working in noisy areas, as established during preliminary discussions with the owner/ manager of the enterprise. The employee sample was obtained by firstly, enrolling volunteers or company designated employees in targeted noisy jobs and then approaching employees individually, until the enrolment goal was achieved. The sampling frame was then drawn up, with at least an initial target of 30 employees in each NIHL risk category. Employees carrying out the target tasks were then invited to participate and given an information sheet and informed consent form to complete.

Company visits and data collection took place over a one or two day period. The first day usually involved initial contact with the company, selection of employees for inclusion in the study, distribution of the noise at work questionnaires, together with identification of noise sources, paths and controls and noise level measurements of equipment. On the second day personal noise exposure monitoring was undertaken. Workplace assessments were also undertaken to determine the nature and extent of noise exposure data currently available within industry sectors and the efficacy of the preventive controls.

4.4. Data collection

Data collection for the workplace surveys are divided into 3 component parts.

Part 1 described the nature and effectiveness of interventions currently used in industry to reduce noise exposure and identify barriers to the implementation of noise management strategies.

Part 2 determined whether identified “high-risk” sectors and occupations were complying with current recommendations (e.g. Codes of Practice) and legislation to prevent NIHL?

Part 3 determined what aspects of workplace culture affect decisions around noise exposure and NIHL.

The three parts of the workplace survey strategy, with their specific data collection instruments and methodologies, were incorporated into one integrated survey tool. This aimed at reducing the impact of research team members engaging the organisations selected on more than one occasion, for differing survey objectives; eliminate duplication of data collected and provided a single point of contact and communication for the industry sector and individual organisation’s management and employees. Table 4.2. summarises the data collection methodologies utilised.

Table 4.2: Data collection methodologies used in workplace surveys.

Data Collection	***Part 1***	***Part 2***	***Part 3***
Workplace Observation	X	X	
Noise exposure assessment	X	X	
Semi-structured interview	X	X	X
Self-administered questionnaire			X
Archival data	X	X	

A combination of both quantitative and qualitative techniques were used in the collection of primary and secondary data. The techniques included; workplace observations, noise exposure assessments, semi-structured interviews, self-administered questionnaires, and reference to archival data. Three workplace surveys (Survey 1, 2 and 3) with their specific data collection instruments and methodologies, were incorporated into one integrated survey tool (Appendix 2 - Noise at Work Survey).

4.4.1. Survey 1 - Noise at Work Survey (Evaluation of existing noise source, exposures and controls)

This section of the survey provided demographic details of the selected organisations, including:

- the physical characteristics and details of work areas assessed,
- identification of existing noise sources,
- identification of existing noise control strategies,
- assessment of the options/ strategies for reducing noise exposure further.

Noise exposure data including area noise levels and personal noise dosimetry.
The data collection proforma is presented in Appendix 2.
Information collected about the organisations included details of work and work areas, existing noise sources and control strategies, and options for reducing noise. Data on exposure to noise were collected including area sound levels and personal sound exposures (noise dosimetry). Observational, interview and archival data were also collected on the extent to which organisations were complying with recommendations (e.g. Codes of Practice) to prevent NIHL.

Measures

Noise sources and controls

Data were collected by observation and semi-structured interviews with management and, where applicable, safety representatives during site visits. Noise sources and controls were identified in terms of the sources of noise (mechanical, aerodynamic, turbulent flow, other); noise paths (airborne, structure-borne, duct-borne, other) and noise receivers (number affected, location, HPD worn, other comments).

Exposure to noise

The noise surveys used Rion type NA14 precision sound level meters and Cirrus Research doseBadges. A "walk through" survey identified the most noisy areas and activities and these areas were sampled to reflect a "worse case" scenario. Sound levels were measured in accordance with standard methods detailed in the Approved Code of Practice for the Management of Noise (2002) and AS/NZS 1269, 1998: Part 1 *Measurement and assessment of noise immission and exposure*. All sound level meters complied with the requirements of AS 1259.1 (IEC 60651) and/or AS 1259.2 (IEC 60804). Sound exposure meters complied with the requirements of IEC 601252. Reference sound sources (calibrators) complied with Class 2 specifications of IEC 60942. Where each workplace provided a range of sound values, the median values for A-frequency weighted time-average level ($L_{Aeq)}$, peak level (L_{Cpeak}) and percent of maximum allowable daily exposure to noise (% dose) were included for analysis to account for outliers.

Personal noise dosimetry devices (Cirrus CR:100B Noise Badge) were used to ascertain noise levels within the work place. The intention was to obtain these measurements for each task carried out by each participant. In cases where it was not possible for the noise dosimeter to be worn by the participant, the noise dosimeter was worn by a substitute employee who worked on the same task in the same work area. It was not possible to observe and supervise the employees wearing the noise dosimeters as there were often up to eight such employees at any one time. Noise versus time output plots were obtained from each episode of measurement, so it was possible to see if a dosimeter was tampered with, such as being left in a quiet room, or showed evidence of noise levels not consistent with the noise environment. It was not always possible to obtain noise measurements for every reported task because of limitations, primarily inability to access to work areas (e.g. in petrochemical plant where instrumentation must be intrinsically safe). The dosimeter was attached to the participant's shoulder by the researcher, and participants were instructed to carry out their usual tasks. Dosimeters were worn for at least 2 hours for each task. Times ranged from 2 hours 38 minutes to 4 hours and 27 minutes; the average time was 3 hours and 38 minutes.

4.4.2. Survey 2 - Noise at Work Survey (Noise control conformance assessment)

This section of the survey essentially audited the employers and employees responsibilities under the Health and Safety in Employment Act 1992 with respect to noise, utilising the Approved Code of Practice for the Management of Noise in the Workplace. Figure 1 outlines the relevant requirements and sections of the Act that were assessed. Data was collected through semi structured interviews, observational data and investigation of archival data and information. The data collection proforma is presented in Appendix 3.

A 10-point checklist (Table 4.3) was developed for this study based on the duties of employers set out in the New Zealand *Health and Safety in Employment Act, 1992*, and the *Approved Code of Practice for the Management of Noise in the Workplace* (Department of Labour, 2002). Data were collected through semi structured interviews, observational data and investigation of archival data and information. The researchers coded 1 for each item where there was evidence that the requirement had been met, otherwise 0. Scores were summed giving each organisation a score from 0-10.

Table 4.3: Conformance elements of the Approved Code of Practice for the Management of Noise in the Workplace.

Element	Requirements
1	**Employers must provide a safe place of work (HSE Act, S.6)** Take all practical steps so that no employee is exposed to noise in excess of the exposure limits.
2	**Employers must identify hazards (HSE Act s7(1)(a))** Employers to carry out preliminary noise surveys to identify possible noise hazards. (This does not need to be done by a “competent” person).
3	**Employers must assess identified hazards to determine whether they are significant (HSE Act s7(1)(c))** Employers to arrange for detailed noise surveys to be carried out to assess noise hazards to determine if these are significant.(Must be done by a “competent” person).
4	**Employers must control significant hazards by elimination, isolation, or minimising the likelihood of the hazard causing harm (HSE Act s8-10).** Employers must investigate, and if practicable, control noise at source.
5	Employers must isolate noise sources away from employees where practicable.
6	Employers must provide hearing protectors when noise hazards are not able to be eliminated or isolated, and while work is being carried out to control noise at source.
7	**Employers must monitor the health of employees who have been exposed to a significant hazard (HSE Act s10(2)(e)).** Employers must arrange for hearing tests (audiometry) to be carried out on all employees who work in an area with hazardous noise. This must be done by a “competent” person when an employee starts work, and at intervals of no longer than 12 months thereafter.
8	DoL must be notified if an employee has a hearing loss that meets the accepted criteria.
9	**Employers must provide information, training and supervision to staff in relation to hazards in the workplace (HSE Act s12-14).** Employers must provide information to employees on identified hazards.
10	Employers must provide training and/or supervision to employees in the safe use of plant or use of hearing protectors.

4.4.3. Survey 3 - Noise at Work Survey- (Evaluation of workplace safety climate)

The third section of the survey sought information on employer and employee attitudes, perceptions, beliefs and behaviour in relation to noise exposure and noise induced hearing loss and how the employer managed safety generally. The data collection questionnaire is presented in Appendix 4.

As there is only a weak link between safe behaviour and accident rates (Cooper & Phillips, 2004), one of the aims of the present study was to examine the relationship between safety climate, workplace noise levels and management actions taken to manage noise hazards. On this basis a series of six hypotheses were developed.

> Hypothesis 1a: Safety climate will be negatively correlated with workplace noise levels.

> Hypothesis 1b: Safety climate will be positively correlated with compliance with requirements to manage noise hazards.

Safety climate, as a set of perceived organisational priorities, influences employee behaviour by indicating the likely outcomes for different behaviours such as prioritising productivity over safety, or vice versa (Zohar, 2008). While safety climate is a group-level rather than individual-level construct, individuals' perceptions of the safety climate in their workplace are likely to be related to their specific safety behaviour, such as the use of hearing protection devices (HPD) (Arezes & Miguel, 2008).

> Hypothesis 2: Safety climate will be positively correlated with self-reported HPD use.

Personal factors such as motivation, attitudes to noise and subjective perceptions of risk also influence use of hearing protection (Arezes & Miguel, 2008; Feyer & Williamson, 1998; Mearns & Flin, 1995; Melamed, Rabinowitz, Feiner, Weisberg, & Ribak, 1996; Williams & Purdy, 2005). Fatalism, or the belief that accidents and illness are unavoidable, is a barrier to HPD use as those with fatalistic attitudes are likely to see barriers to hearing protection as higher and their personal ability to prevent hearing loss as lower (Arezes & Miguel, 2008; Purdy & Williams, 2002; Williams & Purdy, 2005). In contrast, self-efficacy, or a person's belief in the ability to successfully perform a given task (Bandura, 1977), is an important positive predictor of HPD use (Arezes & Miguel, 2008). Williams and Purdy (2005) found that safety climate, conceptualised as workplace safety practices and priorities, was related to the perceived benefits of and barriers to reducing exposure to noise, self-efficacy, attitudes to noise and exposure to noise, and perceived personal susceptibility to noise-induced hearing loss. Based on these findings, the following hypotheses are proposed:

> Hypothesis 3a: Safety climate will be positively correlated with perceived benefits of reducing exposure to noise, self-efficacy for reducing exposure to noise, and perceived personal susceptibility to noise-induced hearing loss.

Hypothesis 3b: Safety climate will be negatively correlated with perceived barriers to reducing exposure to noise and acceptance of noise.

Hypothesis 4a: Self-reported HPD use will be positively correlated with perceived benefits of reducing exposure to noise, self-efficacy for reducing exposure to noise and perceived personal susceptibility to noise-induced hearing loss

Hypothesis 4b: Self-reported HPD use will be negatively correlated with perceived barriers to reducing exposure to noise and acceptance of noise.

Corporate and workplace climate can strongly affect individual performance (Kotter & Heskett, 1992), and HPD use among employees is unlikely without management support (Arezes & Miguel, 2008). Accordingly, safety behaviours like HPD use are likely to be influenced by management decisions and actions as well as by individual factors such as motivation and attitudes (Feyer & Williamson, 1998).

Hypothesis 5: Safety climate will explain more variance in HPD use than the psychosocial variables of perceived benefits of and barriers to reducing exposure to noise; self-efficacy, acceptance of noise and perceived personal susceptibility.

Hypothesis 6: The effects of safety climate on HPD use will be mediated by the psychosocial variables of perceived benefits of and barriers to reducing exposure to noise, self-efficacy, acceptance of noise, and perceived personal susceptibility.

A combination of qualitative and quantitative techniques was used to collect data from 33 New Zealand workplaces. Of these, 20 provided questionnaire data on safety climate and attitudes to noise at work, and these are the focus of the present paper. Participating organisations were selected to include those with low, medium and high risk of noise-induced hearing loss (NIHL) (Thorne, et al., 2008). High risk industries included manufacturing (n=12) and construction (n=1); those with moderate risk included cafés (n = 3) and low risk firms were represented by early childhood education centres (n = 4) (Laird, et al., 2010). A self-report questionnaire covering safety climate and attitudes to noise at work was administered to employees and managers. Questionnaire responses were anonymous and participation was voluntary. The numbers of participants from each organisation are given in Table 1. Numbers of employees within each organisation are not known so response rates cannot be calculated.

One hundred and sixty-three respondents provided usable data. Ages ranged from 16 to 68 (mean 40, s.d. 13). There were no significant age differences between sectors ($F_{3, 93}$=.45, ns). Eighty-two (50.3%) were male, 52 (31.9%) were female; 29 (17.8%) did not provide this information. All respondents in the education sector were female and all in the construction sector were male; eighty-three percent of those in the manufacturing sector were male and 62% of those in hospitality were female. Thirty-four (21%) described their ethnic group as NZ European, Pakeha or Kiwi; 18 (11%) described themselves as European, 3 (2%) as Maori, 15 (9%) as Polynesian, Samoan or Tongan, 7 (4%) as being of other ethnicities and 86 (53%) did not provide this information.

With regard to exposure to noise, 62 (38%) reported that they had previously held noisy jobs; of these 24 reported that they had used HPD, 18 that they had 'sometimes' used it and 25 that they had not used it. Twenty-five (15%) reported that they had noisy hobbies, primarily music, motor vehicle, sport or shooting related. Nine of those with noisy hobbies said that they used HPD, 14 that they 'sometimes' used it and one did not use it.

Perceptions of noise in the workplace

The 20-item Noise at Work questionnaire was used to provide a measure of workers' perceptions of noise at work (Purdy & Williams, 2002). Each item was rated from 1 = Strongly disagree to 5 = Strongly agree. The measure comprises five subscales: susceptibility (e.g. 'my hearing will *not* be damaged by noise at work; α = .80), reverse coded so that higher scores indicated more perceived susceptibility to NIHL; acceptance of noise at work (e.g. 'I work better if it is noisy'; α = .76); benefits (e.g. 'work would be less stressful if it was quieter', coded so that higher scores meant more perceived benefits of managing noise at work (α = .65); barriers to managing noise at work (e.g. I do *not* have time to do anything about the noise at work; α = .67), coded so that higher scores meant more perceived barriers; and self-efficacy (e.g. I cannot reduce noise at work; α = .61), coded so that higher scores meant more self-efficacy for managing noise.

Perceptions of safety climate

A 17 item measure of safety climate was used (Williamson, Feyer, Cairns, & Biancotti, 1997). This measure is short, usable in a range of work settings and appropriate for a study into noise. Twelve items assessed attitudes, perceptions and awareness related to safety. Two items related to the sentence stem: "It would help me to work more safely if" completed by 'my supervisor praised me for safe behaviour' and 'safety procedures were more realistic'. Three items related to the sentence stem "When I have worked unsafely it has been because" completed by 'I didn't know what I was doing at the time', 'I needed to complete the task quickly' and 'the right equipment wasn't provided or wasn't working'. These five items were analysed separately. Rating scales for all items were 1= strongly disagree – 5 = strongly agree for all items.

The 12 items related to safety climate were intended to be one-dimensional but Williams and Purdy (2005) found a two-factor structure, one factor reflecting fatalistic attitudes and the other reflecting perceived safety practices in the workplace (which they labelled safety climate). Accordingly the factor structure was examined for the 12 items. Principal component analysis with direct oblimin rotation identified a three factor structure. Factor 1, accounting for 25.1% of total variance, comprised 5 items reflecting the priority given to safety in the workplace (e.g. 'Safety works until we are busy'). This scale was called Safety Climate: Priority (α = .74) and coded so that high scores represented a higher perceived priority for safety. The second factor, which comprised 4 items and accounted for 17.5% of the variance, was called Safety

Climate: Personal Responsibility (e.g. 'people who don't follow the rules are responsible for the consequences'; α = .68). High scores indicated a stronger perception that individuals were responsible for their own safety. A third factor comprised 3 items about perceptions of a safe workplace (e.g. 'I normally don't encounter dangerous situations') but did not have acceptable reliability and was not included in further analysis.

Safety climate is a group-level construct as it relates to shared perceptions regarding safety (Neal & Griffin, 2006; Shannon & Norman, 2008; Zohar, 2000, 2003, 2008). For comparisons with workplace noise data, individual perceptions of safety climate and personal responsibility were aggregated for each workplace. Due to sample size limitations, individual-level measures were used to assess the relationship between perceived safety climate, measures of HPD use and safety attitudes.

Additional variables

Self-reported hearing protection device (HPD) use was assessed with a single item: "When exposed to noise at work do you wear earmuffs or earplugs?" Self-assessed workplace noise was assessed with a single item: "At work do you have to shout to be heard by someone who is working beside you (arm's length away)?" Both items were scaled from 0 = Never to 4 = All the time.

Demographic information included year of birth, gender, ethnic group. Participants were also asked whether or not they had held previous jobs that were noisy and if so, what they were and whether or not hearing protection was worn; and whether or not they had noisy hobbies or sports, and whether or not hearing protection was worn.

4.5. Ethical issues

Ethical approval for the research including the workplace surveys and personal dosimetry was obtained from the Massey University Human Ethics Committee (MUHECN 08/077).

5.0 Results

Occupational noise sources, exposures and controls

Thirty three (33) workplaces (organisations) and 71 work areas were surveyed in this study. The survey confirmed that the selected organisations within the industry sector were appropriately identified as “high”, “medium” and “low risk” of exposure to noise and NIHL (“high risk” industry sectors had sound levels ≥ $L_{Aeq.8hr}$ 85dB; “medium risk”, ≥ $L_{Aeq.8hr}$ 75-85dB; “low risk” ≥ $L_{Aeq.8hr}$ 75-70dB). Three (3) organisations had employee counts of over 20 employees and were regarded as medium sized enterprises. The remainder (n=30) had employee counts of less than 20 employees and were regarded as small businesses.

5.1 Noise sources and paths

Table 5.1. summarizes the noise sources and paths. For the high risk industry sectors, the sources were primarily due to impact noise; rotational noise due to machinery, gears, conveyers and electric motors; engine noise; high frequency pneumatic noise due to hydraulic equipment and operations; pipe noise due to turbulent flow within pressurized steam lines; compressor noise and alarm noise due to operational alarm activation. For the medium and low risk sectors, noise sources tended to be related to the task, activity and equipment being used and the interaction of other, usually external sources of noise not directly related to the workplace such as traffic noise.

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

Table 5.1: Summary of noise sources and paths in industry sector case studies.

Industry sector	Noise sources	Noise paths
Agriculture (n=4) (Dairy)	Noise exposures identified on farms included tractors, motorbikes, air compressors, chainsaws, radios and other farm machinery. Sources included engines and gears, pneumatic and hydraulic noise, compressor noise and radio noise.	The noise paths were a combination of structural, reflective and airborne paths.
Manufacturing		
Bottling (n=3)	The noise sources in the packing area consisted of primarily impact noise due to bottle and can contact; rotational noise due to machinery, gears, conveyers and electric motors; high frequency pneumatic noise due to hydraulic equipment and operations; pipe noise due to turbulent flow within pressurized steam lines; alarm noise due to operational alarm activation. In the production area noise sources were primarily from separator/ centrifuge operations; filtration systems; boiler and compressor room noise.	The noise paths in the packaging area were primarily open air paths with a large reverberant space in the packing hall. Structure borne.
Engineering (n=3)	The noise sources in the workshop consisted of primarily impact noise due to metal hitting concrete and metal, rotational noise due to machinery and electric motors; high frequency pneumatic noise due to hydraulic equipment and operations, and noise due to welding and drilling and grinding operations. There was also fan noise and significant radio noise present.	The noise paths in the workshop were primarily open air paths with a large reverberant space in the workshop. The workshop area was a large box shape, the ceiling was metal and the floors were concrete. The walls were a combination of concrete and metal. There was no panelling of any type on the walls or ceiling. The noise exposure was due to a combination of structural, reflective and airborne paths.
Textile (n=3)	The sources of noise in the production area were the drive motors and transmission of the frames and some aerodynamic noise from spinning yarn. Radio noise was also significant as it is on for most of the day. Other significant noise sources include mechanical and vibrational noise from	The noise paths were a combination of structural, reflective and airborne paths.

	the operation of the straight knife and rotary blades. There was occasional impact noise from moving equipment about.	
Sawmills (n=8)	Noise sources arose from such activities as sawing, planing, shaping, filing, and tapering of wood for making various products. Circular saw blades are one of the main sources of noise in wood processing.	The noise paths were a combination of structural, reflective and airborne paths.
Construction (n=3)	Noise sources on the residential construction worksites were from many different sources including rotational and impact noise from hand held equipment; saws and drills; pneumatic guns and hammering. The road construction site had noise sources generated by the engine, transmission, and pneumatic operations involved with earthmoving.	The noise paths were a combination of structural, reflective and airborne paths.
Education Preschools (n=5)	Two principal sources of noise occurred in these centres (1) noise generated from activities in the centre, including that generated by children and activities they are engaged in, such as music; and (2) intrusion from outside activities such as traffic and transportation noise sources.	The noise paths were primarily a airborne paths, with a minor combination of structural, and reflective paths.
Cafes & restaurants (n=4)	The noise sources in the cafés consisted of impact noise due to the banging of cutlery and crockery. There was mechanical/equipment noise from the operation of appliances such as food processors and the coffee machine and the till. There was also significant fan and extractor noise. Other important sources of noise included traffic, especially from buses stopping and taking off outside the café and noise from patrons. There was also radio noise.	The noise paths were a combination of structural, reflective and airborne paths.

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

Table 5.2. summarises details of the workplaces' median $L_{Aeq.8hr\ and}$ L_{Cpeak} levels, dose estimates and percentage of work areas equal to (=) or greater (>) than 85 dB. A total of 33 workplaces and 71 work areas were surveyed. L_{Aeq8hr} values ranged from below 60dB to 95dB for all employees across all sectors. Mean and (median) L_{Aeq8hr} levels ranged from 69dB (70dB) to 91.8dB (94dB). L_{Cpeak} ranged from 100dB to 138dB. Mean and (median) L_{Cpeak} levels ranged from 116dB (70dB) to 125dB (130dB). These two measures of noise exposure were only moderately correlated (r=0.57, p<000). Due to the variety of industry sectors and job functions of personnel participating in the survey, noise levels were determined for those production, operations or other employees who were exposed to noise generated by the business or process during their normal work shift. Most (61%) recording times were in excess of 6 hrs or longer and the L_{Aeq8hr} was calculated from these data. Shorter recording times were often used as it was impractical to access all employees at the start of their shift.

The distribution of $L_{Aeq.8hr\ and}$ L_{Cpeak} levels for employees across all sectors are shown in Figures 5.1 and 5.2. A large proportion (>48%) of L_{Aeq} levels recorded were in excess of 85dB.

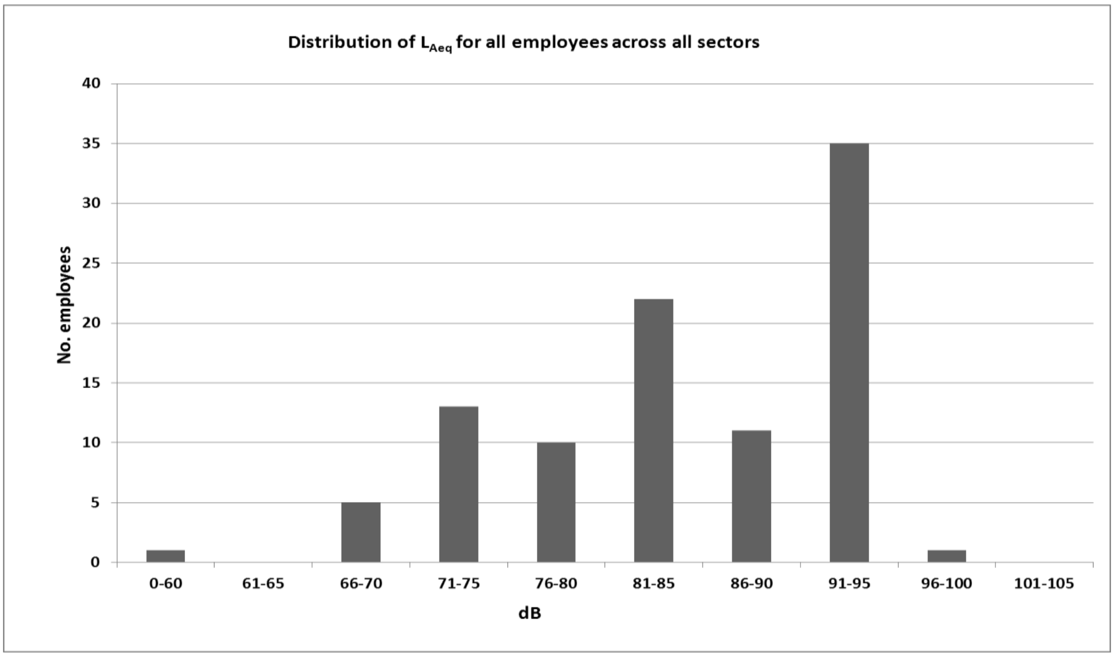


Figure 5.1: Distribution of LAeq8hr for employees across all sectors

Table 5.2: Summary of sound levels and dose estimates of workplace surveys by industry sector.

	Agriculture	Manufacturing				Construction	Hospitality	Education
	Dairy	Bottling	Engineering	Textile	Sawmills		Cafes	Preschool
No. workplaces	4	3	3	3	8	3	4	5
No. work areas	9	10	10	6	10	6	10	10
Median $L_{Aeq.8hr}$	85 dB	83dB	92 dB	80 dB	94 dB	90 dB	74 dB	70 dB[1]
Median L_{Cpeak}	115 dB	105 dB	125 dB	100 dB	130 dB	120 dB	105 dB	110 dB
Dose range (%)	70 – 125%	10 – 147%	10 – 588%	10 – 50%	60 – 600%	30 – 400%	8 – 26%	4 – 98%[1]
Median dose (%)	89%	72.5%	227%	27%	400%	200%	13%	23%[1]
% work areas => 85 dB $L_{Aeq.8hr}$	55	30	80	0	90	66	0	0

[1.] Range excludes recorded dose values for two subjects of 194% and 316% (outliers).

L_{Cpeak} levels for employees across all sectors is shown in Figure 5.2. A large proportion (>62%) of L_{Cpeak} levels recorded were in excess of 110dB.

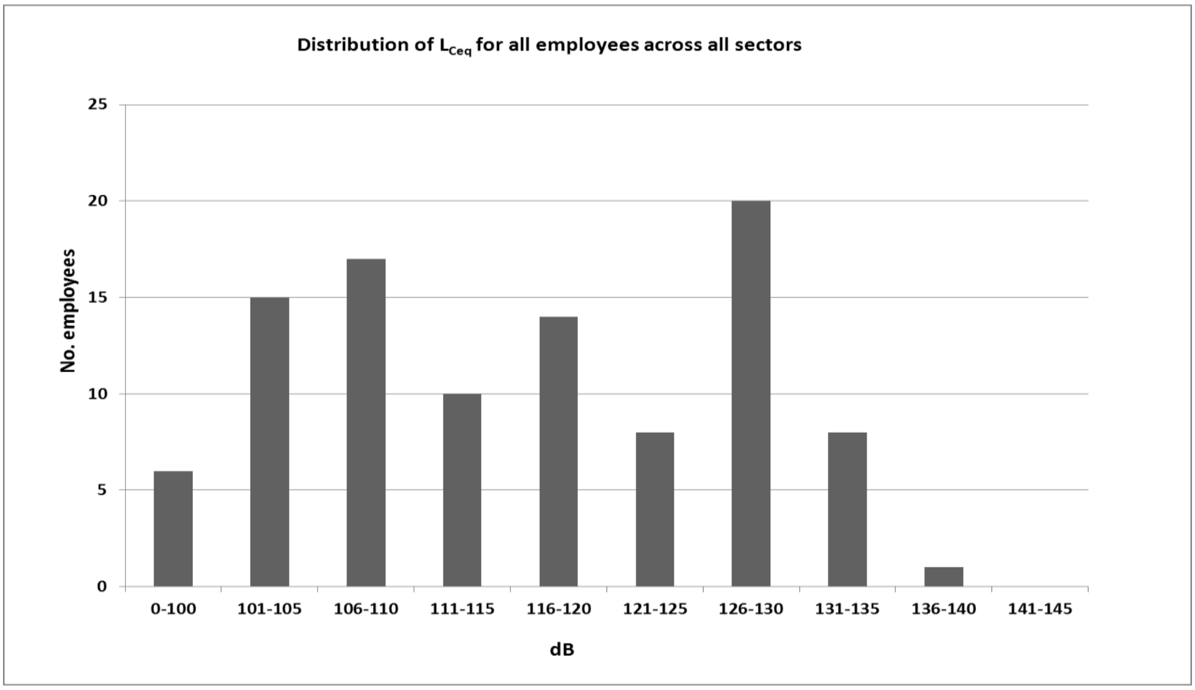


Figure 5.2: Distribution of LCpeak for employees across all sectors

The relationship between L_{Aeq} and L_{Cpeak} are shown in Figure 5.3. These two measures of noise exposure were moderately correlated (r=0.571, p<0.0001).

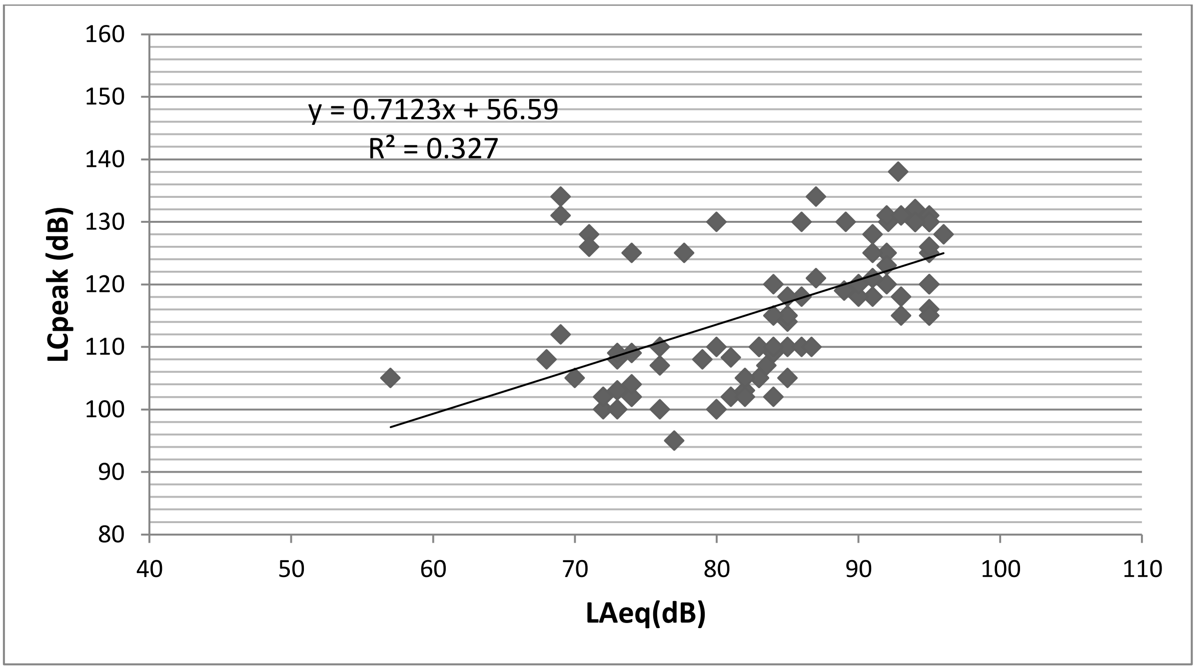


Figure 5.3: The relationship between LCpeak and LAeq for employees across all sectors

Noise exposure by sector

Overall, 122 employees in all sectors were monitored by dosimetry and the mean and median noise levels (L_{Aeq}) are shown in Figures 5.4 and 5.5. Of the "high" risk industry sectors, wood processing, sawmills, engineering manufacturing sites and construction operations experienced the highest time average levels with median $L_{Aeq.8hr}$ values of 94 dB, 92 dB and 90 dB respectively. Median L_{Cpeak} levels were also high at 130 dB, 125 dB and 120 dB. Farms included in the agricultural sector surveys had median $L_{Aeq.8hr}$ values of 85 dB, and median L_{Cpeak} level of 115 dB. The remaining high risk industry sectors surveyed (bottling and textile industry) had median $L_{Aeq.8hr}$ values of 83 dB and 80 dB, and median L_{Cpeak} levels of 105 dB and 100 dB respectively.

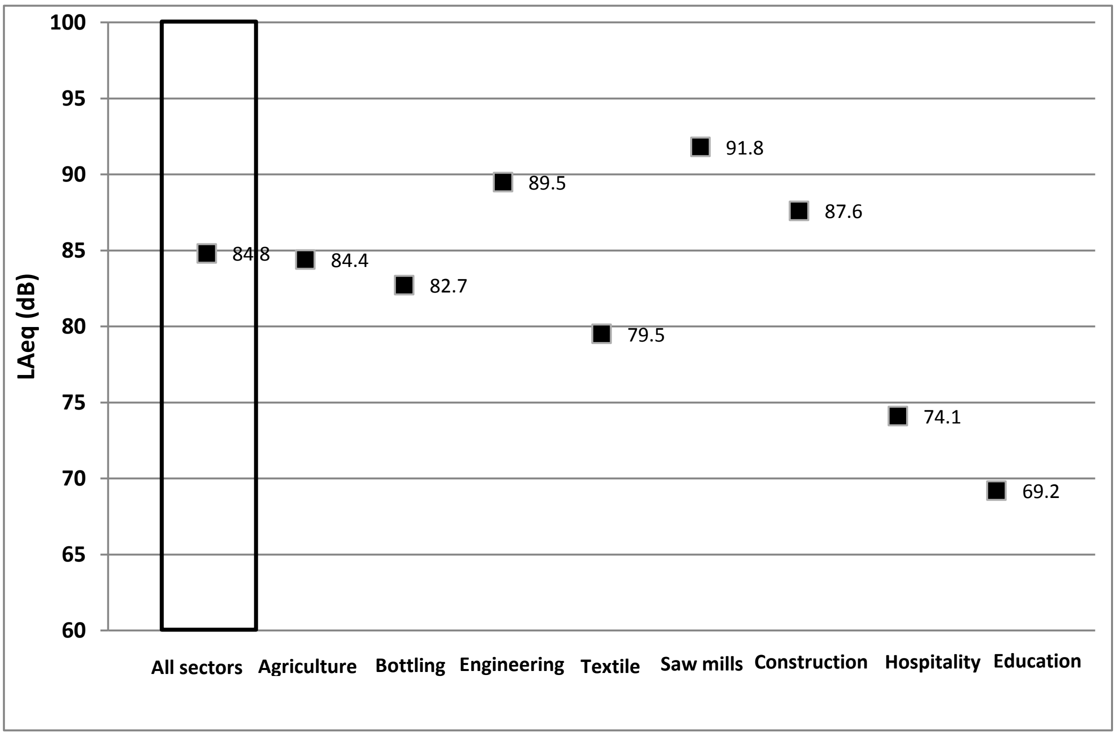


Figure 5.4: Mean employee LAeq8hr levels by sector.

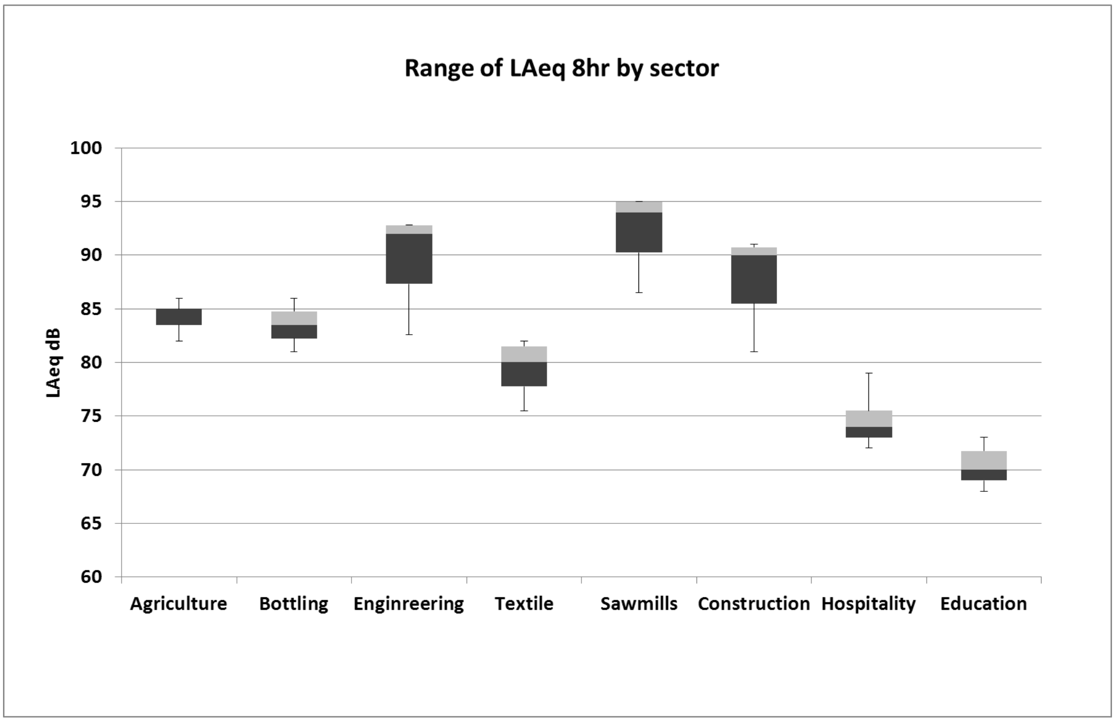


Figure 5.5: Median LAeq8hr levels by sector. The box boundaries show the 25th percentile and the 75th percentile. Error bars indicate the 90th and 10th percentiles.

Noise dose estimates for 122 employees show a very wide range of personal exposures (10 – 600%), with wood processing and sawmills, engineering and construction operations experiencing the highest dose and widest dose range. The medium risk industry sector (hospitality, specifically cafes) surveyed had a median $L_{Aeq.8hr}$ values of 74 dB, and median L_{Cpeak} level of 105 dB. Noise dose estimates for cafes employees ranged between 8 – 26%.

The low risk industry sectors (cafes and preschools) had median $L_{Aeq.8hr}$ values of 74dB and 70dB, and median L_{Cpeak} levels of 105dB and 110 dB respectively. However, the noise dose estimate ranges for employees working in preschools (4 – 98%) was very large in comparison to café measurements.

The proportions of daily noise exposure for employees in excess of 1 Pa^2h are shown in Figure 5.4. Saw mills, construction and engineering had the greatest percentage of employees exposed to noise levels above 85dB L_{Aeq} (85%, 83% and 75% respectively). For other sectors, agriculture and bottling plants had lesser percentages of employees exposed to levels in excess of 1 Pa^2h. No employees in textiles and cafes were exposed to noise above 85dB $L_{Aeq.8hr}$. Two employees in preschool facilities had daily dose estimates of 194% and 316%. However, these values were regarded as outliers and were excluded from the analysis in Table 5.2. and Fig. 5.4.

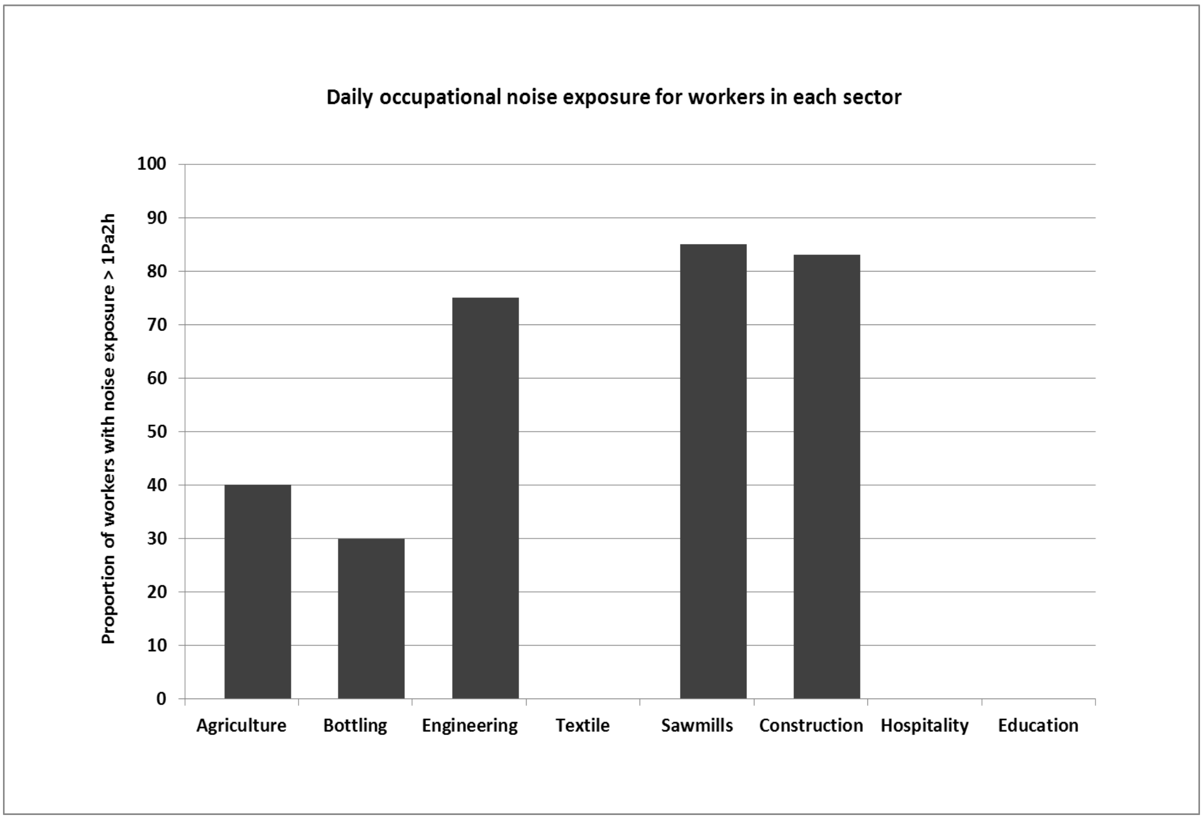


Figure 5.6: Proportion of employees with noise exposure in excess of 1 Pa^2hr by industry sector.

Similarly, of the work areas surveyed, saw mills, engineering and construction had the greatest percentage of work areas where noise levels were above 85dB L_{Aeq} (90%, 80% and 65% respectively). For agriculture and bottling, work areas where noise levels were above 85dB L_{Aeq} were 55% and 30% respectively. The percentage of work areas where daily noise exposure for employees in excess of 85dB L_{Aeq} are shown in Figure 5.5.

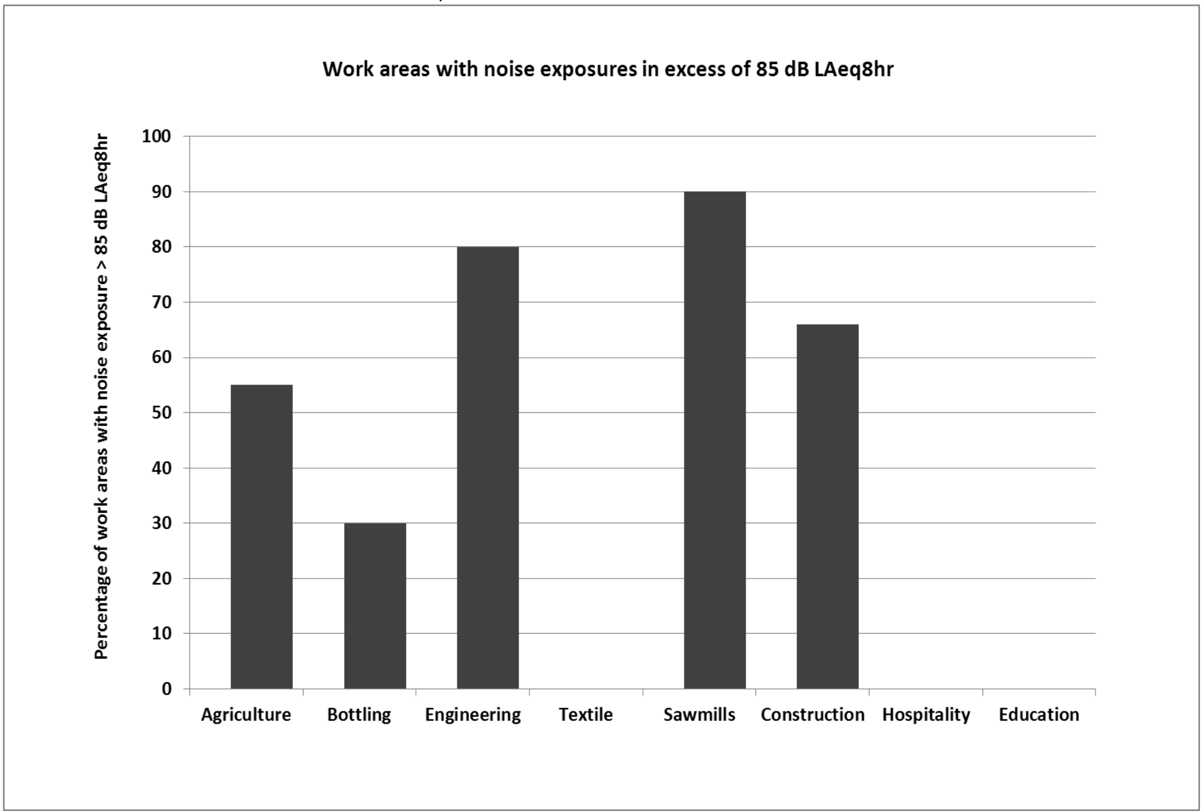


Figure 5.7: Percentage of work areas where noise exposure in excess of 85dB LAeq by industry sector.

Daily noise exposure by sector

The distribution of the L_{Aeq} noise exposure values for 98 workers by each sector are shown in Figures 5.6 – 5.13. Note the differing scales for cafes and pre-schools data.

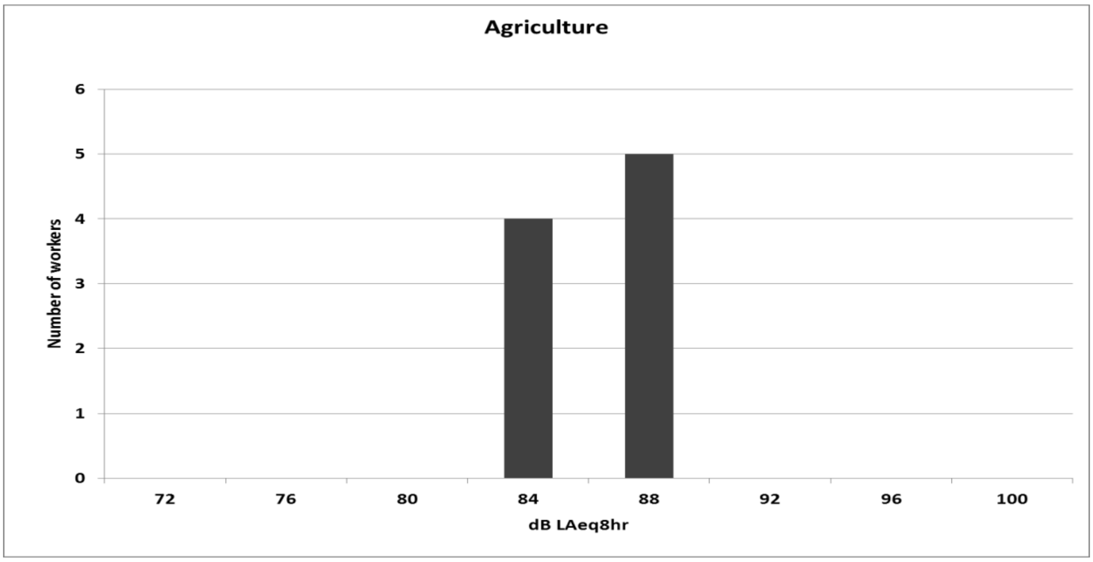


Figure 5.8: The distribution of LAeq values for agriculture workers.

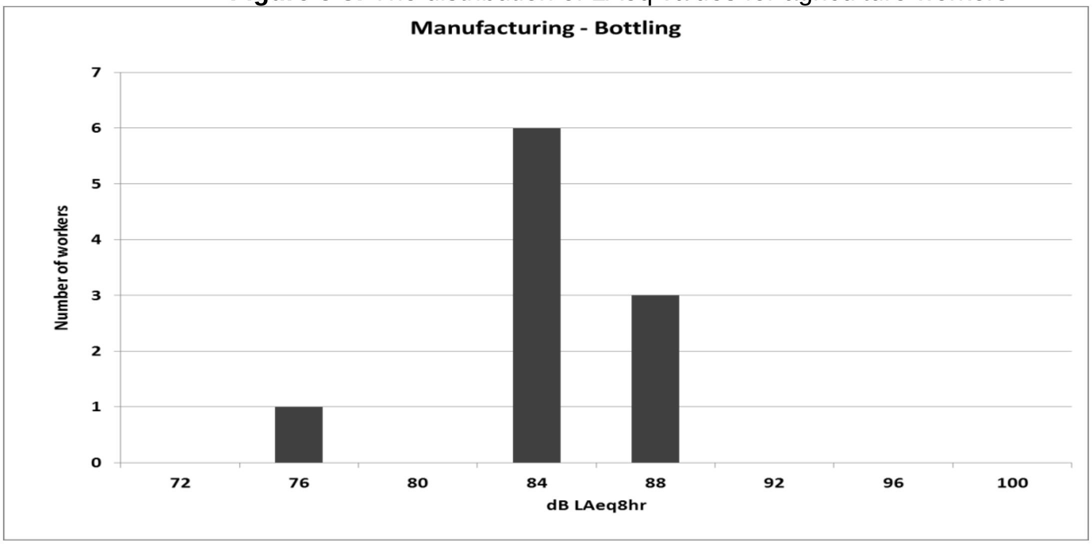


Figure 5.9: The distribution of LAeq values for manufacturing - bottling workers.

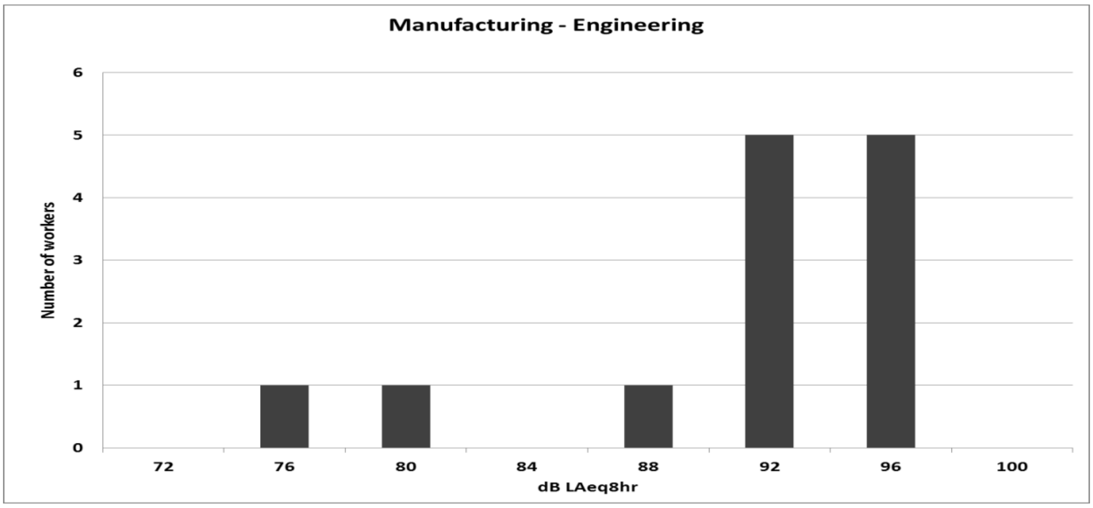


Figure 5.10: The distribution of LAeq values for manufacturing – engineering workers.

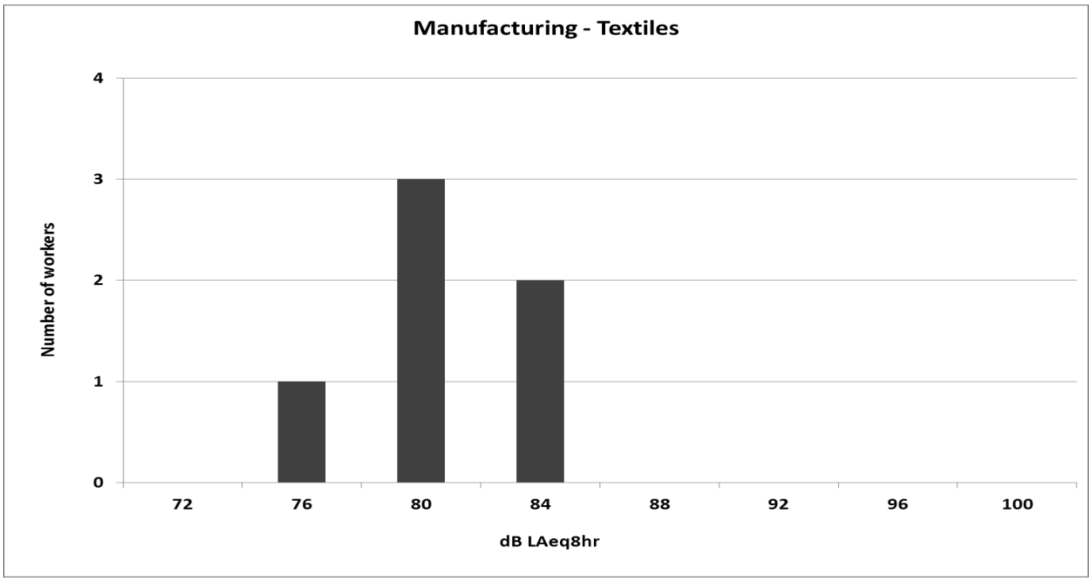


Figure 5.11: The distribution of LAeq values for manufacturing – textile workers.

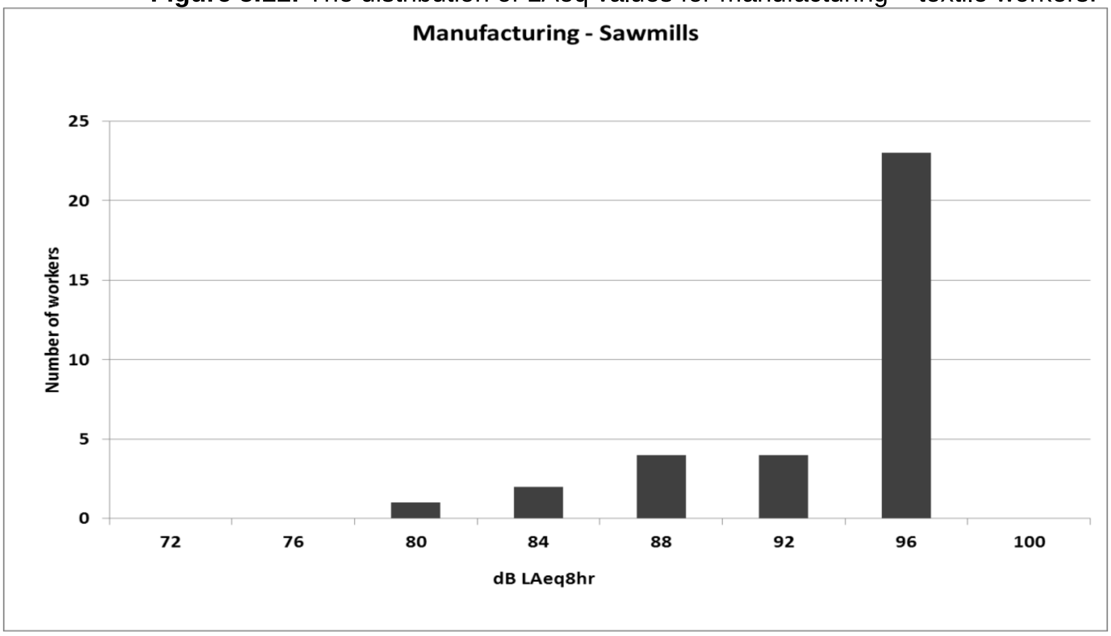


Figure 5.12: The distribution of LAeq values for manufacturing – wood processing / saw mill workers.

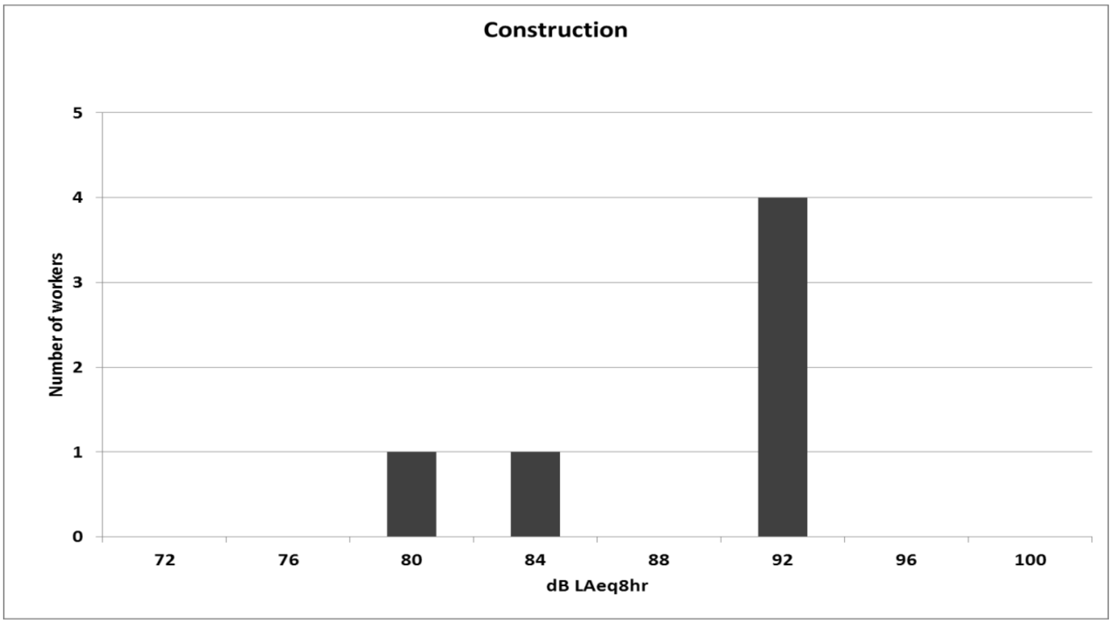


Figure 5.13: The distribution of LAeq values for constructions workers.

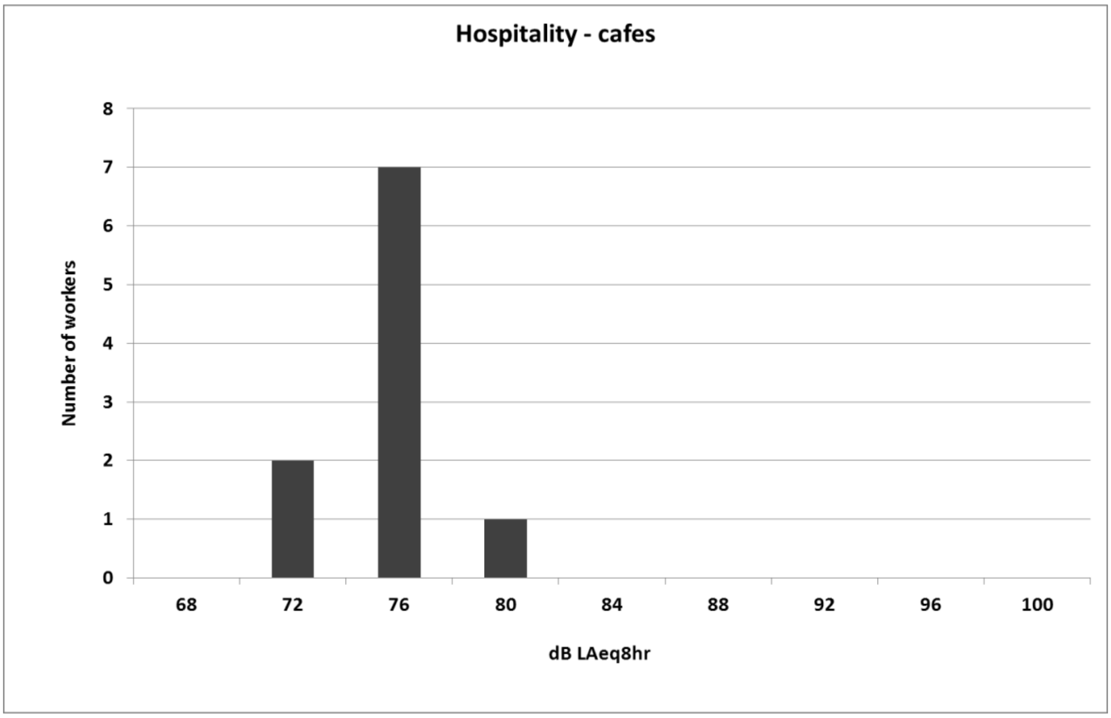


Figure 5.14: The distribution of LAeq values for hospitality - cafe workers.

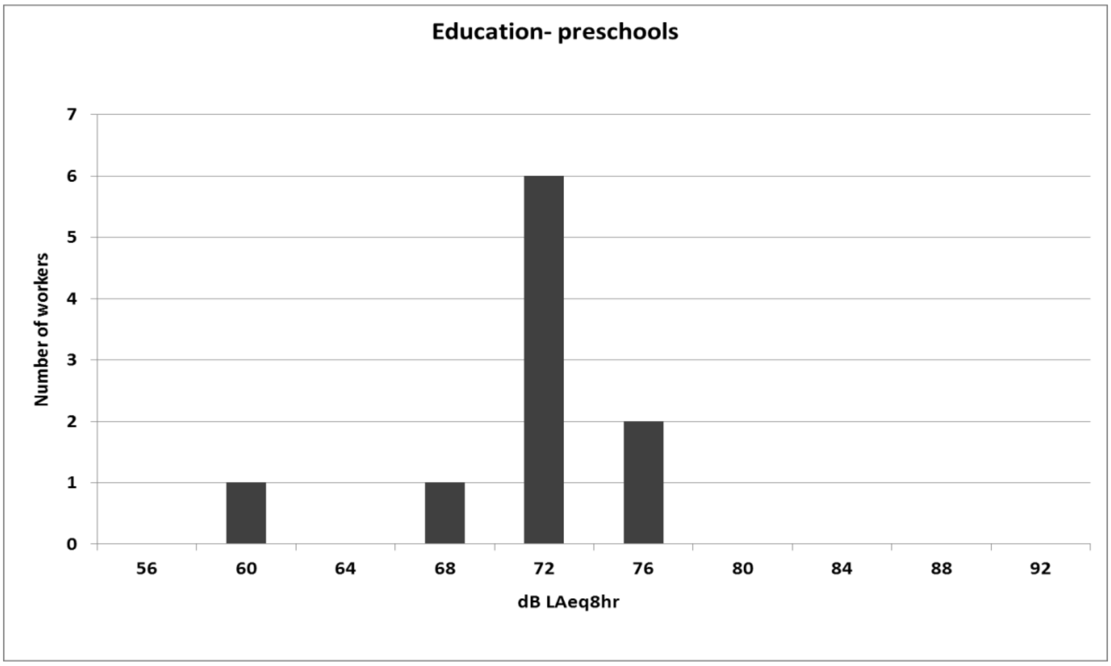


Figure 5.15: The distribution of LAeq values for education - preschool workers.

5.3. Noise controls and conformance assessment

The predominant noise control strategy in the majority of organisations surveyed was that of minimisation, specifically the use of personal hearing protection. Of the 33 organisations assessed, twenty (20) had explored options for elimination and isolation of noise sources. Of those, only 4 businesses had undertaken modifications or replacement of equipment, which resulted in a self-reported reduction of noise exposure in the workplace. The remaining businesses (16) had not pursued these control options. Administrative controls were not used in any of the organisations surveyed.

This section of the survey essentially audited the employers and employees responsibilities under the Health and Safety in Employment Act 1992 with respect to noise, utilising the Approved Code of Practice for the Management of Noise in the Workplace (2002). Data was collected through semi structured interviews, observational data and investigation of archival data and information. Conformance values ranged from 0 to 6 out of 10, with the median 2 and mean 1.9 (sd.1.7).

Figure 5.14.shows the total scores for the 10 elements of the conformance assessment from the Approved Code of Practice. Table 5.3. details the conformance elements.

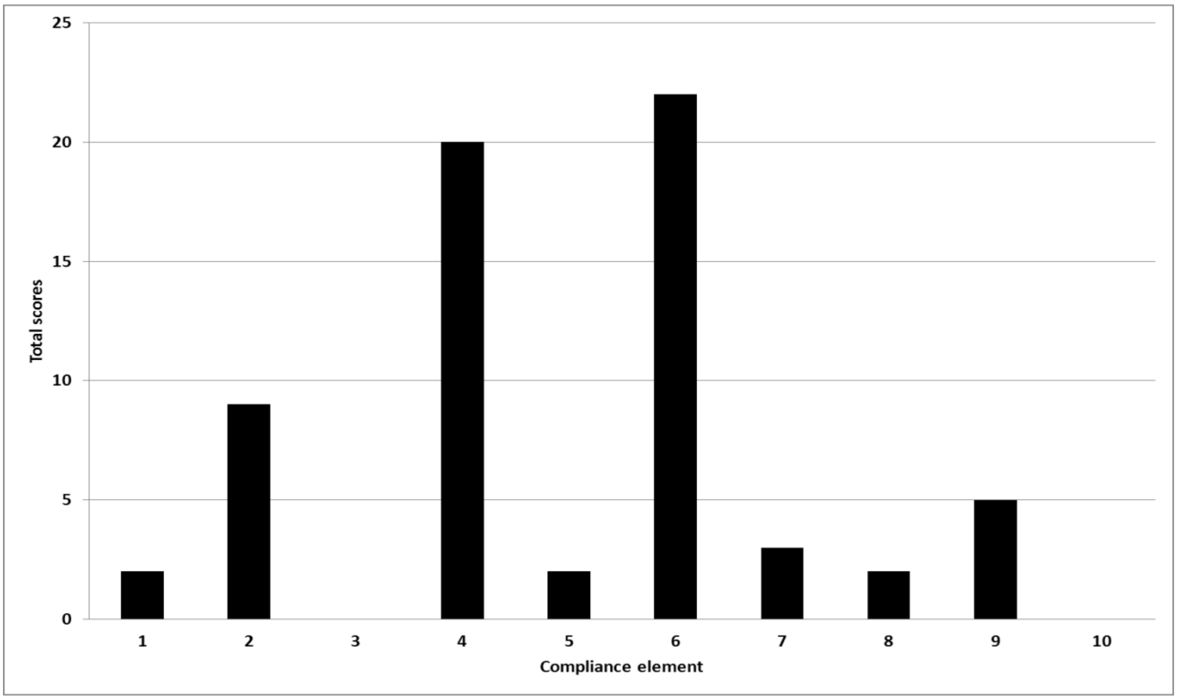


Figure 5.16: Total scores by conformance element.

Figure 5.14. shows that the conformance element most commonly addressed was the provision of personal hearing protection (element 6), followed by the requirement to investigate and if practical, control noise at source (element 4). A number (16 of the 20) did indicate that they had investigated control at source options, but had not pursued these options. The reasons most commonly given for not pursuing these was cost of putting in controls or replacement equipment and technical expertise on how to reduce noise further. Nine of the 33 businesses had undertaken some form of preliminary noise survey (element 2), although only 2 businesses could provide documentation that the surveys had been carried out. Five businesses indicated they had provided information on noise to employees (element 9) as part of their hazard management programme.

Table 5.3: Conformance elements of the Approved Code of Practice for the Management of Noise in the Workplace.

Element	Requirements
1	**Employers must provide a safe place of work (HSE Act, S.6)** Take all practical steps so that no employee is exposed to noise in excess of the exposure limits.
2	**Employers must identify hazards (HSE Act s7(1)(a))** Employers to carry out preliminary noise surveys to identify possible noise hazards. (This does not need to be done by a "competent" person).
3	**Employers must assess identified hazards to determine whether they are significant (HSE Act s7(1)(c))** Employers to arrange for detailed noise surveys to be carried out to assess noise hazards to determine if these are significant.(Must be done by a "competent" person).
4	**Employers must control significant hazards by elimination, isolation, or minimising the likelihood of the hazard causing harm (HSE Act s8-10).** Employers must investigate, and if practicable, control noise at source.
5	Employers must isolate noise sources away from employees where practicable.
6	Employers must provide hearing protectors when noise hazards are not able to be eliminated or isolated, and while work is being carried out to control noise at source.
7	**Employers must monitor the health of employees who have been exposed to a significant hazard (HSE Act s10(2)(e)).** Employers must arrange for hearing tests (audiometry) to be carried out on all employees who work in an area with hazardous noise. This must be done by a "competent" person when an employee starts work, and at intervals of no longer than 12 months thereafter.
8	DoL must be notified if an employee has a hearing loss that meets the accepted criteria.
9	**Employers must provide information, training and supervision to staff in relation to hazards in the workplace (HSE Act s12-14).** Employers must provide information to employees on identified hazards.
10	Employers must provide training and/or supervision to employees in the safe use of plant or use of hearing protectors.

Less than 10% of the businesses undertook audiometry of employees, isolated noise sources or had notified the Department of Labour of a hearing loss case (elements, 7, 5 and 8). As a consequence only 2 businesses were evaluated as taking all practical steps to provide a safe place of work.

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

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

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

Mean conformance scores by industry sector were calculated and shown in Figure 5.15.

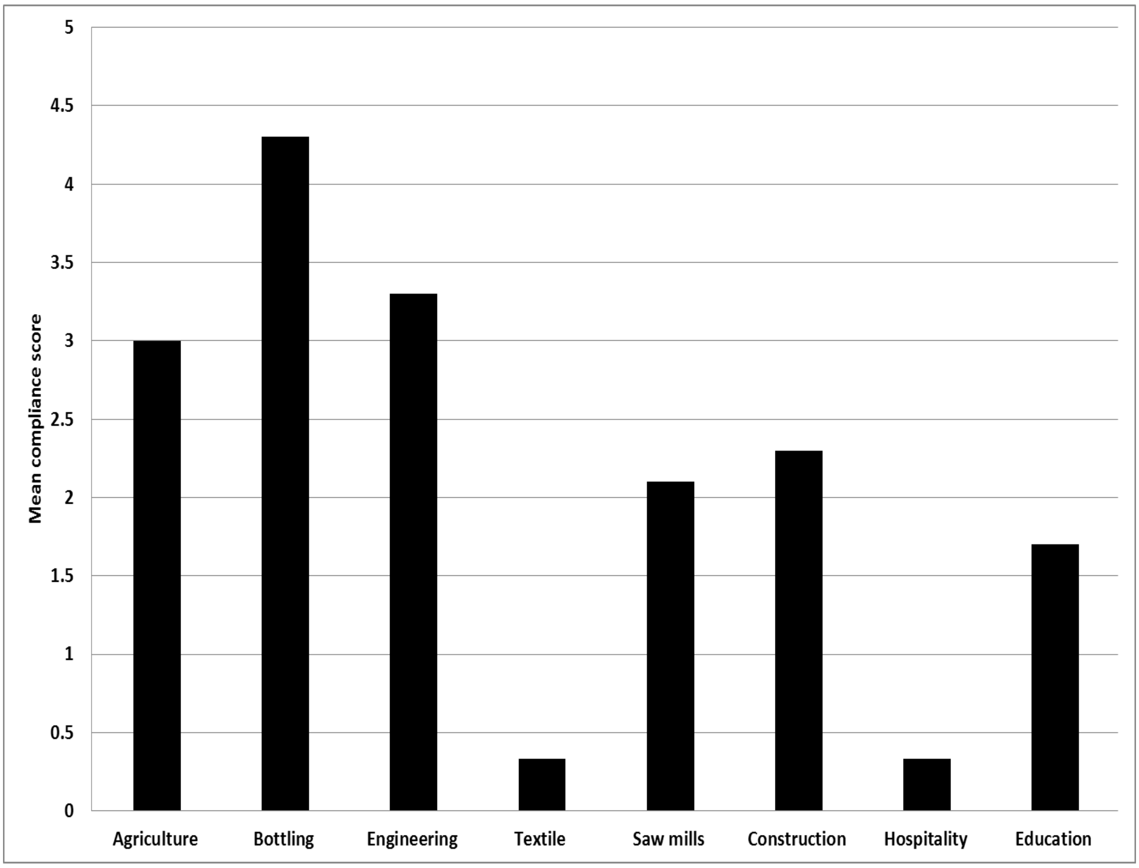


Figure 5.17: Mean conformance scores by industry sector

Agriculture (n=4); Manufacturing Bottling (n=3); Manufacturing Engineering (n=3); Manufacturing Textiles (n=3); Manufacturing Sawmills/Wood processing (n=8); Construction (n=3); Hospitality (n=4); Education (n=5).

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

5.4. Safety climate and attitudes to noise and exposure to noise

A combination of qualitative and quantitative techniques was used to collect data from 33 New Zealand workplaces. Of these, 20 provided questionnaire data on safety climate and attitudes to noise at work, and these are the focus of the present paper. Participating organisations were selected to include those with low, medium and high risk of noise-induced hearing loss (NIHL) (Thorne, et al., 2008). High risk industries included manufacturing (n=12) and construction (n=1); those with moderate risk included cafés (n = 3) and low risk firms were represented by early childhood education centres (n = 4) (Laird, et al., 2010).

One hundred and sixty-three respondents provided usable data. Ages ranged from 16 to 68 (mean 40, s.d. 13). There were no significant age differences between sectors ($F_{3, 93}$=.45, ns). Eighty-two (50.3%) were male, 52 (31.9%) were female; 29 (17.8%) did not provide this information. All respondents in the education sector were female and all in the construction sector were male; eighty-three percent of those in the manufacturing sector were male and 62% of those in hospitality were female. Thirty-four (21%) described their ethnic group as NZ European, Pakeha or Kiwi; 18 (11%) described themselves as European, 3 (2%) as Maori, 15 (9%) as Polynesian, Samoan or Tongan, 7 (4%) as being of other ethnicities and 86 (53%) did not provide this information.

With regard to exposure to noise, 62 (38%) reported that they had previously held noisy jobs; of these 24 reported that they had used HPD, 18 that they had 'sometimes' used it and 25 that they had not used it. Twenty-five (15%) reported that they had noisy hobbies, primarily music, motor vehicle, sport or shooting related. Nine of those with noisy hobbies said that they used HPD, 14 that they 'sometimes' used it and one did not use it.

5.4.1 Company level noise exposure and compliance

Noise sources could readily be identified in the workplaces. For the high risk industries, sources were primarily due to impact noise, engine noise, high frequency pneumatic noise, pipe noise due to turbulent flow within pressurised lines, compressor noise and noise from alarms. For the medium and low risk firms, noise sources tended to be related to the task, activity and equipment being used and the presence of other external sources of noise e.g. traffic noise.

Of the 'high risk' occupations, wood processing, engineering and construction demonstrated the highest exposure to noise with median $L_{Aeq.8hr}$ values of 95 dB, 92 dB and 90 dB respectively. Other high risk firms included agriculture, packaging and textile industry operations with sound levels of 85 dB, 84 dB and 80 dB. The medium risk industry sector (cafes) had median $L_{Aeq.8hr}$ values of 74 dB. The low risk industry sector (preschools) had median $L_{Aeq.8hr}$ values of 70 dB. Details for the participating companies are given in Table 5.4.

Table 5.4: Noise exposure and compliance data for participating companies.

Company	Sector	Compliance	Median measured $L_{Aeq.8hr}$ dB	Median measured L_{Cpeak} dB	Median measured dose %	No. of questionnaire respondents
1	Education	0	70	108	24	12
2	Education	0	71	122	15	7
3	Education	unavailable	72	114	14	9
4	Education	2	69	122	24	5
5	Manufacturing	5	85	108	89	10
6	Hospitality	1	72	105	13	4
7	Manufacturing	1	85	128	246	7
8	Manufacturing	0	79	103	31	2
9	Manufacturing	3	93	120	500	40
10	Manufacturing	2	91	122	227	15
11	Manufacturing	2	91	130	280	3
12	Manufacturing	2	94	130	600	21
13	Construction	unavailable	91	123	225	13
14	Manufacturing	unavailable	95	123	620	3
15	Manufacturing	unavailable	95	125	220	1
16	Manufacturing	6	92	128	259	3
17	Manufacturing	2	82	104	47	3
18	Manufacturing	1	81	101	40	1

19	Hospitality	0	76	107	16	2
20	Hospitality	0	74	101	12	2
Total						163

There was little evidence of compliance with the key requirements of the Approved Code of Practice. Compliance scores ranged from 0 – 6 out of a maximum of 10. Fourteen of the 20 companies had scores of 0-3. Noise was generally identified as an issue but noise assessments were generally informal (e.g. difficulty having a conversation). There was evidence of the use of elimination and isolation strategies to reduce exposure to noise but no evidence of administrative controls being used. Hearing protection tended to be the key control strategy that was identified by respondents. There was no evidence that information or training was provided for noise control/ management in the workplace, and no evidence that noise monitoring or audiometry were routinely undertaken.

Companies with higher compliance scores and higher risk of NIHL also had higher noise levels, as measured by the median value of the $L_{Aeq.8hr}$ measures (Table 5.5). Table 5.5. also shows that compliance was unrelated to safety climate or to employee acceptance of noise. NIHL risk however, coded as low, medium or high, was correlated with employees' perceptions of benefits of and barriers to managing noise at work, with employees in higher risk workplaces perceiving fewer barriers to or benefits from managing noise, perhaps because noise hazards were already being addressed in these workplaces. Similarly, employees in noisier workplaces saw fewer barriers to managing noise. Only the 'personal responsibility' facet of safety climate was correlated with noise levels, so Hypothesis 1 was not supported. Personal responsibility for safety was also correlated with stronger perceptions that there were barriers to noise management and lower self-efficacy for HPD use. The Safety Priority facet of safety climate was correlated with less acceptance of noise, and fewer perceived barriers to managing noise.

Table 5.5: Correlations for company level data (n=20).

	1	2	3	4	5	6	7	8	9	10	11	12
1. Compliance	-											
2. NIHL risk	.47	-										
3. Median $L_{Aeq.8hr}$ dB	.62*	.85**	-									
4. Median L_{Cpeak} dB	.37	.20	.59**	-								
5. Median dose %	.42	.56*	.82**	.66**	-							
6. SC: Safety as a workplace priority	.15	.24	.34	.11	.10	-						
7. SC: Personal responsibility	-.24	-.36	-.56**	-.25	-.43	-.17	-					
8. Susceptibility to NIHL	.21	-.15	.02	.25	-.05	.38	.27	-				
9. Acceptance of noise	-.32	-.04	-.14	-.29	.00	-.49*	-.24	-.87**	-			
10. Benefits of noise management	-.22	-.47*	-.23	.12	.02	.18	.28	.55*	-.47*	-		
11. Barriers to noise management	-.40	-.71**	-.72**	-.32	-.34	-.48*	.56*	-.16	.41	.23	-	

12. Self- efficacy for hearing protection	-.18	.22	.41	.29	.31	.35	-.64**	.21	-.22	.24	-.60**	-

* p<.05; ** p<.01

Linear regression analysis to identify which of the company-level variables predicted compliance with noise management requirements found that the only predictor accounting for unique variance was sound level, as measured by the median LAeq.8hr dB (Table 5.6).

Table 5.6: Regression analysis predicting compliance scores

Predictor	B	SE B	Beta
Noise risk	-3.068	1.853	-1.404
Median $L_{\mathrm{Aeq.8hr}}$ dB	.639	.263	3.192*
Median L_{CPeak} dB	-.063	.079	-.398
Median dose %	-.010	.006	-1.041
SC: Safety as a workplace priority	-1.261	1.182	-.288
SC: Personal responsibility	1.569	1.311	.435
Adj R^2	.327		

5.4.2 Individual level data

Respondents were asked to indicate whether their workplaces were noisy enough that they had to shout to be heard at work. Where workplaces were subjectively perceived to be noisy, there was increased use of HPD (Table 5.7).

Table 5.7: Correlations for individual level data (n=163).

	1	2	3	4	5	6	7	8	9
1. Noisy at work?	-								
2. HPD use at work?	.34**	-							
3. SC: Safety as a workplace priority	.03	-.03	-						
4. SC: Personal responsibility	-.07	-.18*	.11	-					
5. Susceptibility to NIHL	-.24*	-.10	.46**	.40**	-				
6. Acceptance of noise	-.09	.05	-.48**	-.49**	-.78**	-			
7. Benefits of noise management	-.14	-.25**	.04	.24**	.38**	-.37**	-		
8. Barriers to noise management	.00	-.41**	-.28**	.11	-.23**	.19*	.29**	-	
9. Self- efficacy for hearing protection	.04	.08	-.02	-.33**	-.10	-.11	-.12	-.32**	-

Mean (SD)	1.49 (1.04)	2.26 (1.66)	2.98 (.85)	3.25 (.84)	3.29 (1.10)	2.65 (1.06)	3.22 (.80)	3.14 (.95)	2.69 (.10)

* p<.05; ** p<.01

Hypothesis 2 was not supported, as safety climate was uncorrelated with self-reported HPD use.

Hypothesis 3a was supported as regards the positive relationship between safety climate and perceptions of being personally susceptible to NIHL and benefits of noise management but not for self-efficacy, as higher self-efficacy was related to lower personal responsibility scores and unrelated to safety priority. Hypothesis 3b was supported as safety climate was negatively related to barriers to and acceptance of noise.

Hypothesis 4a was not supported. Self-reported HPD use was negatively, not positively, correlated with perceived benefits of reducing exposure to noise and was not related to self-efficacy for HPD or to perceived susceptibility to NIHL. Hypothesis 4b was supported as HPD use was related to lower perceived barriers to noise management and increased personal responsibility for safety, but not to acceptance of noise.

Hypothesis 5, that safety climate would explain more variance in HPD use than personal factors was not supported (Table 5.8). Although safety climate (personal responsibility) did explain significant unique variance in HPD use, safety as a workplace priority did not. Measured sound level was the main predictor of self-reported HPD use along with perceptions of fewer barriers to noise management.

Table 5.8: Predictors of self-reported HPD use.

	B	Std. Error	Beta
Median $L_{Aeq.8hr}$ dB	.152	.015	.818***
Median L_{CPeak} dB	-.052	.012	-.268***
Have to shout?	.220	.102	.127*
SC: Safety as a workplace priority	-.103	.128	-.044
SC: Personal responsibility	.374	.168	.130*
Susceptibility to NIHL	-.081	.145	-.035
Acceptance of noise	-.300	.161	-.117
Benefits of noise management	-.128	.139	-.056
Barriers to noise management	-.427	.140	-.235**
Self- efficacy for hearing protection	-.156	.110	-.079
Adj R^2			

Hypothesis 6 explored the mediation role of personal factors on the effects of safety climate on HPD use. Only one facet of safety climate, personal responsibility for safety, was related to HPD use and so mediation of this relationship was explored. Significant mediation was found for only one of the personal factors, perceived benefits of managing noise (Table 5.9).

Table 5.9: Perceived benefits as a mediator between safety climate and self-reported HPD use.

DV	*IV*	*B*	*SE B*	*Beta*	*Sobel test*
1. HPD use	SC: Personal responsibility	-.351	.159	-.176	1.67*

2. Benefits	SC: Personal responsibility	.230	.074	.243
3. HPD use	SC: Personal responsibility	-.238	.162	-.119
	Benefits	-.440	.170	-.211

Perceptions of the benefits of managing noise therefore appear to play an important role. Where few benefits are perceived in managing noise, it appears unlikely that HPD use will be high even when there is a perception that safety is a personal responsibility.

Participants were asked whether praise for safe work from supervisors, or more realistic safety procedures, would help them to work more safely. They were also asked why they had worked unsafely (they didn't know what they were doing wrong, they needed to complete the task quickly, the right equipment wasn't available). Mean answers for all of these items were all in the 'neither agree nor disagree' midpoint of the scale.

5.5 Summary

The key findings of the workplace surveys are as follows:

A total of 33 workplaces, 71 work areas and noise exposure from 98 workers were measured. Three (3) organisations had employee counts of over 20 employees and were regarded as medium sized enterprises. The remainder (n=30) had employee counts of less than 20 employees and were regarded as small businesses.

1. Noise sources

- For the high risk industry sectors, the sources were primarily due to impact noise; rotational noise due to machinery, gears, conveyers and electric motors; engine noise; high frequency pneumatic noise due to hydraulic equipment and operations; pipe noise due to turbulent flow within pressurized steam lines; compressor noise and alarm noise due to operational alarm activation.
- For the medium and low risk sectors, noise sources tended to be related to the task, activity and equipment being used and the interaction of other, usually external sources of noise not directly related to the workplace such as traffic noise.
- Identification of noise paths in relation to the noise sources was complex as it included indoor and outdoor environments. However, airborne paths were the primary route for noise, with some cases of structure-borne and duct-borne noise/vibration transmission.
- Agriculture, construction and saw milling sound sources and paths were similar in the fact that sound from many key activities, tasks and use of equipment and machinery were generated and transmitted in outdoor environments.
- This is opposed to the other traditional manufacturing sectors (bottling, textile, engineering) where key activities, tasks and machinery and equipment use were usually undertaken within a building structure (indoor), where structure borne sound transmission became more evident.

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

- Median $L_{Aeq.8hr}$ and L_{Cpeak} levels, employee dose estimates and percentage of work areas equal to (=) or greater (>) than 85 dB were measured.
- L_{Aeq8hr} values ranged from below 60dB to 95dB for all employees across all sectors. Mean and (median) L_{Aeq8hr} levels ranged from 69dB (70dB) to 91.8dB (94dB). L_{Cpeak} ranged from

100dB to 138dB. Mean and (median) L_{Cpeak} levels ranged from 116dB (70dB) to 125dB (130dB).

- A large proportion (>48%) of L_{Aeq} levels recorded were in excess of 85dB and >62% of L_{Cpeak} levels recorded were in excess of 110dB.
- Of the “high” risk industry sectors, wood processing/sawmills, engineering manufacturing sites and construction operations experienced the highest time average levels with median $L_{Aeq.8hr}$ values of 94 dB, 92 dB and 90 dB respectively.
- The remaining high risk industry sectors surveyed (agriculture, bottling and textile industry) had median $L_{Aeq.8hr}$ values of 85dB, 83 dB and 80 dB, and median L_{Cpeak} level of 115dB, 105 dB and 100 dB respectively.
- The low risk industry sectors (cafes and preschools) had median $L_{Aeq.8hr}$ values of 74 dB and 70 dB, and median L_{Cpeak} levels of 105dB and 110 dB respectively. However, the noise dose estimate ranges for employees working in preschools (4 – 98%) was very large in comparison to café measurements.
- Saw mills, construction and engineering had the greatest percentage of employees exposed to noise levels above 85dB L_{Aeq} (85%, 83% and 75% respectively).
- For other sectors, agriculture and bottling plants had lesser percentages (40% and 30% respectively) of employees exposed to levels in excess of 1 Pa^2h.
- No employees in textiles and cafes were exposed to noise above 85dB $L_{Aeq.8hr}$. Two employees in preschool facilities had daily dose estimates of 194% and 316%. However, these values were outliers and were excluded from the analysis.

3. Noise controls and conformance assessment

- The predominant noise control strategy in the majority of organisations surveyed was that of minimisation, specifically the use of personal hearing protection.
- Of the 33 organisations assessed, twenty (60%) had explored options for elimination and isolation of noise sources. Of those, only 4 businesses (12%) had undertaken modifications or replacement of equipment, which resulted in a self-reported reduction of noise exposure in the workplace.
- The remaining 16 businesses (48%) had not pursued these control options.
- Administrative controls were not used in any of the organisations surveyed.
- Conformance values across all sectors ranged from 0 to 6 out of 10 (with 10 being total conformance), with the median value 2.0 and mean 1.9 (sd.1.7).
- The conformance element most commonly addressed was the provision of personal hearing protection, followed by the requirement to investigate and if practical, control noise at source.
- A number (16 of the 20, 80%) did indicate that they had investigated control at source options, but had not pursued these options.
- The reasons most commonly given for not pursuing these was (1) cost of putting in controls or replacement equipment and (2) technical expertise on how to reduce noise further.
- Nine of the 33 businesses (27%) had undertaken some form of preliminary noise survey, although only 2 businesses (6%) could provide documentation that the surveys had been carried out.
- Five businesses (15%) indicated they had provided information on noise to employees as part of their hazard management programme.
- Less than 10% of the businesses undertook audiometry of employees, isolated noise sources or had notified the Department of Labour of a hearing loss case.
- As a consequence only 2 businesses (6%) were evaluated as taking all practical steps to provide a safe place of work.

- Of the “high risk” industry sectors surveyed the bottling, engineering businesses and farms were the most compliant (mean (sd) conformance scores; 4.3(2.1), 3.3(2.3) and 3(0) respectively).
- Construction and saw mill/ wood processing businesses had mean (sd) conformance scores of 2.3(0.58) and 2.1(0.35) respectively.
- Of the remaining “high risk” industry sectors, textile manufacturing had the lowest mean conformance score of 0.33 (0.57), which was comparable with the “medium risk” hospitality sector (mean 0.33(0.57)).
- The “low risk” sector, education, had a mean conformance score of 1.7(1.5) indicating that at least some effort was being undertaken to address the noise exposure issue in this sector.

4. Safety climate and attitudes to noise and exposure to noise

- One hundred and sixty-three respondents provided usable data. Ages ranged from 16 to 68 (mean 40, s.d. 13). There were no significant age differences between sectors ($F_{3, 93}$=.45, ns). Eighty-two (50.3%) were male, 52 (31.9%) were female; 29 (17.8%) did not provide this information.
- With regard to exposure to noise, 62 (38%) reported that they had previously held noisy jobs; of these 24 reported that they had used HPD, 18 that they had ‘sometimes’ used it and 25 that they had not used it.
- Twenty-five (15%) reported that they had noisy hobbies, primarily music, motor vehicle, sport or shooting related. Nine of those with noisy hobbies said that they used HPD, 14 that they ‘sometimes’ used it and one did not use it.
- Companies with higher compliance scores and higher risk of NIHL also had higher noise levels, as measured by the median value of the LAeq.8hr measures.
- Compliance was unrelated to safety climate or to employee acceptance of noise.
- NIHL risk however, coded as low, medium or high, was correlated with employees’ perceptions of benefits of and barriers to managing noise at work, with employees in higher risk workplaces perceiving fewer barriers to or benefits from managing noise, perhaps because noise hazards were already being addressed in these workplaces.
- Employees in noisier workplaces saw fewer barriers to managing noise. Only the ‘personal responsibility’ facet of safety climate was correlated with noise levels, (Hypothesis 1 was not supported).
- Personal responsibility for safety was also correlated with stronger perceptions that there were barriers to noise management and lower self-efficacy for HPD use. The Safety Priority facet of safety climate was correlated with less acceptance of noise, and fewer perceived barriers to managing noise.
- Linear regression analysis to identify which of the company-level variables predicted compliance with noise management requirements found that the only predictor accounting for unique variance was sound level, as measured by the median LAeq.8hr
- Respondents were asked to indicate whether their workplaces were noisy enough that they had to shout to be heard at work. Where workplaces were subjectively perceived to be noisy, there was increased use of HPD.
- Hypothesis 2 was not supported, as safety climate was uncorrelated with self-reported HPD use.
- Hypothesis 3a was supported as regards the positive relationship between safety climate and perceptions of being personally susceptible to NIHL and benefits of noise management but not for self-efficacy, as higher self-efficacy was related to lower personal responsibility scores and unrelated to safety priority.

- Hypothesis 3b was supported as safety climate was negatively related to barriers to and acceptance of noise.
- Hypothesis 4a was not supported. Self-reported HPD use was negatively, not positively, correlated with perceived benefits of reducing exposure to noise and was not related to self-efficacy for HPD or to perceived susceptibility to NIHL.
- Hypothesis 4b was supported as HPD use was related to lower perceived barriers to noise management and increased personal responsibility for safety, but not to acceptance of noise.
- Hypothesis 5, that safety climate would explain more variance in HPD use than personal factors was not supported. Although safety climate (personal responsibility) did explain significant unique variance in HPD use, safety as a workplace priority did not. Measured sound level was the main predictor of self-reported HPD use along with perceptions of fewer barriers to noise management.
- Hypothesis 6 explored the mediation role of personal factors on the effects of safety climate on HPD use. Only one facet of safety climate, personal responsibility for safety, was related to HPD use and so mediation of this relationship was explored. Significant mediation was found for only one of the personal factors, perceived benefits of managing noise
- Safety climate: perceptions of safety as a workplace priority explained little variance in anything. Safety as a personal responsibility did.
- After decades of effort in trying to improve safety management, this is disappointing.
- Maybe perceptions of safety climate follow rather than lead safety management efforts.
- Hazard management:
    - Needs management commitment and workforce involvement - aspects of safety climate
    - Hazards are best managed directly rather than indirectly through attempts to change climate through marketing, training, attitude change…
- SC is complicated: different facets have different correlates and implications
- In focusing on psychosocial factors, don't overlook the physical work environment – actual noise levels were more strongly related to HPD use and management compliance than SC or attitudes.

6.0 Discussion

6.1 Workplace surveys

6.1.1. Noise sources and paths

The noise sources and paths identified in this study are consistent with those identified in a range of surveys from a variety of traditionally noisy industry sectors (construction, agriculture, manufacturing, mining) and are primarily impact generated (metal on metal) and rotational components of engine and machinery operation (Hattis, 1998; Suter, 2002; Nieuwenhuijsen et al, 1996; McBride et al, 2003; Depczynski et al, 2005; Kock et al, 2004; Tak et al, 2009). The noise sources for specific pieces of equipment and operations/ tasks have also been reported.

Noise sources in agricultural work identified in this study are consistent with those identified in other studies and usually linked to specific equipment and tasks (Nieuwenhuijsen et al, 1996; McBride et al, 2003; Depczynski et al, 2005). Sources included engines and gears, pneumatic and hydraulic noise, compressor noise and radio noise. McBride et al (2003) suggested however, that the common and everyday sources of noise exposure in farming are not intense but because of this, the effects could be subtle and the onset of hearing loss insidious.

Noise sources in the manufacturing sectors in this study were extremely varied and very much dependent on the manufacturing process and machinery used in the process in a similar way to those identified by Kock et al (2004) and Tak et al (2009). The key feature of noise sources found in the manufacturing sectors was the relationship of the sound emission to an enclosed or semi-enclosed workspace (bottling plant, engineering workshop and textile factory). The sound fields in the workplaces were complex, due to the involvement of many sources including air-borne noise and structure-borne noise, reflections from the floors, walls, ceilings and machinery surfaces and absorption on surfaces. The basic mechanism of noise generation was due to mechanical noise, impact noise, fluid noise and/or electromagnetic noise.

The noise sources identified in the construction activities in this study were compatible with the categories identified by Hattis (1998) and capture broad groups of problem types with different opportunities for abatement. Suter (2002) suggests that controlling construction noise at the source is the most reliable way to protect worker hearing. U.S. (and New Zealand) manufacturers and contractors should benefit from the activities of the European Community, where noise control and product labelling in construction has been carried out for more than 20 years.

The noise sources in the cafés were consistent with those identified by Christie and Bell-Booth (2004), including impact noise due to the banging of cutlery and crockery, mechanical/equipment noise from the operation of the till, appliances such as food processors and the coffee machine and fan and extractor noise. Other important sources of noise include traffic, patron generated and radio/music background noise. A large proportion of noise sources contributing to background noises were those associated with kitchen areas, especially coffee machines and grinders. These sources may contribute a great deal to the overall acceptability of the workspace.

Two principal sources of noise identified in the preschool centres surveyed included noise generated from the children and the activities they are engaged in. e.g. music, and noise intrusion from outside activities. e.g. traffic and transportation noise sources. This is consistent with surveys undertaken by McLaren and Dickinson (2005) and (2009), where some activities and equipment were found to be especially noisy, indicating that controls on the level of noise for these were needed. This included some music sessions from amplified music and the use of percussion instruments such as claves. In addition, major construction work carried out in the vicinity of centres was another source of noise generated at the time of the survey and highlighted the influence of external sources on individual noise exposures.

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

6.1.2. Exposure to noise and dose measurements

The results of this study shows that of the "high risk" industry sectors surveyed, most had median sound levels that were at or above $L_{Aeq.8hr}$ 90dB. These results are consistent with exposures reported by numerous researchers (Hattis, 1998; Kock et al, 2004; Williams et al, 2008; McBride et al, 2003; Daniell et al, 2006; Middendorf, 2004; Tak, 2009).

Median noise exposures recorded in "moderate" and "low risk" industry sectors (cafes and preschools respectively) were at or below $L_{Aeq.8hr}$ 85dB and also consistent with those reported in previous studies (McLaren and Dickinson, 2005; McLaren and Dickinson, 2009; Christie and Bell-Booth, 2004).

Agriculture (n=4)

Noise exposure measurements on the farms studied were consistent with earlier studies (Nieuwenhuijsen et al, 1996; Beckett et al, 2000; Firth et al, 2001; Hwang et al, 2001; McBride et al, 2003; Depczynski et al, 2005). Five of the 9 measurements (55%) were at or exceeded $L_{Aeq.8hr}$ 85dB and the highest value of $L_{Aeq.8hr}$ of 86 dB recorded on a mixed dairy and sheep farm. The noise sources most prevalent included tractor engine noise, farm bike engine noise, compressor and machinery noise and music. The range of noise dose estimates (70 – 126%) is related to the diverse range of activities and equipment used in farming operations and intermittent exposures to these sources. Prevention through either noise reduction at source or isolation of the noise is best practice but not always practicable so that hearing protection could be the only control option available. However, Jenkins et al (2007) report that of a survey of 209 farmers screened for NIHL, 92% of them identified strategies to reduce noise hazards, and 13% successfully reduced or removed exposure at source.

Manufacturing (n=17)

Noise exposures in the manufacturing industry sectors surveyed (bottling, engineering, textile and sawmills) were some of the highest recorded in this study (median $L_{Aeq.8hr}$ range 83.5 – 95dB). For the bottling process operations (median $L_{Aeq.8hr}$ 83 dB) the significant noise exposures were generated by glass on glass and glass on metal impacts. This is evident with the median L_{Cpeak} ranges between 102 – 110 dB. One of the three bottling plants had replaced existing filling lines and sterilising units with newer equipment where the noise specifications had been taken into consideration at the time of purchase. This business had also been successful with a strategy of isolating noisy operations and restricting access to high noise exposure areas.

The three engineering firms surveyed were primarily metal fabrication and general engineering workshops (median $L_{Aeq.8hr}$ 92 dB). The L_{Cpeak} ranges between 110 - 138 dB were characteristic of the high but infrequent impulsive noise exposures from metal fabrication. The wide range of personal noise dose exposures recorded (10 – 588%) are also indicative of varied activities in the workshops and the close proximity of exposed employees to machinery and equipment, the high impulsive noise sources and the typical enclosed and highly reverberant workshop environment. These values are consistent with exposures reported by Kock et al (2004) and Williams et al (2008).

Of the three textile manufacturing businesses ($L_{Aeq.8hr}$ range 76 – 82dB), all of the work areas had $L_{Aeq.8hr}$. values below 85 dB, with subsequent personal noise dose ranges between 10 and 50%. Even with the close proximity of employees to the noise sources (cutting and spinning machinery), the exposures were relatively low. A more significant source of noise in all textile firms was the factory music/ radio system. However, the exposures reported in this study are significantly lower than exposures reported in early studies (Bailey et al, 1973; Ohstrom et al, 1979; Bhatt et al, 1990; Yhdego, 1991 and Bedi, 2006).

Eight saw mill and wood processing businesses and 33 work areas were surveyed in this study. Noise exposures in these businesses were some of the highest recorded in this study ($L_{Aeq.8hr}$ range 80 – 95dB). The L_{Cpeak} ranges between 108 - 134 dB were characteristic of the high and frequent noise exposures with subsequent personal noise dose ranges between 60 and 600%. Previous studies of noise exposure in sawmills were related to the technology of the time (Lamb, 1971; Dost, 1974a,b; Ruedy et al., 1976; Lamb, 1981; Patrick, 1981; Tupper, 1981; Chung et al., 1983; Pyykko et al., 1989; NIOSH, 1991). These studies demonstrated that noise exposures in most sawmill are hazardous due to the nature of the work (cutting, sawing, planing, and the associated machinery) and the volume of timber that passes through on a daily basis. These noise sources, together with machine engines and air cylinder exhausts, create a substantial noise hazard in any sawmill or planermill (Dost and Gorvad, 1979). Other studies have also identified the planer as one of the loudest woodworking machines in the industry and high on a priority list for engineering controls (Lamb, 1971; Ruedy et al., 1976). Another study also noted that noise levels measured in the sawmill exceeded the suggested guidelines for annoyance potential, speech interference, and effect on job performance; the latter being the most important according to the author (Lamb, 1981). The present study described noise exposures in modern sawmill and wood processing operations and found that the values recorded are consistent, if slightly lower, than the earlier reports using the technology of the time. This may indicate the gradual replacement and substitution of older machinery (1980's 1990's) with newer equipment (2000's) that may have quieter noise profiles during operation.

Construction (n=3)

Noise exposure measurements in the construction companies studied were consistent with earlier studies (LaBenz et al, 1967; Sinclair and Haflidson, 1995; Legris and Poulin, 1998; Lusk et al, 1998; Neitzel et al, 1999; Blute et al, 1999; Lusk et al, 1999; Seixas et al, 2001; Kerr et al, 2002; Suter, 2002; Kock et al, 2004; Neitzel and Seixas, 2005; Williams et al, 2008). Of the three construction companies in this study two were residential construction and the other a road construction company. $L_{Aeq.8hr}$ measurements for the residential construction activities and equipment ranged from 80 – 91 dB and from 90 – 91 for the road construction companies and are consistent with values reported by Kock et al (2004) and Williams et al (2008). Similarly dose estimates for workers ranged from 30 – 400% dose residential construction and 200 – 250% dose for road construction. This is potentially explained by not only the differing work environments, activities and equipment, but also by the proximity of the workers to the noise-generating equipment. Generally, peak values (L_{Cpeak}) were consistently higher than other industry sectors studied.

Cafés (n=4)

Exposures to noise in cafés reported in this study are also consistent with previous research (Christie and Bell-Booth, 2004). Median $L_{Aeq.8hr}$ values of 74 dB, and median L_{Cpeak} level of 105 dB, with noise dose estimates for cafes employees ranging between 8 – 26%, indicate that by industrial standards, noise exposures in cafés do no constitute a significant hazard. However, previous research has typically acknowledged that bars, cafes and restaurants produce less than desirable acoustic conditions for comfortable social interaction (Camp, 2005; Christie, 2004; Hannah, 2004; New Scientist, 2004; Rindel, 2002; Wouters et al, 1999). That is, it has been found that the average noise level in restaurants and cafes is around 80dBA and can even reach up to 110dBA (Bear et al, 2001; Cozby, 1997). In comparison, the ear is most sensitive to speech for conversation purposes between 48-72dBA (Egan, 1998). A large proportion of noise sources contributing to background noises were those associated with kitchen areas, especially coffee machines and grinders. These sources may contribute a great deal to the overall acceptability of a space. In addition, the influence of external factors, such as traffic and general road noise and non-task specific noise (music) also may contribute to interior noise acceptability.

Preschools (n=5)

The results of sound level surveys undertaken in preschools in this study are consistent with studies in New Zealand by McLaren and Dickinson (2005) and (2009) and in Australia by Grebenikov (2006), where some staff members had experienced daily sound exposures in excess of 100%. These findings are consistent with the results of the present study, where two employees in preschool facilities had daily dose estimates of 194% and 316%, indicating significant “industrial” levels of noise exposure.

In addition, and possibly more significantly, although not obviously covered by the health and safety legislation, children too can be affected by excessive noise levels in early childhood centres. The recently enacted legislation requires that all reasonable steps are taken to promote the good health and safety of children enrolled in the centre or service (Ministry of Education, 2008a). Underpinning that, the Health and Safety Criterion No 15 (Ministry of Education, 2008b) requires that all practicable steps are taken to ensure noise levels do not unduly interfere with normal speech and/or communication or cause any child attending distress or harm.

Many of the centres in the present study had no form of acoustical treatment of internal surfaces. As McLaren (2010) suggests, due to scarce resources in this sector, it is not possible for many centres to engage professional advice to carry out acoustic treatment. Low cost solutions and DIY (do it yourself) options could be explored which may result in improvement even if they do not meet the optimum level. The development of a resource kit could be implemented giving a wide range of solutions to improve acoustical quality of learning spaces.

Overall, as McLaren (2010) suggests – “It is of considerable importance to investigate thoroughly the extent of occupational noise exposure with this group of workers, and if a significant risk is established, to implement regular testing programmes as is done with other at-risk work places. It may be necessary, based on establishing the level of risk among these workers, to propose amendments to address occupational noise issues in the legislation and the associated code of practice as applicable to this profession”.

6.1.3. Noise control and conformance to standards

The results of the compliance assessment in this study [range 0/10 to 6/10 with score 10 being fully compliant; median 2; mean 1.9 (sd.1.7)] provide disappointing evidence that businesses are not identifying, assessing or putting in place and supporting appropriate noise controls strategies for their industry sector. This contrasts the results of the Williams et al (2008) Australian study, where in 45% of workplaces surveyed (n=113), managers reported that there was a noise control policy and 76% of managers stated that a noise assessment had been conducted. In addition, 46% were aware of the noise exposure standards and 47% were aware of the code of practice. However, Williams et al (2008) noted that awareness of noise regulations and self-compliance was lower in small businesses (employing fewer than 20 people) compared to medium and large businesses. Approximately, 20% of managers in small businesses were aware of the noise exposure standards and code of practice, compared with 62% in medium and large businesses. This was not the case with the New Zealand workplaces surveyed in this study.

However, some results of this study are consistent with those of Williams et al (2008) in that it was found that industry in general tends to be heavily reliant on the use of hearing protective devices (HPDs) for exposure control. Moreover, small businesses place more reliance on the use of HPDs and much less reliance on hazard control using structured programme involving engineering, administrative and maintenance controls (Williams et al, 2008). These issues have been extensively reviewed in the wider OHS context (Mayhew, 1997, 2002; Lamm, 2000; Gardner, 2000; Lentz, et al, 2001; Okun, et al, 2001; Oldershaw, 2002; Champoux & Brun, 2003; Lamm & Walters, 2003; Larsson, 2003; Barbeau, et al, 2004; Hasle & Limborg, 2006; Walters, 2006; Legg et al, 2009).

The consensus of opinion in these studies is that management in small businesses is more informal; the lines of communication are short, the communication is more often oral than written, the structure is simple and commercial pressures are very high and immediately felt. Moreover, it is impossible to separate OSH practices from other aspects of small business management such as financial management, selection and recruitment of staff, task training.

As the owner-manager is the key person in the small enterprise, it is their values that determine the businesses approach to health and safety management (Vickers, Baldock, Smallbone, James & Ekanem, 2003; Hasle & Limborg, 2006; Antonsson, 2007). Many owners however, consider health and safety to be the employees' responsibility (Vickers, et al, 2003; Hasle & Limborg, 2006) and often are not aware of legislative requirements (Vickers et al, 2003; Caple, 2006; Hasle & Limborg, 2006; Antonsson, 2007; Legg, et al, 2009). This has the effect that compared with large and medium sized businesses, small businesses appear to be less aware of noise exposure standards, and less likely to have noise management policies or to have undertaken sound level surveys. This was evident in the findings of the present study where few managers of the small businesses were aware of any specific occupational noise exposure standards.

3. Which interventions are currently in place in high-risk New Zealand industrial/ service sector(s)?

At the national level, the Workplace Health and Safety Strategy for New Zealand to 2015 provides a framework for the workplace health and safety activities of government agencies, local government, unions, employer and industry organisations, other nongovernment organisations, and workplaces. It is aimed at significantly reducing New Zealand's work toll, and will also raise awareness of workplace health and safety; help co-ordinate and prioritise the actions of a wide range of organisations and improve the infrastructure that supports workplace health and safety. The Strategy is consistent with the Health and Safety in Employment Act 1992 (HSE Act), but has a wider scope. Whereas the HSE legislation places requirements on workplaces, the Strategy includes actions for all levels – national, industry and enterprise. It also seeks to encourage and achieve higher levels of workplace health and safety performance in New Zealand through just compliance and enforcement alone. The Strategy identifies 8 national priorities, of which noise and the prevention of NIHL is not specifically identified.

In addition to the overall Strategy an Action Agenda has been developed that identifies a discrete set of national-level actions that will be delivered progressively over the next 3 years. The Action Agenda aims to ensure government agencies prioritise their work programmes to focus on five sectors; construction, agriculture, forestry, manufacturing and fishing. Current national intervention programmes and strategies relating to noise exposure and prevention of NIHL tend to be industry sector specific and a component part of a more general health and safety intervention strategy (e.g. Worksafe, Farmsafe, SiteSafe, etc.). The Department of Labour and ACC provide educational material and information on noise, prevention noise exposure and noise control solutions, in addition to regional project and event based noise management activities.

At the organisational level, the interventions currently used in the high risk industry sectors, as evidenced in this study, included undertaking preliminary noise surveys to identify noise hazards; investigating, and if practicable, controlling noise at source; providing hearing protection; providing training and information and undertaking regular audiometry (Fig. 5.14).

Of those strategies, the most common implemented by the enterprises in this study (n=24) were (a) undertaking preliminary noise surveys (37.5%), (b) investigation of the practicability of control of noise at source (70.8%) and (c) provision of personal hearing protection (87.5%).

The preliminary noise surveys and investigation of noise control at source options were more commonly undertaken in the manufacturing sectors rather than agriculture of construction enterprises. However, even though noise control options at source were investigated within the workplaces in this study, few enterprises pursued these options further to effectively manage noise exposure. This could have included more specific and direct enclosure of machinery and equipment, use of vibration isolation, regular maintenance of machinery and equipment, elimination or replacement of old machinery and implementation of a “buy quiet” purchasing policy.

The majority of high risk industry sector enterprises surveyed, did however, provide hearing protection for workers. The provision of information and training in relation to reducing noise exposure and regular audiometry were strategies not well utilised by high risk industry sectors surveyed. Administrative controls were not used in any of the organisations surveyed.

How effective are these interventions?

Questions of the effectiveness of interventions are varied and complex. The first question is whether or not the intervention was carried out as intended? Of course, this question assumes that there is a well described plan for the intended intervention. Such a plan is a prerequisite for internal as well as external validity. The second question is the issue of impact or prevention effectiveness: Did the intervention lead to the intended changes in exposure? The next question is whether or not the changed exposure had the intended effect on health and other study outcomes. It is important to be able to distinguish between lack of impact of the intervention and lack of effect of exposure on health. In addition, in many intervention studies it is unclear whether the aim is to find out how to reduce exposure or how to reduce the occurrence of the disease. This is regrettable since the methodological requirements for carrying out prevention effectiveness studies and aetiological studies of diseases are very different (Kristensen, 2005).

The most effective way to prevent NIHL is to remove the hazardous noise from the workplace or to remove the worker from the hazardous noise. Implementation of engineering and administrative controls of noise represents a top occupational health and safety priority and should be fully utilized to reduce hazardous noise exposures. Of the 33 enterprises assessed, twenty (60%) had explored options for elimination and isolation of noise sources. Of those, four (12%) had undertaken modifications or replacement of equipment, which resulted in a self-reported reduction of noise exposure in the workplace.

However, the reliance, primarily, on the individual use of hearing protection as the key intervention strategy in this study, is problematic, as the protection provided by the HPD depends on both the HPD's attenuation level and the time the HPD is used. In addition, the high proportion of workplaces where HPD use was prevalent suggests that engineering noise controls have not been optimally implemented in the workplaces.

Manufacturing and construction industries in particular demonstrated high potential for noise-induced hearing loss in employees. While self-reported use of HPD was high in these companies, there was little evidence of in-depth compliance with the requirements of the relevant Code of Practice. This apparent emphasis on individuals to protect themselves from noise was consistent with the safety climate data. There were few correlations between safety as an organisational priority and other variables, while perceptions of safety as a personal responsibility had more explanatory power.

Objectively measured sound levels were the only significant predictor of compliance with Code of Practice requirements at the organisational level. Sound levels also predicted self-reported HPD use, as did the perception that safety was a personal responsibility and that there were few barriers to noise management. Where respondents perceived safety to be an organisational priority, they were less prepared to accept noisy workplaces and less likely to see barriers to the effective management of noise.

The study highlights the complexities of managing workplace hazards. Effective hazard management requires a multi-faceted approach that includes management commitment, a work environment conducive to good safety, commitment to safety and a focus on continuous improvement (Barraclough & Carnino, 1998). Most importantly it requires the anticipation, identification, assessment and control of hazards, preferably at source (Kovalchik, Matetic, Smith, & Bealko, 2008).

What are the barriers to quiet workplaces, and, if quiet workplaces are not possible, what are the barriers to use of Personal Protective Equipment?

Barriers to interventions to achieve quiet workplaces were identified and extensively reviewed in Section 2, Literature Review. These come under twelve broad headings;

1. Incomplete implementation of Hearing Loss Prevention Programmes
2. Inconsistencies of what management say to what they do in the workplace (role models)
3. Supervisors not enforcing HP usage
4. Reluctance to jeopardise management/ union relations.
5. Lack of incentive to enforce company policies.
6. Mobile workforce and management.
7. Requires effort to encourage employers/ employees to fulfil statutory requirements.
8. Long term persistence of change uncertain.
9. Engineering controls are situation and site specific.
10. Implementing engineering controls may be a lengthy and costly process, solutions may not be simple.
11. There may be a perceived gap between knowledge of experts and actual action in the workplace.
12. Changes in attitudes, perceived benefits, barriers, susceptibility is not associated with more preventive behaviour.

For engineering controls, a number of enterprises in this study (16 of the 20, 80%) did indicate that they had investigated control at source options, but had not pursued these options. The reasons most commonly given for not pursuing these was (1) cost of putting in controls or replacement equipment and (2) technical expertise on how to reduce noise further.

In addition, key barriers to this strategy identified in the literature review suggest;

1. Controls are situation and site specific
2. Requires multidisciplinary collaboration: acoustic engineering, construction and industrial expertise all necessary
3. A lengthy and costly process in tough industries where solutions are not simple (e.g. longstanding work by NIOSH Pittsburgh Research Group in underground coal mining (Kovalchik, Smith et al. 2007; Kovalchik, Matetic et al. 2008))
4. Perceived "..gap between knowledge of the experts, as displayed in professional journals and at national and international noise conferences, and actual action taken (or lack thereof) in real workplaces. What solutions were available, were normally perceived by industry as being too complicated or too expensive for an average workplace to implement…" (Gunn 2007), personal opinion.

For administrative controls, potential barriers identified were safety (for job rotation, ability of workers to perform multiple tasks, potential for exposure to other risks including musculoskeletal, dust/chemical), proximity to other work stations (so time efficiency) and acceptability to workers.

Specific barriers to hearing protector effectiveness

While all authors consistently acknowledge the low place of HP in the hierarchy of controls for NIHL prevention, they remain a prominent part of most occupational noise strategies. Much of the hearing protection training described in the interventions in the literature review is based on the premise that "consistent use of HP prevents NIHL" (Kerr, Savik et al. 2007).

Unfortunately as "consistent" use generally means 100% of the time, it is also unrealistic. It is clear that there are very significant problems with the practical application of this directive (well summarized by Williams 2006), and the low acceptability to wearers of HP was reflected again in the qualitative literature included in this review. The ineffectiveness of training to promote the use of hearing protection may be related more to the overwhelming barriers associated with their use, rather than any insufficiency of the training model theory or implementation.

Qualitative studies reporting on barriers are included in Table 3. (p.55. Appendix 1). The main concerns are very consistent across studies, and break down to:

- They are uncomfortable
- I can't hear sound information required for efficient workplace functioning (e.g. warning signals, speech)

These specific barriers seem very difficult to address. For example, high clamping pressures are associated with the discomfort of prolonged earmuff use; a lower clamping pressure would reduce the attenuation of the muff, making it ineffective. (Williams 2007 Noise at Work Conference: Is it reasonable to expect individuals to wear earmuffs for extended periods).

Key barriers to this strategy

1. Underlying difficulties when key goal of intervention is to promote hearing protection use (requirement for 100% of time use, low wearer acceptability, variability in attenuation)
2. Changes in attitudes, perceived benefits/barriers/susceptibility not associated with more preventive behaviour, so evidence base for what to include in training is low

Key enablers for this strategy

1. Face-to-face informal training sessions appear more effective
2. Practical participation involving selection and use of devices important
3. Messages focussing on the positive aspects of NIHL prevention more effective than those emphasizing the negative results of no prevention.

What else could be done applying the statutory control hierarchy (eliminate, minimise, isolate)?

National Strategies

The WHSS 2015 prioritises preventive activities on an industry sector basis, and does not specifically identify noise exposure and NIHL as a national priority. It is essential that noise is identified and resourced in the WHSS National Action Agenda (2010) and also the Occupational Health Action Plan (2011).

Legislation and standards

Exposure standards

The adoption of action levels could be a driver for noise management activities at the organisational level. For example a lower action level at 80dB(A) where training and the provision of information is required could complement the existing 85dB(A) criterion for noise management. Likewise an upper action level at 85(A) where noise control measures become mandatory would similarly reinforce the existing standards.

Recent changes incorporated in the UK Control of Noise at Work Regulations have seen reductions of the first/second action levels from 85/90 to 80/85dB(A). There are peak action levels of 135 dB(C) and 137 dB(C). There are also new exposure limit values of 87 dB(A) (LEP,d) and 140 dB (peak) which must not be exceeded after taking into account wearing hearing protection. There is now a specific requirement to provide health surveillance where there is a risk to health. The guidance states that this is when there is frequent exposure at 85 dB(A).

Additionally limits on the number of permissible impacts or impulse noises, or correspondingly lower criterion levels for high impact environments, could be introduced. For specific situations of shift work and atypical work patterns in New Zealand, an alternate criterion based upon a 24 hour exposure period for applicable industries could also be investigated (Thorne et al, 2007).

Enforcement expectations

Also in the UK, there have been significant changes in expectations with respect to policing the requirements of the UK noise regulations. These could be very applicable in the New Zealand context:-

- Less reliance on PPE is required not an acceptable long term solution unless noise control can be shown to be impractical
- Much more of a risk based approach is required
- Much better compliance with the duty to reduce noise by engineering means is expected
- Risk Assessments should identify a programme of work
- Less assessment and "process", more Action is expected
- If solutions have been identified "stop assessing and start controlling"
- Health Surveillance is required above 85dB(A) which can be considered to be "a tax on failure to control the risks" ..

This approach by the HSE has yet to be evaluated but highlights the conceptual shift from a “protection” to a “prevention” focus on noise management. Similarly, Williams et al (2008) suggests that the approaches that could be adopted to achieve better compliance within the small business sector (e.g. regulatory enforcement or an assistive and educational approach) need to be determined.

Technical advice and support

A range of initiatives providing technical advice and support for primarily small enterprises have been developed and trialled in Australia, UK and Europe with varying levels of success. These have been reviewed extensively by Legg et al. (2009). Many of these initiatives could be very appropriate for the effective management of noise in New Zealand. They include;

Technical advice

The Confirmation of Advice Record (CAR) is a document intended to support and promote the advisory focus of WorkCover. It allows H & S inspectors to provide a written record of advice during workplaces visits and leave it with the employer and employee representative. It is not a notice, nor is it enforceable, and it does not replace enforceable notices or orders. However, it can be used in conjunction with notices or orders. For example, if WorkCover advises an employer to develop more effective safety procedures, the CAR will suggest ways to do this. The CAR is intended for use during all workplace visits; not just intervention activities traditionally associated with advisory activities.

Small Business Safety Program was established by WorkSafe (Victoria) to help small businesses in Victoria evaluate and minimise the risks of injury and claims in the workplace. This programme offers an easy and fee-free opportunity for businesses to work with an independent consultant to check their workplace and systems, to ensure that potential risks are minimised. The programme involves a three-hour assessment of the workplace by external consultants. Consultants assess the environment and provide businesses with advice on changes that can be made to improve safety in the workplace.

Small Business Advisors Looking at issues at workplaces, providing information and developing action plans, are available to provide free workplace consultations of up to three hours. As part of their consultation, the advisors will: look at the health and safety issues and risks in the workplace; prioritise issues according to seriousness provide information on the types of solutions available to control risks; work with the small business owner to develop an action plan to reduce health and safety risks. A written copy of the action plan is sent to the small business owner after the consultation.

Worker Safety Advisors (WSA). Some projects have experimented with multi-party collaboration to enhance health and safety practice. One scheme considered main five sectors in which there were particular problems with worker involvement and participation, namely small automotive/fabrication, civil construction, hospitality (notably public houses), retail and the voluntary sector. The HSE (UK) was responsible for recruiting employer volunteers; the TUC (UK) recruited the WSAs. The WSAs were paid a salary and were seconded from their union.

Roving safety representatives (RSRs) are health and safety consultants who visit farms carry out joint inspections of the workplace, looking at documents relevant to health and safety, discussing the causes of injury and ill health in agriculture, encouraging worker involvement in health and safety by looking at consultation procedures, obtaining their views on health and safety and examining concerns, providing the farmer information on standards of agriculture, and carrying out further visits to check progress and promote further improvements.

Mentoring or partnership programmes.

Partnership Programme. Industry associations (termed referring organisations) were asked to nominate companies with strong areas of OHS expertise (mentors) and other companies that lacked OHS expertise (mentees). Mentors with particular OHS strengths were partnered with mentees with corresponding OHS weaknesses. The conclusions were that partnerships are not for everyone. If the partnership is to succeed, each company must be committed to the Partnerships concept as a means of building OHS expertise in small businesses. The concept appears to have been uniformly embraced by participants, non-participants and referring organisations involved in the trial of the pilot programme. It should be borne in mind, however, that all the companies were hand-picked by a referring organisation. The reality is that the success of the partnerships is directly related to the enthusiasm of the individuals involved.

The Safety Ambassador Program is a natural progression of the case study programme. This programme will identify safety ambassadors/champions who have an exceptionally strong commitment to safe business practices and will act as ‘change agents’ in their industry. Safety Ambassadors will also promote safe business practices at a variety of forums and seek to influence and assist small to medium business.

The Good Neighbour forum scheme was designed to encourage supportive relationships between large and small firms in managing health and safety. In particular, it aimed to build upon existing relationships between large firms and the smaller businesses that were contracted to supply them with goods and services. The principal aims of the forums were: for larger firms to make a public commitment to help smaller organisations with managing OHS issues for the small businesses attending forums to become aware of the range of OHS advice that was being offered and encourage them to take up the offer of support; to stimulate interest amongst businesses not already participating in the scheme; to change attitudes to health and safety in small firms and promote behaviour that will lead to improved performance. This scheme was open to companies operating in any sector. The emphasis was on improving health and safety standards within small businesses, but was designed to involve large and medium-sized businesses, the focus of the initiative being on developing relationships between different sizes of company. Participation by businesses was voluntary, and there were no fees involved.

Incentive schemes

The Safety Solutions Rebate Program is an incentive programme to encourage small business operators to work with their employees to identify safety problems and fix them. Employers who qualify for the rebate receive half the costs (excluding GST), up to $500, of adopting an effective solution to a safety problem in their workplace. The rebate is provided after the purchase or implementation of an eligible safety improvement. To qualify for the rebate, the small business operator must first attend a WorkCover safety workshop or have a business advisory officer or inspector visit the workplace. The owner must also complete an action plan based on information gleaned from the workshop or advisory visit, and submit an application form and copies of relevant tax invoices.

The Small Business Grants Scheme provides funding to assist industry associations to develop and implement health and safety outcomes within their specific industry sector. The Small Business Grants Scheme was created in 2005 to provide funding for industry groups to assist employers to better manage and improve workplace health and safety. Proposals are sought from industry groups between February and April each year, and the grants are allocated on a financial year basis commencing on 1 July that year.

Safety and Support for Business (SAS) a health and safety management support project was developed in an economically deprived area, within a large industrial city in the north-west of England. The project aimed to provide an infrastructure of basic health support and advice for small (<50 employees) and micro businesses (<10 employees), as part of a programme of urban regeneration for the area, a central objective of which was to address issues of social inequality in health and well-being. The approach adopted has been described as one of facilitative action, designed to assist and empower small businesses to address workplace health and safety issues. By working closely with small business communities over an 18-month period, the initiative sought to establish trusting partnerships between project staff and local businesses. Initial interactions centred on identifying the health and safety needs for small businesses; this resulted in the identification of four health and safety interventions.

Information services

A Safety Information Centre may provide a two-fold benefit to the SME, first, by providing practical guidance in the creation of the requisite bureaucracy of health and safety compliance, and second, by providing a broader and more strategic understanding of health and safety practice. However, as with other interventions, safety information centres have still to overcome employers' suspicion that free services lack expertise and the concern that centres have close affiliations with trade unions.

Workplace Health Connect (WHC) was launched in February 2006. It was a free, no obligation service providing SMEs with advice on workplace health and safety. WHC aims to build the capacity for SMEs to tackle future challenges internally or with the help of recommended specialists through the transfer of occupational health and safety and return to work (OHSR) knowledge and skills direct to companies. The WHC scheme, which is currently a pilot initiative, was designed to exist at three levels: Level 1 – a free, national advice line taking calls from both employers and employees, offering detailed and tailored practical advice. This is supported by a dedicated website. Level 2 – free problem-solving visits from qualified advisors for employers calling Level 1 with postcodes within five regions. 'Pathfinders' (contractors that are often based on regional partnerships) deliver this service according to a two-visit model (with a telephone follow-up three months later). Level 3 – 'signposting' to approved local specialists, by the advice line and pathfinders, for employers requiring further support.

4. Are key ACC "target" industries and other high-risk sectors/occupations complying with current recommendations (e.g. Codes of Practice) and legislation to prevent NIHL?

The results of the compliance assessment in this study [range 0/10 to 6/10 with score 10 being fully compliant; median 2; mean 1.9 (sd.1.7)] provide disappointing evidence that businesses are not identifying, assessing or putting in place and supporting appropriate noise controls strategies for their industry sector. This contrasts the results of the Williams et al (2008) Australian study, where in 45% of workplaces surveyed (n=113), managers reported that there was a noise control policy and 76% of managers stated that a noise assessment had been conducted. In addition, 46% were aware of the noise exposure standards and 47% were aware of the code of practice. However, Williams et al (2008) noted that awareness of noise regulations and self-compliance was lower in small businesses (employing fewer than 20 people) compared to medium and large businesses. Approximately, 20% of managers in small businesses were aware of the noise exposure standards and code of practice, compared with 62% in medium and large businesses. This was not the case with the New Zealand workplaces surveyed in this study.

However, some results of this study are consistent with those of Williams et al (2008) in that it was found that industry in general tends to be heavily reliant on the use of hearing protective devices (HPDs) for exposure control. Moreover, small businesses place more reliance on the use of HPDs and much less reliance on hazard control using structured programme involving engineering, administrative and maintenance controls (Williams et al, 2008). These issues have been extensively reviewed in the wider OHS context (Mayhew, 1997, 2002; Lamm, 2000; Gardner, 2000; Lentz, et al, 2001; Okun, et al, 2001; Oldershaw, 2002; Champoux & Brun, 2003; Lamm & Walters, 2003; Larsson, 2003; Barbeau, et al, 2004; Hasle & Limborg, 2006; Walters, 2006; Legg et al, 2009).

The consensus of opinion in these studies is that management in small businesses is more informal; the lines of communication are short, the communication is more often oral than written, the structure is simple and commercial pressures are very high and immediately felt. Moreover, it is impossible to separate OSH practices from other aspects of small business management such as financial management, selection and recruitment of staff, task training.

As the owner-manager is the key person in the small enterprise, it is their values that determine the businesses approach to health and safety management (Vickers, Baldock, Smallbone, James & Ekanem, 2003; Hasle & Limborg, 2006; Antonsson, 2007). Many owners however, consider health and safety to be the employees' responsibility (Vickers, et al, 2003; Hasle & Limborg, 2006) and often are not aware of legislative requirements (Vickers et al, 2003; Caple, 2006; Hasle & Limborg, 2006; Antonsson, 2007; Legg, et al, 2009). This has the effect that compared with large and medium sized businesses; small businesses appear to be less aware of noise exposure standards, and less likely to have noise management policies or to have undertaken sound level surveys. This was evident in the findings of the present study where few managers of the small businesses were aware of any specific occupational noise exposure standards.

A lack of financial resources in small businesses is also important from an OHS intervention perspective, as paying for health and safety advice, information, tools and controls will always be implicitly or explicitly evaluated by a cost-benefit analysis (Mayhew, 1997a). Tight budgetary constraints often mean that there is a lack of financial resources to implement health and safety initiatives, such as noise surveys, the installation of engineering controls or personal protective equipment. Economic incentives are therefore an important encouragement for small businesses to improve health and safety practices generally (Mayhew, 2002).

Leinster et al (1994) applied a risk management model to investigate managerial, organisational and psychological factors involved in managing exposure to noise and preventing hearing loss in 48 UK organisations and found that only 40% of the organisations carried out assessments to comply with legislation; that noise was taken for granted, not perceived as a serious barrier; there was a lack of leadership with no clear allocation of responsibilities and the perception by management that control measures were expensive. Similar findings were also reported by Royster and Royster (2003) and Toivonen et al (2002).

In addition, the findings of Daniell et al (2006) also raise serious concerns about the adequacy of contemporary occupational hearing loss prevention, regulation and enforcement strategies in the United States after 20 years of regulations. Most of the 76 companies in the 2006 study had been inspected by State OSHA at some point in time, but only 9% had received a citation related to noise or hearing conservation. Neither a past inspection nor citation was associated with current programme completeness or use of hearing protection. These findings suggest the need either for increased regulatory enforcement or consultation to make this strategy effective or for greater emphasis on reducing levels of noise at source.

6.1.4. Safety climate and noise exposure

Manufacturing and construction industries in particular demonstrated high potential for noise-induced hearing loss in employees. While self-reported use of HPD was high in these companies, there was little evidence of in-depth compliance with the requirements of the relevant Code of Practice. Many workplaces continue to rely on hearing protection devices to address noise risks. This apparent emphasis on individuals to protect themselves from noise was consistent with the safety climate data. There were few correlations between safety as an organisational priority and other variables, while perceptions of safety as a personal responsibility had more explanatory power.

There was little support for the hypothesised importance of safety climate, conceptualised as perceptions of workplace priorities for safety, for noise management. Objectively measured sound levels were the only significant predictor of compliance with Code of Practice requirements at the organisational level. Sound levels also predicted self-reported HPD use, as did the perception that safety was a personal responsibility and that there were few barriers to noise management. Where respondents perceived safety to be an organisational priority, they were less prepared to accept noisy workplaces and less likely to see barriers to the effective management of noise.

A different aspect of safety climate was more noticeable, that of safety as a personal responsibility. Those who saw safety more as a personal responsibility also felt that there were more barriers to effective noise management, and were less confident in their own ability to use HPD effectively. Changes in perceptions of safety climate do not necessarily match changes in behaviour (Cooper & Phillips, 2004) and it is important to identify which facets of safety climate are being discussed when implications are examined.

The study highlights the complexities of managing workplace hazards. Effective hazard management requires a multi-faceted approach that includes management commitment, a work environment conducive to good safety, commitment to safety and a focus on continuous improvement (Barraclough & Carnino, 1998). Most importantly it requires the anticipation, identification, assessment and control of hazards, preferably at source (Kovalchik, Matetic, Smith, & Bealko, 2008). This requires commitment from management in terms of time and expenditure, and a long-term visible program of effective hazard management.

Perceptions of safety climate may follow, rather than drive, hazard management. Attempts to address safety climate directly through changing attitudes and behaviours, training, promotion, marketing and special campaigns (Choudhry, Fang, & Mohamed, 2007) may be less effective than explicit and observable hazard management. The insidious nature of NIHL can mean that noise hazards are underestimated (Purdy & Williams, 2002). Effective approaches include active management with use of elimination, design and engineering noise controls, while less effective approaches focus on individual behaviour with little management support (Laird, et al., 2010). Cooper and Phillips (2004) argue that the primary focus should be on changing unsafe conditions and behaviours at *all* organisational levels, rather than focusing on changing attitudes, beliefs and perceptions. Effective safety management involves management commitment and workforce involvement. Both are aspects of safety climate (Vecchio-Sadus & Griffiths, 2004) but are best managed directly rather than indirectly through attempts to manage safety climate *per se*.

There is still a need to build a positive focus on safety. In order to improve behaviour that protects hearing, it may be valuable to increase perceptions of personal susceptibility to NIHL e.g. through audiometric test programs (Williams, et al., 2004; Zohar, Cohen, & Azar, 1980), and to increase awareness and knowledge about noise as a hazard through communication, workshops and training initiatives (Prince, Colligan, Stephenson, & Bischoff, 2004; Purdy & Williams, 2002; Williams, Purdy, Storey, Nakhla, & Boon, 2007). Employee participation in safety training was not measured in this study, so future research should examine training. Marketing approaches that use communication strategies to prompt and maintain behaviour change can also be of value (Stephenson, et al., 2005; Vecchio-Sadus & Griffiths, 2004). However awareness alone is insufficient to change behaviour and training may be more strongly related to risk perception and safety climate than to actual HPD use (Arezes & Miguel, 2008). The health effects of noise can be difficult for individuals to perceive and the consequences of poor hearing protection behaviour may be slow to appear. Effective management includes managing the consequences as well as the triggers of complying (and non-complying) behaviour. This can include developing reinforcers that are immediate, certain and positive, and providing appropriate messages, systems, procedures, role models and, most importantly, social norms (Quick, et al., 2008; The Keil Centre, 2002; Vecchio-Sadus & Griffiths, 2004; Williams & Purdy, 2005). Given the difficulties in sharing information and providing training when there is high staff turnover, diverse workforces, an increased number of contingent and contract workers and fewer permanent staff, on-going attention to safety is required (Clarke, 2003)

Interventions to reduce risks from noise at work need to be multi-faceted and to focus on senior management and supervisory levels as well as front-line employees, as staff at different levels have different needs and priorities (Vecchio-Sadus & Griffiths, 2004; Zohar & Luria, 2005). Interventions need to be cyclical and on-going, from needs assessment, intervention development, implementation and evaluation to renewed assessment of needs (Laird, et al., 2010). Given the risk of NIHL in NZ industry, commitment is required at national as well as organisational levels to develop strategies for noise injury prevention including those that are suitable for small businesses (Hasle & Limborg, 2006). Safety needs to be maintained as a high priority given that it competes for resources with other organisational goals. Evidence is required of ways in which safety and business goals can be aligned, as well as evidence for the value of safety activities (Legg, et al., 2010; Vecchio-Sadus & Griffiths, 2004). This requires coordinated effort at the organisational, sector, national and even international levels, as New Zealand workplaces compete in a global marketplace with ever-changing expectations.

5. What aspects of workplace culture affect decisions around NIHL?

Safety climate, as a set of perceived organisational priorities, influences employee behaviour by indicating the likely outcomes for different behaviours such as prioritising productivity over safety, or vice versa (Zohar, 2008). While safety climate is a group-level rather than individual-level construct, individuals' perceptions of the safety climate in their workplace are likely to be related to their specific safety behaviour, such as the use of hearing protection devices (HPD) (Arezes & Miguel, 2008).

Safety climate, or the "perceptions of policies, procedures and practices relating to safety in the workplace" (Neal & Griffin, 2007, p. 69,), is one of the factors related to effective hazard management, including management of noise.

There is growing consensus that core aspects of safety climate include the role of managers and supervisors, co-worker support for safety, employee participation, work procedures and worker involvement (Davies, et al., 1999; Fernandez-Muniz, Montes-Peon, & Vazquez-Ordas, 2007; Flin, Mearns, O'Connor, & Bryden, 2000; Guldenmund, 2000; Håvold, 2005; Neal, Griffin, & Hart, 2000; Pousette, Larsson, & Torner, 2008; Seo, Torabi, Blair, & Ellis, 2004; Shannon & Norman, 2009; Vecchio-Sadus & Griffiths, 2004; Yule, 2003; Yule, O'Connor, & Flin, 2003).

In particular what are the cultural barriers to the development of a proactive, preventive workplace stance regarding NIHL?

From the findings of the present study, it would appear that lack of prioritisation of noise exposure and perceptions of the seriousness of NIHL over other things affecting the business are key cultural barriers facing effective noise management in workplaces in New Zealand. This is supported by the fact that the finding that the only real predictor of either compliance with the Approved CoP (organisation level) or the wearing of PPE (individual level) was *noise levels*. Culture/climate was much less important. This suggests that we are losing sight of the actual workplace issues in focusing on the psychology of safety (safety culture/ climate). This also implies that if strategies are effective in identifying and controlling noise hazards (control at source), then climate (attitudes, perceptions, beliefs) will follow. i.e. “fix the hazards and the climate will follow”.

What motivates employers and employees to prevent hearing loss?

When a NIHL prevention intervention has been effective, it is still not always clear why. Very few studies have identified the mediating factors by which the intervention may have effected behaviour change. When mediating factors have been identified, they have not always appeared responsive to the measures used (Neitzel, Meischke et al. 2008). In most cases the enabling factors identified with each of the key intervention strategies from Review Question 1 have been identified by the authors of each study; in some cases a statistical correlation was demonstrated between the enabling factor and the preventive behaviour, but not often.
In addition to the intervention studies described, many non-intervention, qualitative studies have sought to identify positive factors associated with NIHL prevention. Most of these concentrated on enablers for the use of personal hearing protection. As in literature on the barriers to NIHL, studies examining the influence of workplace safety climate, social, organisational and environmental factors are becoming more prominent, although as yet mostly in the qualitative rather than qualitative literature.

The factors/ motivators associated with effective NIHL (including factors associated with HP use from qualitative studies) can be considered in terms of regulation (motivated by legislative requirement), management (company noise policy; commitment from senior management; demonstrated budgetary savings; cost benefit/ noise control effectiveness), workplace culture (management and supervisor example in wearing HP (role models); immediate behavioural feedback; clearly marked and signed HP zones; noise levels constant and unchanging; positive support from peer groups; unionised workplaces), characteristics of the intervention (multidisciplinary teams had responsibility for planning and implementation; regular and sustained follow-up; mostly change effected by engineering controls; needs assessment and personalised interventions and local solutions), and individual qualities (individual awareness of exposure to actual sound levels; higher educational background; use of humour; recognition that hearing loss effects not only individual but also family members; .

6.2. Industry and Stakeholder views

The background and results of this study (Prevention of NIHL), in addition to results of the Epidemiology of NIHL (Project 1) study were presented to industry and stakeholder representatives at the Symposium on Noise-Induced Hearing Loss, School of Population Health, University of Auckland. 29th November 2010. Comments and feedback was sought on the research and is summarised below. The key issues identified at the Symposium were categorized under the following headings;

Legislation and enforcement

It was felt that regulation and enforcement was the key issue in the prevention of NIHL. That in the 1980's the role of the Department of Labour was more prominent and preventive, occupational health nurses undertook pre-employment audiograms, sound level surveys were undertaken by Labour inspectors and courses were also available. In addition, the Department of Labour had technical experts that could and did provide free advice for noise control and management and that there was the perception that there were more Labour inspectors and nurses working in and with industry. It was felt that future, enforcement activities could be implemented in a positive way, rather than a negative narrow compliance focus, and that enforcement activities should be the control at noise source.

Change in culture

Participants highlighted that a change in industry and society culture was needed. It needed to be more preventive rather than reactively focused. The social acceptance of some control strategies (wearing PPE) is changing but is a slow process. It was felt that youth currently entering the workforce are more aware of safety issues surrounding noise and hearing loss. However, this approach should be supported and promoted much earlier in the school system (pre-school, primary and secondary schools). A key issue was that a change in culture to make loud noise exposure unacceptable and that hearing was sense "to be treasured", needs to be at the forefront of any national programme. However, it was noted that in the current employment relations environment, workers are afraid to raise noise issues with employers for fear of their jobs, especially in small businesses.

Intervention strategies

In addition to enforcement and cultural changes, suggestions were outlined for intervention and programme development. Some concepts to incorporate included; the concept of a dB tax for work and leisure environments for failure to adequately control noise exposure; noise control is not a safety issue, it is an engineering issue; demonstrate that noise control at source options are cost-effective and that they can save money in the long term for employers; potentially provide some form of tax relief possibly for noise reduction efforts, in a similar fashion to incentives for insulation installation in houses to improve power savings and energy efficiencies etc; top management buy in and commitment is essential; get buy in from master trade ITO's with co-ordinated national strategy led by Department of Labour; promotional material/ media needs to be positive and amusing rather than negative and confrontational.

Surveillance

Participants expressed the view that surveillance was a key issue for the future prevention of NIHL, and that surveillance of noise exposures industry in addition to audiometry was important. The surveillance strategy needed to be appropriately resourced and linked to a national framework.

Advice and resources

It was felt that an agency should be set up to provide advice to industry on how to control noise at source in a cost effective way; the benefits of occupational health centres (primarily with occupational health nurses) established in the 1980's in key industrial areas in the major cities were highlighted, they provided a focus for OHS activities and had skilled OHS staff who undertook surveillance and advisory roles to businesses and were very effective; a question was asked on what had become of the national database of audiograms, that were compiled in the 1980's and 1990's through the OH centres, presumably then with the Department of Health.

6.3. Future areas for research

In addition, areas for future research have been identified as a consequence of this study and developed as recommendations from the International Symposium. They include further detailed case study research on control of noise at source strategies in construction, agriculture and manufacturing industry sectors particularly in relation to small enterprises; more extensive sound level surveys and personal sound exposure measurements in cafes and preschools and assessments of noise management strategies in these sectors; research into the efficacy of enforcement strategies and tools (Codes of Practice) in relation to compliance with legislation and standards of noise management and further research into the management of noise in small, medium and large enterprises. How is noise managed? What are the driving factors and barriers to the effective management of noise? Concepts of “best” or “good” practice? and further intervention effectiveness research into the evaluation of noise management strategies

6.4. Limitations of the study

The industry sectors and companies selected for this study were considered representative for noise exposure levels in these sectors throughout the country, but it is an obvious limitation from a surveillance perspective that many sectors with potential high noise levels and many other occupations were not included. This limitation could easily be remedied in future surveys by extending the range of industry sectors and companies studied.

The case study design was used in this research, as unlike aetiological studies where large samples, randomization, and blinding are typically required, intervention effectiveness studies utilise case studies of different settings in which to test the programme theory for prevention effectiveness (Rogers et al, 2000; Kristensen, 2005). The small sample size utilised in this case study approach (n=33), however, remains a limitation of this study. Increasing the number of cases surveyed would improve the representativeness of these findings.

The main risk of bias was related to the enlisting of companies, the majority of which were initially rather reluctant to participate in the study. Although some of the reasons for declining participation such as time commitments or organisational changes may not be related to noise exposure levels, it does represent a problem that some companies whose sound levels were high and resources limited may have exhibited adversity to entering the study, thus skewing the data towards lower sound level estimates and, accordingly, underestimation of exposure levels. However, it is also conceivable that companies that have effectively solved a noise problem would be less interested in participating for that very reason.

7.0 Conclusions

Literature Review

1. The evidence identified and collated in this review suggests that NIHL prevention is a complex issue without simple solutions. Effective interventions will require a combination approach, taking the best strategies from different types of intervention. In the intervention studies identified, the best of these approaches combined “high level” interventions (e.g. active management targeted with greater use of noise elimination, design and engineering noise controls). The least effective contained a lower level component (e.g. person-centred behavioural approaches with little management support to promote the wearing of personal hearing protection).

2. The review and critical evaluation of the recent literature this study has identified five key features associated with more effective NIHL prevention (legislation and enforcement, leadership, multifactorial interventions, implementation of engineering and design controls, and one-off training interventions). Reviewed studies varied widely in intervention type but interventions to promote the use of personal hearing protection dominated. Most interventions were conducted in the USA amongst white, middle-aged male workers, so the evidence may not be directly applicable to women or indigenous workers. A range of industries was represented with manufacturing, mining, construction and agriculture the top four. In agreement with previous reviews (Verbeek, Kateman, Morata, Dreschler et al., 2009), the overall methodological quality of studies was weak. However, findings were sufficient to make recommendations for future prevention studies in NIHL.

3. There is currently limited evidence for the effectiveness of interventions developed from behavioural psychology models to prevent NIHL. However, this may be explained due to;

   1. *Limitations of the models utilised*. To date most of the interventions used models which focused on personal attitudes and motivations alone (i.e. HPM and EPPM). More promising models are ecological in scope, and recognise the social, organisational and environmental influences on worker behaviour (e.g. LaMontagne et al 2004), and (possibly) the different stages of the change process at all levels.
   2. *Nature of the intervention developed*. The behavioural models were almost always utilised to develop one-off training interventions, or brief written interventions.
   3. *The desired outcome of the intervention* in all cases was to increase use of personal hearing protection. The underlying problems associated with this low ranking approach to noise management (wear time, attenuation, worker attitude) may confound efforts to achieve change, thus making the model appear ineffective.

4. There is insufficient evidence available to determine whether a social marketing framework is effective in developing interventions to prevent NIHL, as no studies were identified that adopted this approach. However, a number of effective interventions and new initiatives demonstrate encouraging aspects of social marketing in NIHL prevention. The most promising include formative research, pre-marketing and re-evaluation, targeting, exchange, and completeness rather than piecemeal attention to the components of the social marketing approach.

Workplace Surveys

5. From the 33 workplaces surveyed, most noise sources could be readily identified. Identification of noise paths in relation to the noise sources was complex as it included indoor

and outdoor environments. However, airborne paths were the primary route for noise, with some cases of structure-borne and duct-borne noise/vibration transmission.

6. There appears to be a lack of prioritization of noise exposure as an issue in the workplaces surveyed, and although noise control options at source were considered by most managers/ business owners, these options were not pursued.

7. Even though it is difficult to generalize and promote noise control strategies across all the industry sectors surveyed as these are site, situation and equipment/ machinery/ task specific, a basic understanding of noise enclosure, isolation, barriers and damping was not evident in these businesses. The potential for administrative solutions should be actively pursued by all industry sectors.

8. Noise exposures from machinery and equipment used primarily in outdoor environments in agriculture, construction and saw mill work remain a complex issue for noise management. However, potential strategies for control include collaborations between industry sector associations, machinery and equipment manufacturers and distributers and government agencies to review manufacture and emission specifications for equipment manufacture or importation. International consensus is needed on appropriate limits on the noise emission from machines and devices accompanied by labels that describe or “declare” the noise emission level under standardized conditions.

9. Employers have the primary responsibility to provide protection for the health and safety of their employees. This protection primarily must be achieved by the design or purchase and installation of machines and devices producing noise levels that will not cause the sound exposure over the duration of a working shift to exceed prescribed limits. The adoption of the “Prevention through Design” (NIOSH, 2010) principles would be a useful mechanism for industry sectors and government agencies to collaborate in designing out equipment and machinery noise emissions.

10. L_{Aeq8hr} values ranged from below 60dB to 95dB for all employees across all sectors. Mean and (median) L_{Aeq8hr} levels ranged from 69dB (70dB) to 91.8dB (94dB). A large proportion (>48%) of L_{Aeq} levels recorded were in excess of 85dB and >62% of L_{Cpeak} levels recorded were in excess of 110dB. Of the “high” risk industry sectors, wood processing/sawmills, engineering manufacturing sites and construction operations and agriculture experienced the highest time average levels. Saw mills, construction and engineering had the greatest percentage of employees exposed to noise levels above 85dB L_{Aeq8hr}. These levels are consistent with data reported in the literature for these industry sectors and also with data from Project 1 (Epidemiology of NIHL; Thorne et al, 2011).

11. Of the “moderate” and “low” risk industry sectors (cafes and preschools), no employees were exposed to noise above 85dB $_{LAeq.8hr}$. These levels are consistent with data reported in the literature for these industry sectors.

12. The results of the compliance assessment in this study provide disappointing evidence that businesses are not identifying, assessing or putting in place and supporting appropriate noise controls strategies for their industry sector. As the owner-manager is the key person, particularly in the small enterprise, it is their values that determine the businesses approach to health and safety management. Many owners however, considered health and safety to be the employees’ responsibility.

13. The predominant noise control strategy in the majority of “high risk” organisations surveyed was that of minimisation, specifically the use of personal hearing protection. The reason behind HPD use in the organisations were complex but was uncorrelated with safety climate assessments. Measured sound level was the main predictor of self-reported HPD use along with perceptions of fewer barriers to noise management. Only one facet of safety climate, personal responsibility for safety, was related to HPD use.

14. Evidence from this study suggests that an employee’s sense of personal responsibility for safety is the main motivator for protective behaviour in the workplaces surveyed rather than management initiatives or leadership. After decades of effort in trying to promote and improve health and safety management at the organisational level, this is disappointing.

15. It is concluded that noise hazards are best managed directly rather than indirectly through attempts to change climate through marketing, training or attitude change. Safety climate is complicated. Different facets have different correlates and implications. The findings from this study suggest that perceptions of safety climate follow, rather than lead, safety management efforts in relation to noise control.

Industry and stakeholder views

16. It was felt that regulation and enforcement was the key issue in the prevention of NIHL. It was felt that future, enforcement activities could be implemented in a positive way, rather than a negative narrow compliance focus, and that enforcement activities should be the control at noise source. Participants highlighted that a change in industry and society culture was needed to make loud noise exposure unacceptable and that hearing was sense “to be treasured”, and needs to be at the forefront of any national programme.

17. A variety of intervention approaches were proposed that included; the concept of a dB tax for work and leisure environments for failure to adequately control noise exposure; demonstrate that noise control at source options are cost-effective and that they can save money in the long term for employers; potentially provide some form of tax relief possibly for noise reduction efforts, in a similar fashion to incentives for insulation installation in houses to improve power savings and energy efficiencies etc; top management buy in and commitment is essential; get buy in from master trade ITO’s with co-ordinated national strategy led by Department of Labour; promotional material/ media needs to be positive and amusing rather than negative and confrontational.

18. Participants expressed the view that surveillance was a key issue for the future prevention of NIHL, and that surveillance of noise exposures industry in addition to audiometry was important. The surveillance strategy needed to be appropriately resourced and linked to a national framework.

19. It was felt that an agency should be established to provide advice to industry on how to control noise at source in a cost effective way.

Proposals for intervention

20. To become of national significance to industry and other government agencies the Prevention of NIHL needs to be identified and resourced as a priority. The Prevention of NIHL is not identified as a national priority under the WHSS 2015, nor as a priority in the WHSS National Action Agenda (2010), nor as a priority in the Construction Sector Action Plan 2010 -

2013 (2011). However, it has been included as a priority in the Occupational Health Action Plan (2011).

21. Community wide (leisure and home) intervention strategies such as the National Foundation for the Deaf (NFD) “Noise Induced Hearing Loss Project” need to be inter-related with workplace (occupational) initiatives. Unlike the consequence of other hazardous exposures, NIHL is linked to both work and leisure activities and the “administrative” separation of these components make effective prevention/ management interventions difficult.

22. Evidence suggests that the Prevention through Design (PtD) initiative developed by NIOSH (2010) could be successfully applied to reduce the noise exposure of equipment and machinery used in “high” risk industry sectors. Through utilizing the four functional areas (research, policy, practice, and education) of the PtD process, the PtD approach consists of developing collaborations or partnerships, procedures, resources, implementation plans, design strategies, case studies, and research to practice (r2p) initiatives from identification of the problem to implementation.

23. Increased enforcement activity from the Department of Labour is seen as an important part of a multilevel national strategy for the prevention of NIHL. In addition, the potential for introducing into New Zealand legislation a strata of action levels similar to those recently introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards. For example a lower action level at 80dB(A) where noise assessment, training and the provision of information is required, and an upper action level at 85dB(A) where noise control measures become mandatory would similarly reinforce the existing standards.

24. There have been significant changes in expectations with respect to policing the requirements of the UK noise regulations. These could be very applicable in the New Zealand context. They include - less reliance on PPE; much more of a risk based approach; much better compliance with the duty to reduce noise by engineering means is expected; risk assessments should identify a programme of work; less assessment and "process", more Action is expected; if solutions have been identified "stop assessing and start controlling"; health surveillance is required above 85dB(A) which can be considered to be "a tax on failure to control the risks".

25. Evidence suggests that industry specific intervention strategies for “high” risk industry sectors can be effective. Research found that increased awareness, prominence, self-efficacy, economic and regulatory incentives, and managerial commitment are the most promising enablers of the adoption of effective control. The findings suggest that this may be achieved by visits from regulators, the influence of peers and role-models, and by other social marketing strategies. Raising the awareness of the potential benefits of effective noise control by developing easily accessible and useable noise control cost-benefit models and templates is also suggested. Business owners and managers could access these templates from government or industry websites.

26. A variety of “best” or “good” practice models for noise control have been identified. These include noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding. In addition, the introduction and continued promotion of “buy quiet” purchasing policies by industry sectors and business owners, is seen as an important component of these best practice models.

27. Surveillance schemes for occupational hearing loss are identified as a key strategy in effective noise management programmes. Surveillance for occupational hearing loss is

primarily about providing information to the employer to assist in their duty to manage risks to their employees. In addition, surveillance of workplace noise exposure is vital to prevention of NIHL because it can identify the most problematic industries, occupations and tasks and because it can be used to evaluate the effectiveness of intervention activities.

28. At the organisational level, evidence suggests that the utilisation of intervention strategies designed for small businesses (employee count between 1-19) is effective. Small businesses place more reliance on the use of HPDs and much less reliance on hazard control using structured programme involving engineering, administrative and maintenance controls (Williams et al, 2008). Of the “high” risk industry sectors (agriculture, construction and manufacturing) identified in this report, over 90% of enterprises within these sectors have less than 20 employees (NZ Statistics, 2010).

29. A range of initiatives providing technical advice and support for primarily small enterprises have been developed and trialled in Australia, UK and Europe with varying levels of success. These have been reviewed extensively by Legg et al. (2009). Many of these initiatives could be very appropriate for the effective management of noise in New Zealand.

30. Interventions need to be cyclical and on-going, from needs assessment, intervention development, implementation and evaluation to renewed assessment of needs (Laird, et al., 2010). Given the risk of NIHL in NZ industry, commitment is required at national as well as organisational levels to develop strategies for noise injury prevention including those that are suitable for small businesses (Hasle & Limborg, 2006).

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Appendix 1

Prevention of Noise Induced Hearing Loss: Literature Review

Please visit http://www.acc.co.nz/preventing-injuries/at-work/workplace-health-issues/PI00081 to download this document.

Appendix 2

Noise Assessment Report Form (Survey 1 – Noise at Work)

Noise Assessment Report Form (Survey 1 – Noise at Work)

Organisation: **Date:** **Location:**

	Identify Noise Issue	Obvious Treatments	Changes Proposed
1.Sources: 1.1 Mechanical: • Impact • Vibration • Rotation 1.2 Aerodynamic: • Pneumatic • Fan 1.3 Turbulent flow: • Duct • Pipe 1.4 Other: • ( ) • ( ) • ( )	 Yes No ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐		
2. Paths: 2.1 Airborne: • Open air • Reverberant space • Barrier 2.2 Structure borne: • Building • Coupling to surface 2.3 Duct-borne: 2.4 Other: • ( ) • ( ) • ( )	 Yes No ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐		
3. Receivers: 3.1 No. affected: • Operator(s) • Bystander(s) • Other 3.2 Location: • Operator(s) • Bystander(s) • Other 3.3 HP Worn: • Operator(s) • Bystander(s) • Other	 Yes No Number: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐		

3.4 Other comments:			

Appendix 3

Noise Conformance Report Form (Survey 2 – Noise at Work)

Appendix 3

Noise Conformance Report Form (Survey 2 – Noise at Work)

Requirements	
1. Employers must provide a safe place of work (HSE Act, S.6) • Take all practical steps so that no employee is exposed to noise in excess of the exposure limits. Comments:	Yes ☐ No ☐
2. Employers must identify hazards (HSE Act s7(1)(a)) • Employers to carry out preliminary noise surveys to identify possible noise hazards. (This does not need to be done by a "competent" person). Comments:	Yes ☐ No ☐
3. Employers must assess identified hazards to determine whether they are significant (HSE Act s7(1)(c)) • Employers to arrange for detailed noise surveys to be carried out to assess noise hazards to determine if these are significant.(Must be done by a "competent" person). Comments:	Yes ☐ No ☐
4. Employers must control significant hazards by elimination, isolation, or minimising the likelihood of the hazard causing harm (HSE Act s8-10). • Employers must investigate, and if practicable, control noise at source. • Employers must isolate noise sources away from employees where practicable. • Employers must provide hearing protectors when noise hazards are not able to be eliminated or isolated, and while work is being carried out to control noise at source. Comments:	Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐
5. Employers must monitor the health of employees who have been exposed to a significant hazard (HSE Act s10(2)(e)). • Employers must arrange for hearing tests (audiometry) to be carried out on all employees who work in an area with hazardous noise. This must be done by a "competent" person when an employee starts work, and at intervals of no longer than 12 months thereafter. • DoL must be notified if an employee has a hearing loss that meets the accepted criteria. Comments:	Yes ☐ No ☐ Yes ☐ No ☐
6. Employers must provide information, training and supervision to staff in relation to hazards in the workplace (HSE Act s12-14). • Employers must provide information to employees on identified hazards. • Employers must provide training and/or supervision to employees in the safe use of plant or use of hearing protectors. Comments:	Yes ☐ No ☐ Yes ☐ No ☐

7. Organisational data	
7.1 Previous sound level surveys	Yes ☐ No ☐
7.2 Previous results of audiometry	Yes ☐ No ☐
7.3 Previous H & S audits	Yes ☐ No ☐
7.4 Other documentation …	Yes ☐ No ☐

Appendix 4

Safety Climate/ Culture Questionnaire (Survey 3 – Noise at Work)

Massey University

Reg	Ind	Sect	CoName

Noise at work

Thank you for agreeing to take part in our research. This questionnaire will ask about noise and health and safety at your work.

- By 'hearing protectors' we mean earmuffs or earplugs.
- Please read the information sheet before answering the questions.
- Please do not write your name on this questionnaire.

Part A – Noise at Work

PLEASE TICK ONE BOX ONLY

	Never	**Rarely**	**Some-times**	**Often**	**All the time**
1. At work do you have to shout to be heard by someone who is working beside you (arm's length away)?	0	1	2	3	4
2. When exposed to noise at work do you wear earmuffs or earplugs?	0	1	2	3	4

Part B - Noise at Work

The following questions are about noise in your workplace. Please mark the number that best represents your answer.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agre e**	**Strongly agree**
1. My hearing will ***not*** be damaged by noise at work.	1	2	3	4	5
2. The noise at work does ***not*** bother me.	1	2	3	4	5
3. My work would be less stressful if it was quieter.	1	2	3	4	5
4. I do ***not*** have time to do anything about the noise at work.	1	2	3	4	5
5. Earmuffs or earplugs would stop me from hearing what I want to hear.	1	2	3	4	5
6. I would feel better if my workplace was less noisy	1	2	3	4	5
7. I can ***not*** reduce noise at work.	1	2	3	4	5
8. Earmuffs and earplugs are uncomfortable.	1	2	3	4	5
9. I like it when it is noisy.	1	2	3	4	5
10. I am ***not*** sure that I can use earmuffs or earplugs correctly.	1	2	3	4	5

Please mark the number that best represents your answer.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
11. Management is ***not*** interested in health and safety	1	2	3	4	5
12. It would make no difference to my hearing if it was quieter at work.	1	2	3	4	5
13. Listening to loud noise at work does ***not*** affect hearing in old age.	1	2	3	4	5
14. I know how to use my earmuffs or earplugs.	1	2	3	4	5
15. It is difficult to make equipment quieter.	1	2	3	4	5
16. My mates at work don't worry about noise.	1	2	3	4	5
17. I work better if it is noisy.	1	2	3	4	5
18. Noise stops me from being able to think.	1	2	3	4	5
19. Noise has bad effects on my health (besides loss of hearing)	1	2	3	4	5
20. Noise only affects hearing in people who have sensitive ears.	1	2	3	4	5

.

Part C – Health and Safety at Work

The following questions are about safety in your workplace. Please mark the number that best represents your answer.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
1. Everyone has an equal chance of having an accident	1	2	3	4	5
2. In the normal course of my job, I do ***not*** encounter any dangerous situations	1	2	3	4	5
3. People who don't follow safety rules are responsible for what happens to them	1	2	3	4	5
4. Safety works until we are busy then other things become more important	1	2	3	4	5
5. If I worried about safety all the time I would ***not*** get my job done	1	2	3	4	5
6. People who follow safety procedures will always be safe	1	2	3	4	5
7. I cannot avoid taking risks in my job	1	2	3	4	5
8. Accidents will happen no matter what I do	1	2	3	4	5
9. It is ***not*** likely that I will have an accident because I am a careful person	1	2	3	4	5

The following questions are about safety in your workplace. Please mark the number that best represents your answer.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
10. Not all accidents are preventable, some people are just unlucky	1	2	3	4	5
11. Everybody works safely in my workplace	1	2	3	4	5
12. All the safety rules and procedures in my workplace work	1	2	3	4	5
13. It would help me to work more safely if:					
my supervisor praised me for safe behaviour	1	2	3	4	5
safety procedures were more realistic	1	2	3	4	5
14. When I have worked unsafely it has been because:					
I didn't know what I was doing wrong at the time	1	2	3	4	5
I needed to complete the task quickly	1	2	3	4	5
The right equipment wasn't provided or wasn't working	1	2	3	4	5

Part D Background Information

We would like some background information. Please tick the relevant boxes.

D1. Are you: ❑ Male ❑ Female

D2. In what year were you born? ______________________

D3. Which ethnic group do you identify with? ___________________________

D4 Have you had previous jobs that were noisy?

❑ Yes (please go to question 5) ❑ No (please go to question D8.)

D5. If yes, what were the jobs?

____

D6. How long did you work in these jobs?____

D7. Did you wear hearing protection when you were doing these jobs?

❑ Yes ❑ Sometimes ❑ No.

D8. Do you have a hobby or sport that may be noisy (for which some people wear earmuffs or earplugs)? ❑ Yes ❑ No

What hobby or sport?

____

D9. Do you wear earmuffs or earplugs when doing this hobby or sport?

❑ Yes ❑ Sometimes ❑ No.

Thank you very much for completing this survey.

Please post it back to me in the reply paid envelope provided or else send it to:
Freepost 114094
Dr Ian Laird,
Centre for Ergonomics, Occupational Safety and Health
Massey University, Private Bag 11222 , Palmerston North