New Zealand Acoustics

Volume 24, 2011 / #3

ISSN 0113-8359

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New Zealand Acoustics

Volume 24, 2011 3rd Quarter

Features

Regulars

Cover Photo: Turbine Blade Convoy for Scout Moor Wind Farm passing through Edenfield

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New Zealand Acoustics is published by the Acoustical Society of New Zealand Incorporated, PO Box 1181, Auckland, and is delivered free of charge.

Contributions to the Journal are encouraged, and may be sent directly to the Editor either by email, or by post c/o the Acoustical Society of New Zealand Incorporated, PO Box 1181, Auckland.

From the President and Editor

From the President

Dear Members,

Greetings to you all this fine Spring edition! As we emerge blinking from winter, it's great to be able to say that our fine Society is also emerging from its chrysalis.

Back in the June / July magazine, we were excited to think that the new Membership regime was imminent, having been voted in with a significant majority. In the first three months of the Membership being activated, there has been a positive initial response to the applications for membership. At the time of writing, the Committee has received :

- 2 applications for Affiliate grade – both have been accepted.
- 7 applications for Member grade – 5 have currently been approved with 2 pending.

While we were expecting perhaps a stronger response, it has meant that the Committee is not being overrun with applications at any one time, and is able to objectively review not just the applications but the process of approvals itself. There have been plenty of discussions behind the scenes (as it were) regarding the wording of some parts of the application, encouraging all reviewers to ensure that all relevant documentation is received and in order, and of course what the certificates of membership look like!

We are aware that there are plenty of current ASNZ members who are intending to formalise their Membership. We are also aware that the Society's mailbox might need to be checked more frequently than has

perhaps previously been the case...

As I said last edition, please visit the website at www.acoustics.ac.nz/membership.php You will find there the link to the membership form, which I

Publication Dates and Deadlines

New Zealand Acoustics is published quarterly in March, June, September, and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 2 weeks prior to this.

Society Membership

Membership in the Acoustical Society of New Zealand is open to anybody interested in acoustics. There are no entry requirements. Members receive benefits including;

- Direct notification of upcoming local events
- Regular mailing of Noise News International
- Reduced charges for local and national Society events
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To become a member of the society, visit www.acoustics.ac.nz or contact the Secretary.

encourage you to download and fill out to keep the Membership growing.

Other progress made recently has been the development of a web-based mailing list of the ASNZ membership. This has replaced our outdated locally-held database and made the tracking of changes to membership much simpler and for relevant members of the Committee. While only the Secretary and Treasurer have editing rights, the availability of the database means than the Committee can readily check to see that the Members' details are correct, and action any changes directly with Larry or Jon.

Finally, my congratulations to our Editor John on the arrival of his new daughter. Not only is John now absorbed with such fatherly duties as nappy-changing and disrupted sleep, he has still also managed to collate this edition, a phenomenal multi-tasking effort if ever there was one.

Best regards to all until the next edition.

Rachel Foster

Editor's Ramble

I have to apologise for the delay to this issue of the journal. I wanted to blame the distractions of the Rugby World Cup, but in fact I put off the final formatting of the documents due to the birth of our second baby girl; I was recently reminded that it is life events like these (births, deaths, weddings, etc.) that are really important, and that other commitments, (like preparing examination questions) are less so.

With the arrival of another child I discovered that there had been a recent change to the procedures for screening babies for hearing loss since the birth of my first daughter in 2009. This change is the Universal Newborn Hearing Screening Programme, which is free of charge for all newborns in NZ and was implemented in our district in 2010.

The programme aims are as follows:

- Babies are to be screened by 1 month of age
- Audiology assessment completed by 3 months of age
- Initiation of appropriate medical and audiological services, and Early Intervention education services, by 6 months of age.

I understand that this programme was a key strategy pursued by the NFD since 2001.

Now on to this Issue. The first paper is a substantial contribution that discusses various strategies for preventing hearing loss in the workplace; I regret that I have had do some editing to reduce the length of this paper due to space limitations. I think that the table on page eight is particularly helpful in summarising the various strategies proposed to date. A recent finding about the mechanisms of hearing loss is briefly described in a snippet on page 36.

The next feature article is from Sweden and reports on some results from experimental measurements using a sandwich floor construction. This paper contains some vey interesting visualisations of the excitations.

The new Ministry for Science & Innovation (MSI) has provided some information about their support for business on page 24. I encourage you to visit the MSI website and consider how you might use the opportunity to do some research, particularly if you can support projects for university Engineering students or researchers!

The following article adds some further information to recent discussions about limits for wind turbine noise. This is an issue that has featured frequently in the pages of this journal (see, for example, Volume 23, Issue 3). As a wind turbine researcher myself, I could not resist the opportunity to use an image of wind turbine blades being transported through a village (a residential area) on the cover of the journal. I must apologise for the quality of some of the text in the tables of this paper. I was not able to obtain higher resolution copies of the text. Email/send me your complaints! (I would love more feedback and suggestions for future issues).

The final paper in this issue has been reprinted (in a slightly abridged form) from the Resource Management Law Journal. It discusses the use of some words in Court that have very specific meanings and should be used with care.

Once again this issue includes a cryptic crossword and solutions to the previous (fiendish) questions.

Best wishes to you and your families.

John Cater

Effective Strategies in the Prevention of Noise Induced Hearing Loss

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A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

Effective strategies for the prevention of noise induced hearing loss have occupied researchers, OHS practitioners and enforcement agencies for many years. This paper reports on the second part of a major study on the epidemiology and prevention of NIHL in New Zealand. The objective of the project was to evaluate existing work-related interventions to reduce NIHL, to identify critical factors in the development and implementation of such strategies, and to propose strategies/interventions where current interventions are considered ineffective. In addition, the research examined those aspects of workplace culture that affect decision-making around NIHL. A systematic review of the research literature was completed specifically focussing on the effectiveness of interventions in the prevention of NIHL and five key strategies were identified. Data collection methodologies were developed for specific industry sectors which were segregated into high, medium and low sectors of risk of NIHL. In addition to area noise measurements and personal dosimetry, assessments of the organisation's conformance to current noise management standards and safety climate data were undertaken. As anticipated, area and personal noise exposures were found to vary considerably within the "high risk" (agriculture, manufacturing and construction; range: LAeq 8hr 80 - 90 dB), "moderate risk" (cafes and restaurants; range LAeq 8hr 60 – 75 dB) and "low risk" sectors (pre-schools; range LAeq 8hr 70 - 80 dB). Data on enterprise conformance with the Approved Code of Practice for the Management of Noise in the Workplace indicated that most enterprises surveyed did not conform to the specific requirements of the Code in relation to noise management. As a consequence of the research, a comprehensive multi level intervention strategy is proposed.

Introduction

Effective strategies for the prevention of noise induced hearing loss (NIHL) have concerned OHS practitioners and researchers for decades. This concern however, has turned to consternation in recent times, by the fact that although the causative mechanisms for NIHL is relatively well understood, exposure response relationships are well characterised, exposure and primary health effect is easily measurable and regulations based on these attributes have been in effect for decades (Daniell et al, 2006), the prevalence and incidence of NIHL remains a significant occupational health problem for society.

For New Zealand, noise induced hearing loss 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 (OH&S JRP) of the Health Research Council 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 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 nonwork-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.

The objective of the second project and topic of this paper 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. 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.

This paper provides an overview of the evidence from recent systematic evidence based reviews of interventions in the prevention of noise induced hearing loss and identifies the barriers and enhancers of effective interventions, presents data from a recently completed survey of workplaces in New Zealand

and outlines a framework for a proposed comprehensive multi- level intervention strategy.

Evidence From Systematic Reviews Of The Literature

A long awaited evidence based review of interventions to prevent occupational noise induced hearing loss has recently been reported (Verbeek et al, 2009). Twenty one studies were included in the review. Of those, one study evaluated a strategy to reduce noise exposure, fourteen studies with 75,672 participants evaluated hearing loss prevention programmes (HLPPs), and six studies with 169 participants evaluated hearing protection. The overall quality of studies was reported as low.

One ITS study evaluated the effect of new legislation in reducing noise exposure. It found that the median noise level decreased by 27.7 dB(A) (95% confidence interval (CI) 36.1 to 19.3 dB) with a change in trend in time of 2.1 dB per year (95% CI 4.9 to 0.7). A hearing protection study in army recruits compared those exposed to impulse noise with non-exposed recruits. The odds ratio (OR) for hearing loss was 3.0 (95% CI 1.1 to 8.0) despite hearing protection. In four studies, workers in a HLPP had a 0.5 dB HL greater hearing loss at 4 kHz than non-noise exposed workers (95% CI 0.5 to 1.7). In one study, the hazard ratio of hearing loss was 3.8 (95% CI 2.7 to 5.3) for workers exposed to noise compared to non-exposed workers. In three studies, a high quality HLPP had a lower risk of hearing loss than lower quality programmes. Noise attenuation ratings of hearing protection under field conditions were consistently lower than the ratings provided by the manufacturers.

The authors concluded that there is low quality evidence that legislation can reduce noise levels in workplaces. The effectiveness of hearing protection devices depends on their proper use. There is contradictory evidence that HLPPs are effective in the long-term. Even though case studies show that substantial reductions can be achieved, there is no evidence that this is realised in practice. Better implementation and reinforcement is needed. Better evaluations of technical interventions and long-term effects are needed. Audiometric and noise measurement data are potentially valuable for such studies (Verbeek et al, 2009).

A systematic evidence based review of literature (1999– 2008) evaluating occupational NIHL prevention strategies was also undertaken as a part of the Prevention of NIHL project undertaken in New Zealand (Johnston, 2009). In particular, the review examined specific features of effective NIHL interventions, and extended the evidence based on which workplace NIHL interventions could be developed and evaluated. The literature review addressed the following questions:

1. How effective are strategies implemented in workplaces to prevent NIHL or noise exposure? What are the barriers to implementation of these strategies?
2. What factors are associated with effective workplace interventions to prevent NIHL or noise exposure, particularly which relate to behavioural psychology or social marketing approaches?

It has been recognized that occupational intervention studies are under reported in the peer reviewed literature (Beahler, Sundheim &Trapp, 2000). To address this, the grey literature was also searched by accessing relevant websites to seek quality evidence for NIHL prevention programs from industry or regulatory bodies. Opinion or editorial pieces were excluded. Only English language publications were accepted. Extracted information was evaluated to determine the strength of the body of evidence supporting emergent aspects of NIHL prevention (NHMRC, 2008). The review included three key components of the body of evidence matrix: study quality (evidence base assessed using the NHMRC criteria (1999) for levels of evidence, study consistency, and impact (size of the effect of the intervention).

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.

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.

While the hierarchy of noise control is an important over-arching 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, multifactorial 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).

The evidence identified from this systematic review has been presented in the NHMRC body of evidence framework for each key strategy in Table 1. 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 (Johnston, 2009).

The key findings of the review are summarised below, including key barriers and enablers of the strategy:

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

Table 1. Strategies to prevent NIHL in body of evidence framework

Key strategy 1: Legislative change		
	Grade, Body of evidence	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 concur-rent controls provide consistent evidence supporting legislative change. Review and cross-sectional study concur.
Workplace impact	B-Good Substantial work-place impact	Clinically significant outcomes in risk of STS(1 study), self reported use of HP (2 studies) and noise exposure (1study)
Key strategy 2: Championed by leaders		
Evidence base	D-poor Level IV studies, or Level I-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 & management support to positive outcomes
Workplace impact	C-satisfactory Moderate work-place impact	More noise controls implemented/ improved staff perceptions but not reflected in noise exposure (2 studies). Good improvements in all outcomes (1). Improved management commitment and employee participation (1)
Key strategy 3: Multifactorial approach		
Evidence base	D-poor Level IV studies, or Level I-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 work-place impact	Moderate-large in-creases in HP use in 4studies
Key strategy 4: Implement engineering		
Evidence base	D-poor Level IV studies, or Level I-III studies with high risk of bias	All level IV studies
Consistency	A-Excellent Most studies consistent & inconsistency may be explained	Consistent reductions in noise exposure, but acceptance (to workers and managers) and sustainability unknown
Workplace impact	C-satisfactory Moderate work-place impact	Only immediate effects on noise exposure reported
Key strategy 5: One-off training		
Evidence base	D-poor Level IV studies, or Level I-III studies with high risk of bias	Three level II studies Two level II studies with high bias (dropouts 34-47%) and five level IV studies
Consistency	B-Good Most studies consistent; 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 work-place impact	Size of effects on reported or intended HP use insufficient to prevent NIHL

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 opinion

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 nonintervention, 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.

The influence of workplace safety climate, an important concept in occupational health and safety literature, has been addressed in some of the NIHL prevention literature. Safety climate may be described as reflecting the priority given to safety in an organisation (or safety culture). Although there appears to be no general consensus on what constitutes safety climate, employee perceptions of management commitment to safety are fundamental (Griffiths 1985; Hofmann, Jacobs et al. 1995).

Evidence from Survey of Workplaces

A primary objective of the Prevention of NIHL project was to undertake workplace studies to (1) 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) determine whether identified "high risk" sectors and occupations are conforming with current industry recommendations (e.g.. Codes of Practice) and standards to prevent NIHL and (3) 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.

The survey of workplaces 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. 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.

A list of high, moderate and low risk industry sectors was developed by reference to 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)

The industry sectors identified included those shown in Table 2. 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.

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. Data collection for the workplace surveys were 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

Table 2. Industry sectors selected for survey of workplaces 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 Residentialbuilding, 3101 Roadconstruction, 3212Demolition
Moderate risk	Hospitality	H – 4511 Cafes, restau-rants and bars
Low risk	Education	P – 8010 Preschool,8021 Primary

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"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. Data collection instruments were modelled after those developed by Purdy and Williams (2002) and Williamson et al. (1997).

Noise at Work Survey (Evaluation of existing noise sources 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.

Noise sources, paths and controls

Generally noise sources could be readily identified in the workplaces. For the high risk industry sectors, the sources were primarily due 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; 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. i.e. 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 primary route for noise, with some cases of structure borne and duct borne noise/vibration transmission.

The predominant noise control strategy in the majority of organisations surveyed was that of minimization, specifically the use of hearing protection. Although many operations were complex, noise control strategies aimed at the noise source and noise paths but 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. Administrative controls were not used in any of the organisations surveyed.

Noise exposure and dose measurements

Median $L_{Aeq.8hr}$ and L_{Cpeak} levels, dose estimates and percentage of work areas equal to (=) or greater (>) than 85 dB were recorded. Of the "high" risk industry sectors wood process and sawmills and engineering manufacturing sites and construction operations experienced the highest noise exposures with median $L_{Aeq.8hr}$ values of 95 dB, 92 dB and 90 dB respectively. Median L_{Cpeak} levels were similarly high at 130 dB, 125 dB and 120 dB. The remaining high risk industry sectors surveyed (agriculture, bottling and textile industry) had median $L_{Aeq.8hr}$ values of 85 dB, 83.5 dB and 80 dB, and median L_{Cpeak} level of 115 dB, 105 dB and 100 dB respectively.

Noise dose estimates for employees working in these businesses indicated a very wide range of personal exposures (10 – 600%), with wood processing and sawmills, engineering and construction operations experiencing the highest dose estimates and widest dose range. The medium risk industry sector (cafes) surveyed had a median $L_{Aeq.8hr}$ values of 74 dB, and median L_{Cpeak} level of 105 dB. Noise dose estimates for cafe employees ranged between 8 – 26%. The low risk industry sector (preschools) had median $L_{Aeq.8hr}$ values of 70 dB, and median L_{Cpeak} level of 110.5 dB.

However, the noise dose estimate ranges for employees working in preschools (4 – 98%) was very large in comparison to café measurements. Two employees in preschool facilities had one daily dose estimates of 194% and 316%.

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. Data was collected through semi structured interviews, observational data and investigation of archival data and information.

With few exceptions, there was insufficient evidence that the key requirements of the Approved Code were met. In summary;

1. Noise tended to be identified as an issue, and some informal assessments were undertaken (e.g. Difficulty having a conversation). No evidence existed that noise was identified as a significant hazard. i.e. Preliminary noise assessments.
2. Some evidence existed that elimination and isolation strategies were explored to reduce noise exposure, but were not generally utilised. Administrative controls were not used in any of the organisations surveyed.
3. Evidence that minimization (use of hearing protection) tended to be employed as the key control strategy.
4. No evidence that information or training was provided for noise control/ management in the workplace.
5. No evidence that noise monitoring or audiometry was routinely undertaken.

The third survey (Noise at Work – Workplace Safety Culture/ Climate) is currently being analysed.

Development of an intervention strategy in prevention of NIHL

The overall outcome of the Epidemiology and Prevention of NIHL project was to provide recommendations for the development of an effective intervention strategy. A key approach would be to incorporate the conceptual model for intervention research proposed by Goldenhar et al, in 2001. The model attempts to provide an integrating framework for diverse activities; articulate relationships among various types of intervention research; facilitate assessment of the current state of the field in order to guide strategic planning (for example, specific requests for intervention research proposals) and develop a common language to facilitate communication.

The model suggests that the intervention research process is cyclical and progressive and involves three broad research phases of intervention development, implementation and evaluation. It includes a set of five tasks that are important in any intervention research study:

1. Gathering background information and conducting needs assessment on the problem and the range of possible intervention strategies.
2. Developing partnerships with relevant stakeholder groups.
3. Choosing appropriate research methods and study designs.
4. Conducting the research.
5. Reporting on and disseminating findings.

Intervention research can be conducted at levels ranging from simple worksite programmes to national or international policy. LaMontagne and Shaw (2004) expanded this approach to describe a conceptual model that relates directly to occupational health interventions. As well as illustrating the intervention research process, it incorporates the differing levels and focus for evaluation; that is, from the national or international policy level, to the national campaign level, to the local/ organisational programme level.

The first phase of this strategy has been developed by the integration and assimilation of a variety of sources of data and information. The extensive evidence based review of literature on the effectiveness of intervention strategies in the prevention of NIHL, provided useful insights into a complex issue without simple solutions.

The survey of workplaces provided data on the nature and effectiveness of interventions currently used in industry to reduce noise exposure and the incidence of NIHL, to identify the barriers to the implementation of noise management strategies and whether identified "high risk" sectors and occupations were conforming to current industry recommendations. Additional components of the first phase include the safety climate/ culture data in relation to attitudes, values and beliefs around NIHL in the workplace, the social marketing and behavioural psychology perspectives on intervention development and the effectiveness of OHS regulatory instruments.

The second phase of the strategy involves developing partnerships and wider consultation. This would lead to the development of an intervention strategy at National, Industry and Organisational level. Phase three involves development of the strategy, Phase four, implementation of the strategy and Phase 5, evaluation of the strategy with Phase 6, reporting and dissemination.

The development of a national strategy should use a multilayered approach, based on consultation with industry associations, union organisations, government, community agencies and professionals. There needs to be a long-term commitment to the development and resourcing of a strategy for noise injury prevention for New Zealand industry, which can be effectively initiated or incorporated into existing/ ongoing programs. A communications system needs to be established that allows information to flow between all stakeholders and establishment of relevant partnerships for action. Related national strategies include the Workplace Health and Safety Strategy for New Zealand to 2015 and the National Foundation for the Deaf (NFD) National Noise Induced Hearing Loss Strategy.

Another key component of a national strategy involves the hierarchy of legislation, regulations and an approved code of practice encompassing the minimum requirements and best practice principles for the management of workplace noise. In general, minimum requirements are at the legislative top of this hierarchy, with increasing detail on how to meet these requirements presented by advisory codes of practice at the base.

Barriers to meeting regulatory requirements and recommendations (e.g. Lack of access to services, lack of information about machinery noise levels / exposure limits, infrastructure costs, confusion about requirements vs. Recommendations, lack of national consistency) also need to be identified where they exist, so that ways of overcoming these may be addressed in both the government and private sectors (Gunningham and Associates, 2008).

A model industry level intervention strategy for the prevention of NIHL (applicable in New Zealand industry) has been recently developed by Farmsafe Australia (2009).

"The Noise Injury Prevention Strategy for the Australian Farming Community 20092012" provides a structure within which to focus efforts to reduce the incidence, severity and impact of noise injury across all members of the farming community.

The Strategy encompasses noise injury prevention / promotion; service delivery; and quality of life issues, for all members of the farming community who may be already affected by noise injury or are at risk of hearing loss from noise. Suggested actions are congruent with a new model for farm safety adoption, drawing on the experience of farm safety programs and research conducted in Australia over the past 20 years.

The Strategy recognises the existence of other types and causes of hearing loss amongst farmers (e.g. Noisy off farm recreational activities, chemical exposure). However, action to reduce the risks associated with exposure to excessive noise during agricultural production is a matter of priority, to reduce the incidence and impact of noise injury and hearing loss in the farming community" (Farmsafe, 2009).

At the organisational level, the practice of occupational hygiene entails the anticipation, recognition, evaluation, and control of exposures to health hazards in the workplace (Mulhausen & Damiano, 1998). The further "upstream" from exposure one aims, the more likely one is to achieve the preferred goal of exposure prevention versus control. The principle in fundamental to OHS practice, but even so relevant and challenging for implementation in small enterprises/ businesses which constitute the largest proportion of NZ businesses, where the burden of exposures to noise and NIHL lie.

Hasle and Limborg (2006) developed a useful model of intervention research in small businesses. They suggest that researchers focusing on the development of interventions for small business need to study the complete system. Developing that model further in relation to small business interactions with government agencies, highlights the important role of intermediaries in the "embedment" or "ownership" of the intervention in the small business.

Conclusions

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 results of the workplace surveys confirmed that within the industry sectors selected, noise sources were extremely varied, but readily identifiable. Noise controls strategies primarily adopted a minimization approach (use of personal hearing protection devices), with little evidence of consideration of control options at the source of the noise or in the air path (engineering controls). Administrative controls were not utilised in any of the cases examined. In assessing the systems, procedures and activities of the organisations surveyed in relation to the requirements of the Approved Code of Practice for the Management of Noise in the Workplace, not one of the businesses surveyed (n=33) conformed to all the requirements. Noise exposure and noise dose estimates for employees working in these businesses were very wide and personal exposures ranged from 4% to in excess 600% daily dose.

A comprehensive multilevel intervention strategy has been proposed that may provide a useful framework for national, industry sector and organisational intervention design and implementation. 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 (Johnston, 2009).

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Sound Attenuation in a Sandwich Floor

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A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

In modern building construction, where light weight structures are preferred for cost reasons, the sound transmission is often a problem to be considered carefully, hence the many studies addressing this issue. A common floor construction in a lightweight building system is using chipboard plates attached to wooden beams by screws and glue. One drawback with such a system is the propagation of vibrations stemming either from harmonic excitation like surround systems especially at low frequencies and/or transient excitation like human walking. In order to accurately predict the sound attenuation and the losses of such building systems, computationally accurate and efficient simulation techniques are needed. The main objective of the present work is to examine sandwiched floor constructs consisting of one and two layers of chipboards attached to supporting wooden beams. Discontinuities between adjacent boards and between boards and beams are of special interest. On one hand, they affect the kinetic energy loss, due to the acoustic attenuation of evanescent waves in the structure. On the other hand, they also alter the phase shift of the waves as they travel past the different types of discontinuities in the floor assembly. A series of measurements have been performed using two-axis accelerometers distributed over the floor and recorded synchronously. A special focus has been put on investigating the low frequency range (10-600Hz), including transient loads.

Introduction

As lightweight constructions get more and more popular for the obvious reasons of the low cost and ease of construction, noise propagation is and remains an issue in light frame buildings [1]. This challenging problem finds its origin in the low weight, density and stiffness compared to traditional materials. Consequently, more nuisances are reported, related to sound transmission, that might cast a undesirable shadow of discomfort over the lightweight building industry.

Due to the large surface they offer, and to their primary function, floors play naturally an important role in terms of sound propagation. Therefore, it is also critical to understand precisely how sound and vibrations are conducted, transmitted or absorbed by floors. The properties of floors depend strongly on their structure [1-4]. This new study proposes to investigate the behaviour of a sandwich floor. As in former studies [2-3], arrays of accelerometers have been used to simultaneously sense the vibrations at different points along the floor, resulting from a single point excitation. In this case, however, we use a shaker as the excitation rather than a tapping machine.

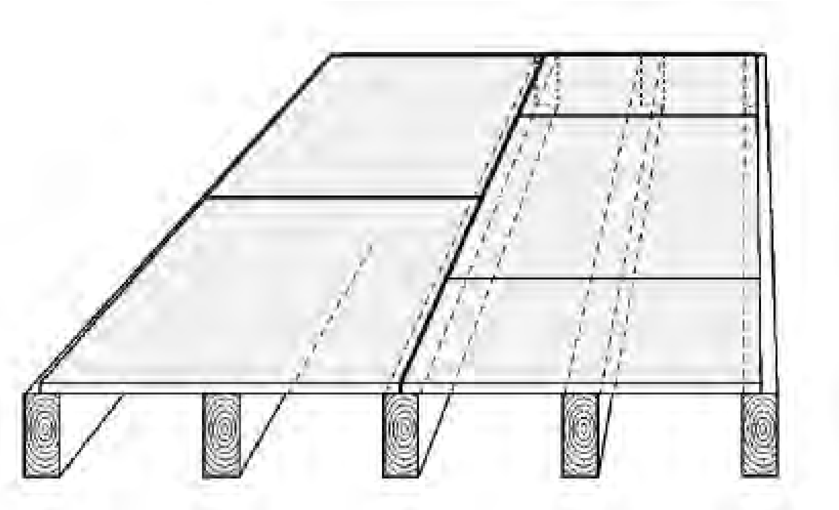

Figure 1: Construction of the floor structure.

Experimental Setup

Floor construct

The floor construct is made from chipboard plates on top of spruce beams. The plates are attached to the beams using screws every 300 mm. This is a common type of floor constructs in modern lightweight building systems in Sweden.

The dimensions of the plates are 1200x2400x22mm and the dimensions of the beams are 60x215x5400mm. In addition to this construct, we have also investigated the case where an additional layer of chipboards has been added on top of the first one. This type of sandwich floor constructs is common in rooms with stricter demands on durability and stiffness i.e. in bathrooms. Figure 1 represents a schematic view of the construct. Note the discontinuities between the different plates.

As the second layer of chipboards is added, the plates in the second layer are shifted to the right with respect to the first layer so that no discontinuities are directly on top on another. The actual floor can be seen in figure 2 and the placing of the second layer can be seen

Figure 2: Picture of the actual tested floor.

Figure 3: Placement of the floors layers within the floor.

Figure 4: The beams and their supports, seen from below the floor.

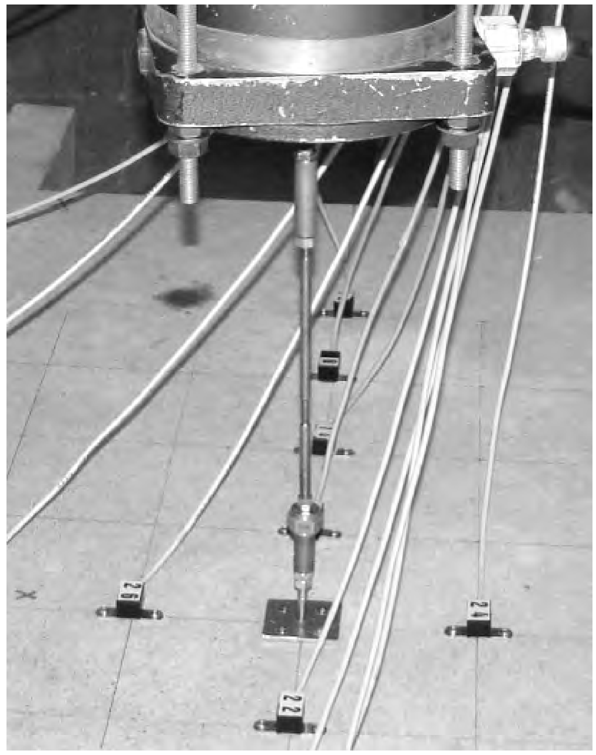

Figure 5: The shaker and the accelerometers surrounding it.

Figure 6: Array of accelerometers along the borders.

in figure 3.

The beams are placed on triangular supports one in each end of each beam and the whole construct is slightly raised above the floor in the test room enabling easy access to underneath the floor as can be seen in figure 4.

Accelerometer setup

The measurements were performed using 27 two-axis accelerometers uniformly distributed over the floor. The accelerometers were placed with 300mm spacing in the direction across the beams and with 600mm spacing along the beams as shown in figure 5. This spacing has been determined to be a good compromise between the spatial resolution and the area covered by the sensor array, given the range of the frequencies we wanted to investigate.

An additional set of 7 accelerometers were placed on the beams, five on the middle of the beams and two placed on the beams on either side of the first shaker position.

As the vibrations in the beams have a much lower magnitude than in the plates the accelerometers on the beams have a higher sensitivity but lower bandwidth (1500Hz compared to 5000Hz). To get the force applied by the shaker a B&K 8200 force transducer was used placed between the shaker rod and the plate attachment as shown in figure 5.

The accelerometers and the force transducer are connected to a computer with a 32–channel acquisition system. The system is capable of synchronous measuring of all the channels up to 100kHz sampling frequency and stores the data in a large and fast temporary buffer before it is transferred to the computer. The acquired data is saved as MATLAB .mat files for later analysis.

In order to get a finer grid over the floor the accelerometers are arranged in a set covering one third of the floor, this set is displaced twice and the measurement repeated accordingly at each position. This whole setup is then repeated for the second shaker position. As the measurements are performed in three different sets the synchronicity over the complete set of accelerometers is lost but is retained within a set.

In order to investigate the behaviour of discontinuities, two other sets of measurements were performed, where the accelerometers were placed along the borders between different plates, as shown on figure 6.

We have also made some walking experiments where two test subjects one male and one female walked over the floor with hard shoes, barefoot and in the case of the male subject with rubber (soft) soles. The test subjects traversed the floor across the beams, on a path between two beams and also on top of one beam.

Measurements

Mode excitation

The very advantage of using frequency sweeps as excitation signals for the shaker is that different floor vibration

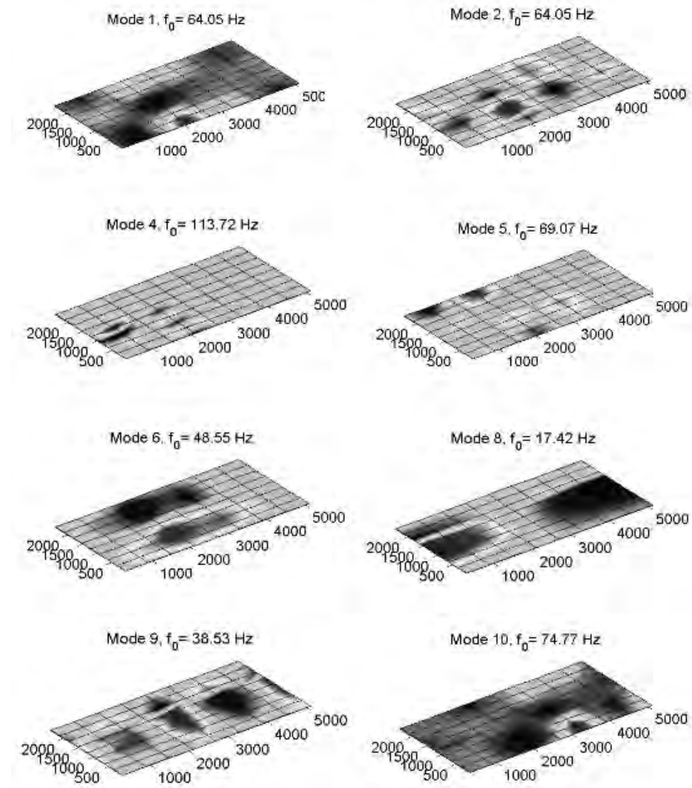

Figure 7: Accelerometer magnitude density plot for the onelayer floor for excitation frequencies corresponding to modes 1, 2, 4, 5, 6, 8, 9 and 10.

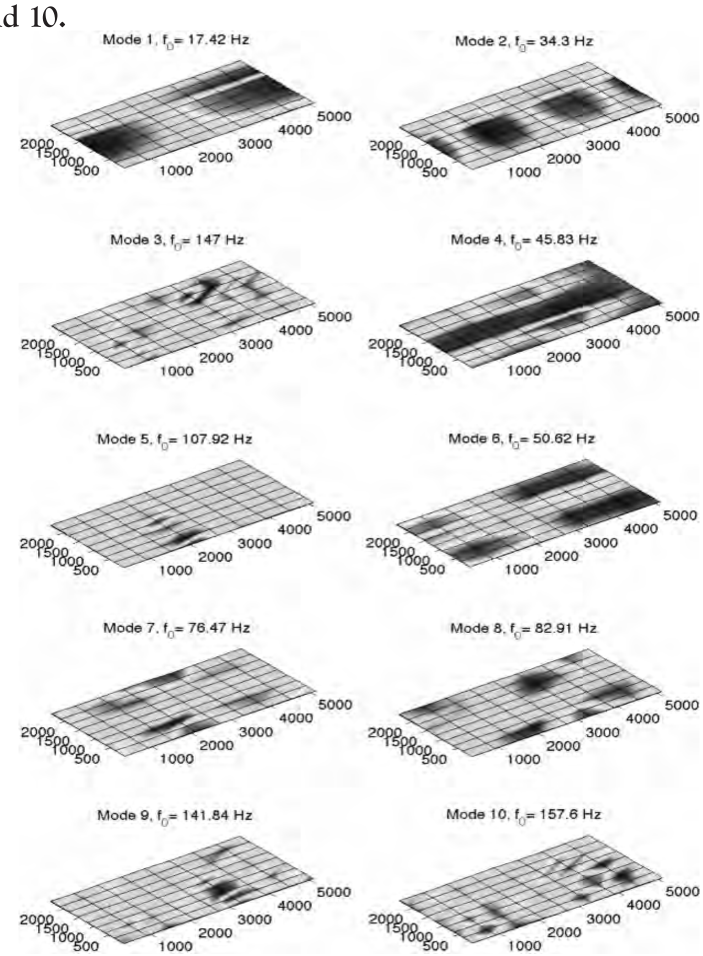

Figure 8: Accelerometer magnitude density plot for the twolayer floor for excitation frequencies corresponding to modes 1 through 10.

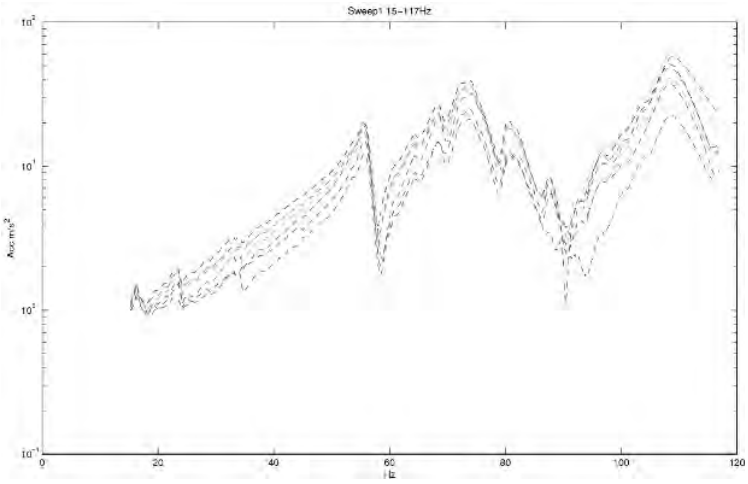

Figure 9: Accelerometer magnitude for a sweep between 15 and 117Hz.

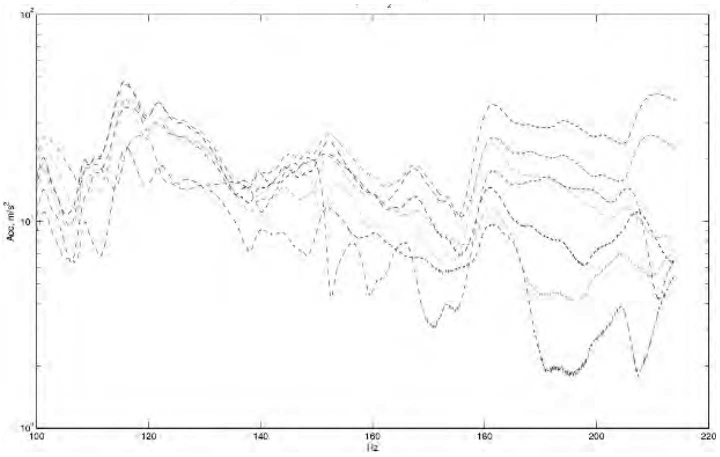

Figure 10: Accelerometer magnitude for a sweep between 100 and 214Hz.

modes get excited as the frequency is increased progressively. Figure 7 represents the acceleration magnitude density plot for the excitation frequencies corresponding to some of the first modes in the case of the one-layer floor. Figure 8 represents the same information for modes 1 through 10, but in the case of the two-layer floor. As it can be observed, the vibration repartition over the floor is modified drastically as various modes are excited, even though the frequency is sometimes just slightly modified.

Frequency sweeps

While the former section showed results with a focus on the spatial distribution of the vibrations, we now focus solely on how the magnitude varies with the frequency as a sweep is applied to the shaker. The figure 9 represents the frequency response of 8 accelerometers as the excitation frequency is increased continuously between 15Hz and 117Hz. The modes can be easily identified here as well, and since the spatial frequency is low, all channels show their minima and maxima at roughly the same frequency.

In figure 10, a similar measurement result is represented, using the same channels, but for a sweep frequency range of 117-214Hz. One can notice that the magnitude changes get out of synchronization as the frequency increases, what makes fully sense, since the spatial frequency also increases as higher order modes are excited. Therefore, small position differences count for high magnitude differences.

Floor discontinuities

Using a large number of accelerometers all over the floor plates allowed us to observe the evolution of the floor behaviour across the discontinuities as the frequency was varying throughout the sweep frequency range of the shaker excitation signal. The next three figures (11, 12 and 13) represent 2-dimensional maps with contour plots of the acceleration magnitude over the plates. Three excitation frequencies have been chosen as representative of the phenomena taking place.

For each frequency, the results are shown with the shaker in either of both tested positions (top versus bottom figures). Finally, and most importantly, the results with one-layer floors and two-layer floors are systematically compared (left side versus right side figures). The dimensions of the plates are outlined by white lines superimposed to the 2-D maps.

Figure 11 represents the measurements for the lowest available frequency of 15.87Hz. Absolutely no attenuation is to be observed across horizontal discontinuities between the plates.

On the contrary, the attenuation across the vertical discontinuity is relatively significant, which is expected, since the plates are attached to the beams

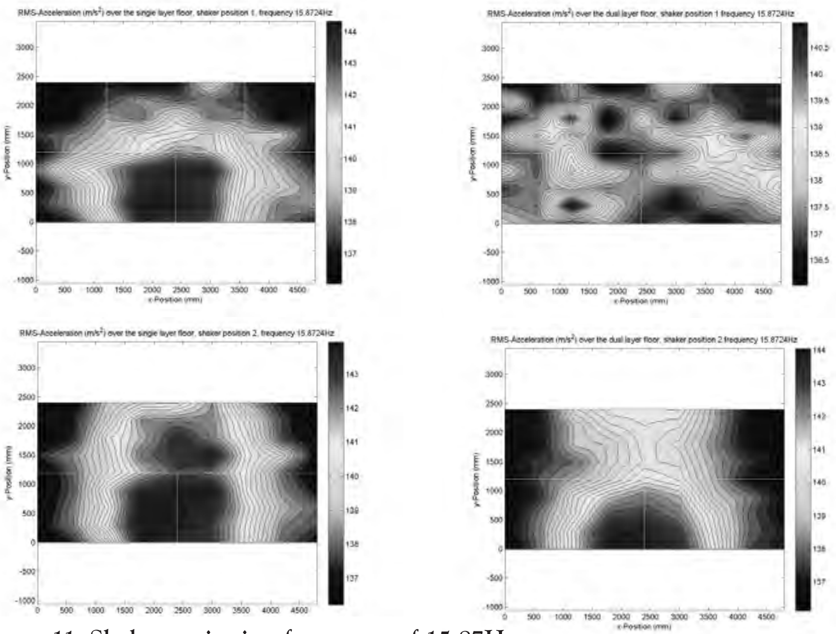

Figure 11: Shaker excitation frequency of 15.87Hz.

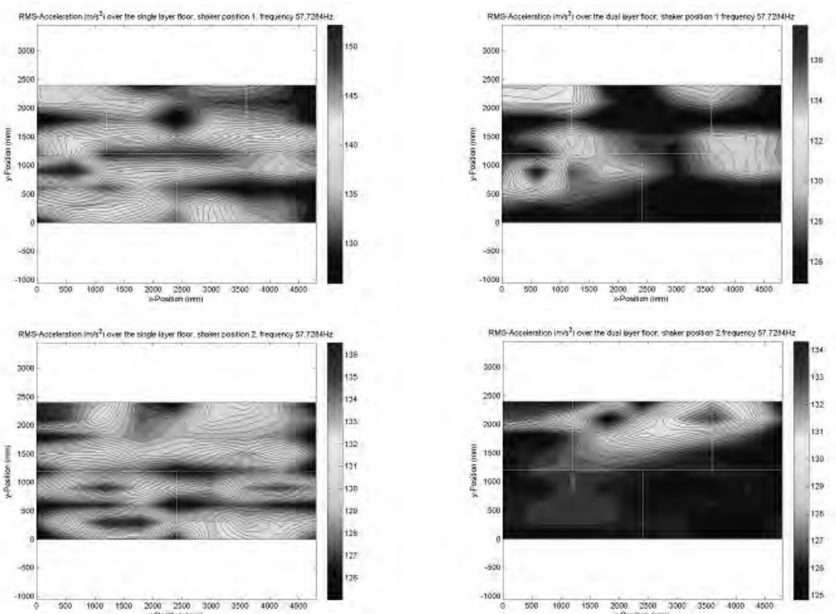

Figure 12: Shaker excitation frequency of 57.73Hz.

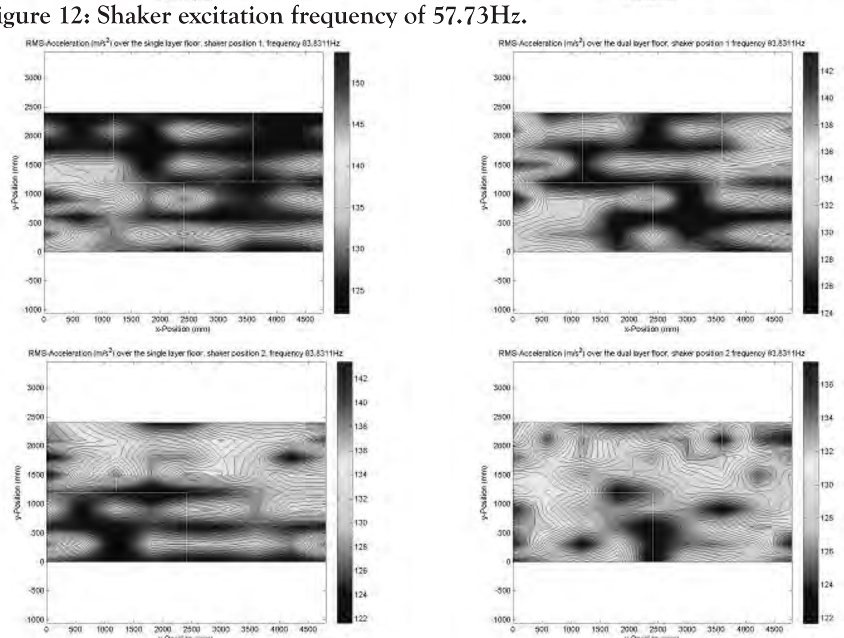

Figure 13: Shaker excitation frequency of 83.83Hz.

precisely along this line.

When comparing the one-layer configuration (left) with the two-layer configuration (right), one notices that the vibrations are much more localized and propagate less far in the case of the double layer floor. In the case of the first position of the shaker (top right), one can even see that the dominant mode is of higher order compared to the one-layer case (top left).

Figure 12 corresponds to measurements done at a higher frequency of 57.73Hz. Interestingly, this frequency appears to excite modes in such a manner that the upper left extremity of the floor is subject to high vibration levels. Nevertheless, it also appears clearly that the vibration is much more localized in the case of the two-layer floor (right) compared to the one-layer floor (left).

Finally, Figure 13 corresponds to a similar measurement, but at an even higher frequency of 83.83Hz. In this case, where higher modes are dominant, the tendency seems to be reversed, as the vibrations seem to stay slightly more localized in the one-layer case (left), and this for either shaker position (top or bottom figures).

Foot steps

The signals from the accelerometers along five beams have also been recorded while a person weighing 81kg was walking on the plate above, on a path between the 4th and the 5th beams. Figure 14 represents the signals from the accelerometers over the time. Whereas the first impact vibration is quickly attenuated when we get further from the walking path, the lower frequency vibration occurring while the foot is already in contact of the floor propagates very well over the whole structure and is merely attenuated, or even gets larger at the opposite end of the plate (top curve).

CONCLUSIONS

An extensive study of vibration propagation in a floor over a wide range of frequencies has been done. A comparison of a one-layer structure and a two-layer structure allowed us to make some interesting observations and to draw instructive conclusions. It has first been established that the dominant mode at a given frequency is

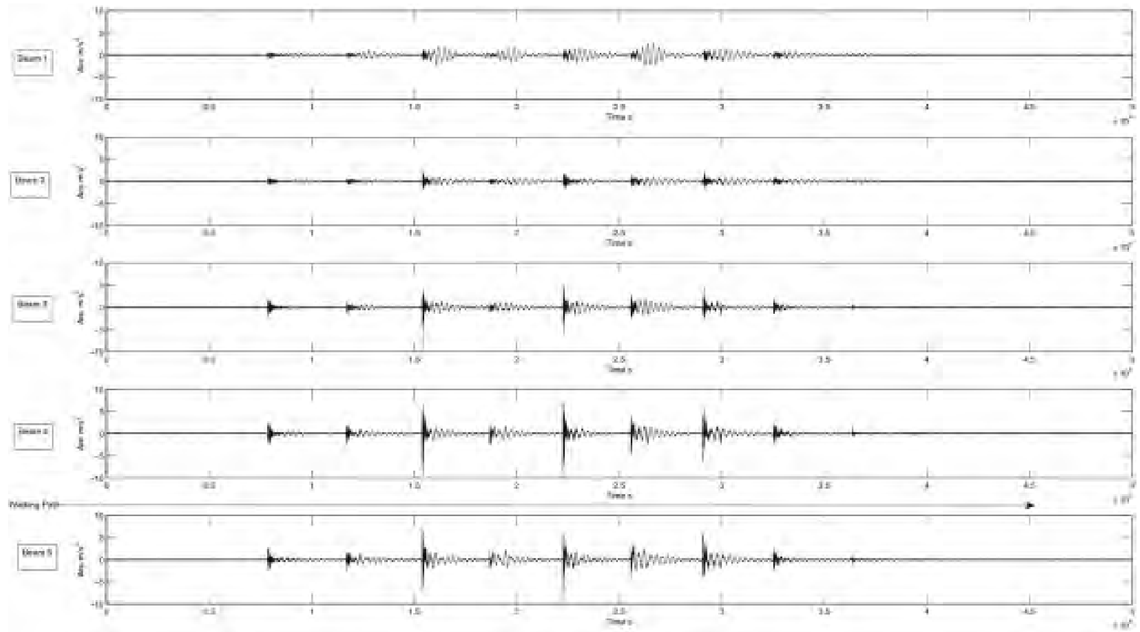

Figure 14: Accelerometer magnitude over time, recording steps.

strongly affected by the type of structure used. Then, as the dependence with the frequency has been investigated over several adjacent accelerometers, it has appeared obvious that the magnitude spread is drastically increased with the frequency, since the spatial frequency also increases. The most interesting part is probably the comparison of 2-dimensional magnitude plots for one-layer floor structures versus two-layer floor structures. The analysis shows that the propagation of the vibrations over the floor at lower frequencies is significantly lowered by the adjunction of a second layer that does not exactly overlap with the first one. At higher frequencies, however, this does not seem to hold any more, the tendency even seems to reverse, the vibrations propagating further in some cases. Finally, the practical case of a person walking on the floor has been investigated, and the investigation of the recorded accelerometer signals shows that the vibrations resulting from the first impact are well absorbed and their magnitude quickly decrease, but the magnitude lower frequency component resulting from the contact of the foot on the floor is merely decreased, if at all, over the span of the floor.

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Noise Level Design Goals & Limits at Residential Receptors for Wind Turbine Developments

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A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

Potential impacts from operational noise produced by wind turbines is a major issue during the project planning and permitting process, particularly for projects east of the Mississippi River in fairly populous areas. While still an issue farther west, more buffer space and lower population densities sometimes make noise less of a factor. In general, however, noise may be the principal obstacle, from an environmental impact standpoint, to the more rapid growth of this renewable energy source in the United States. Proposed projects are frequently opposed on noise concerns, if not outright fear, usually aroused by the highly biased mis-information found on numerous anti-wind websites. While significant noise problems have certainly been experienced at some newly operational projects, they are usually attributable to poor design (siting units too close to houses without any real awareness of the likely impact) or to unexpected mechanical noises, such as chattering yaw brakes or noisy ventilation fans. A common theme at sites with legitimate complaints is that no one - not the developer, their consultants or the regulatory authority – really understood the import and meaning of the sound levels predicted at adjacent homes in the EIS noise modeling. This paper seeks to address this lack of knowledge with suggested design goals and regulatory limits for new wind projects based on experience with the design of nearly 60 large wind projects and field testing at a number of completed installations where the apparent reaction of the community can be compared to model predictions and measurements at complainant's homes.

1.0 Introduction

Typical wind turbine generators (WTG) used today are generally in the 1.5 to 3 MW range of electrical generation capacity and all of them produce a moderate amount of generally mid-frequency aerodynamic noise. All are three-bladed with the rotor forward, or upwind, of the supporting tower so that the blades do not pass through the tower wake avoiding the low frequency noise issues observed in the eighties[1] by downwind blades. This experience appears to have initiated the persistent but incorrect idea that wind turbines are substantial sources of low frequency noise, which, extensive field testing clearly shows, is not at all the case with modern units.

Subjectively, fairly close to a typical wind turbine, one can observe a "whoosh" or "swish" sound with periodicity of about 1 second generated by the down-coming blade. While the "frequency" of this sound is low at about 1 Hz this sound is not low frequency or infrasonic noise, but rather a repeating, mid-frequency sound (with its peak generally around 500 Hz).

This periodic sound becomes less distinct with distance and, usually together with neighbouring units, blends into a more continuous low magnitude "churning" sound that is often likened to a plane flying over at fairly high altitude; particularly since the sound tends to fluctuate or fade in and out randomly in the same way that aircraft noise is usually perturbed by the intervening atmosphere. Wind turbine sound emissions sometimes contain minor tones associated with mechanical components (usually ventilation fans) but almost never produce prominent "pure tones" per the commonly used EPA definition[2].

2.0 Potential For Adverse Noise Annoyance

Adverse impact in the form of annoyance and complaints can occur if facility noise emissions significantly exceed the prevailing environmental background sound level, as with any power project.

Because wind turbine sites are typically in rural areas the existing background sound level is often very low, even when its dependence on wind speed and wind-induced sounds is taken into consideration.

As an example, Figure 1 shows over 2000 ten minute LA90 measurements over a 14 day survey at distances of 300 and 600 meters from an operating wind turbine compared to the average concurrent background level measured at several offsite locations. Hypothetical noise impacts exist wherever the turbine sound level significantly exceeds the background level. In this figure, the maximum differential between the sound level at the house and the background level often occurs at night on nights when the winds are fairly light. When it's windy the differential and the perceptibility of the project is usually less irrespective of time of day as wind generated sources of environmental sound become more dominant.

This time-of-day dependency can be explained by examining the typical wind speed gradient with elevation as a function of time of day. Figure 2 shows the shear exponent, a term that corresponds to the curvature of the gradient, measured empirically over a two year period at a planned wind project site in the Midwest. The shear exponent is low during the day time hours due to atmospheric mixing

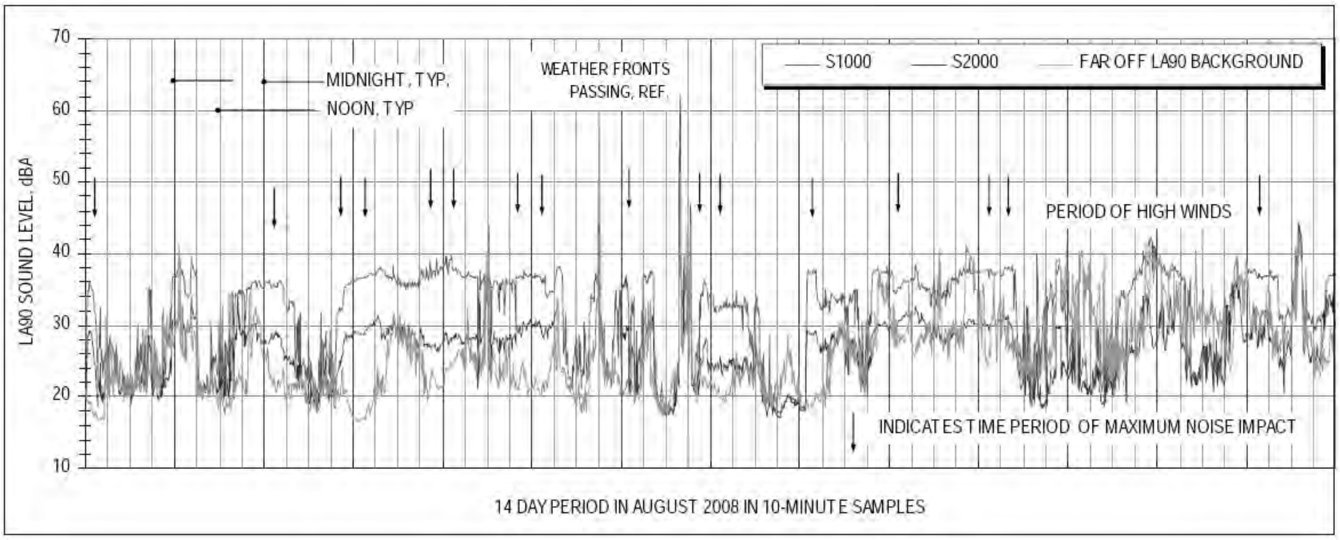

Figure 1. 14 day Survey at a Residence within an Operating Wind Turbine Site. Source: (Author, 2010).

resulting in a nearly vertical gradient, as shown in Figure 3, while the exponent is significantly higher at night due to thermal layering; a phenomenon that is more pronounced during lower wind conditions.

As described and reported by van den Berg[3], at night the upper elevation wind speed can be high enough to operate the turbine while at ground level it is quite low, which can lead to relatively low sound levels, such as those observed most nights in Figure 1.

It can be concluded from these data that the potential for annoyance is most likely during the evening and nighttime and less likely during the day implying that any design goal or regulatory limit should focus on the nighttime sound level.

As a final note on background levels, Figure 4 shows a typical set of natural background sound levels (without any turbine noise) measured in a quiet rural environment plotted as a function of wind speed at a typical hub height elevation of 80 m. Modern wind turbines begin to produce power at a cut-in speed of roughly 3 m/s. Lines on this graphic show an analytical model by Donovan[4] where the background sound has two components: the residual level (shown here at 38 dBA) and the wind generated level plotted as the 6th power of wind speed, which would be expected from a flow-induced acoustic source. The logarithmic summation of these two components would closely track the mean trend of the measured data (black line).

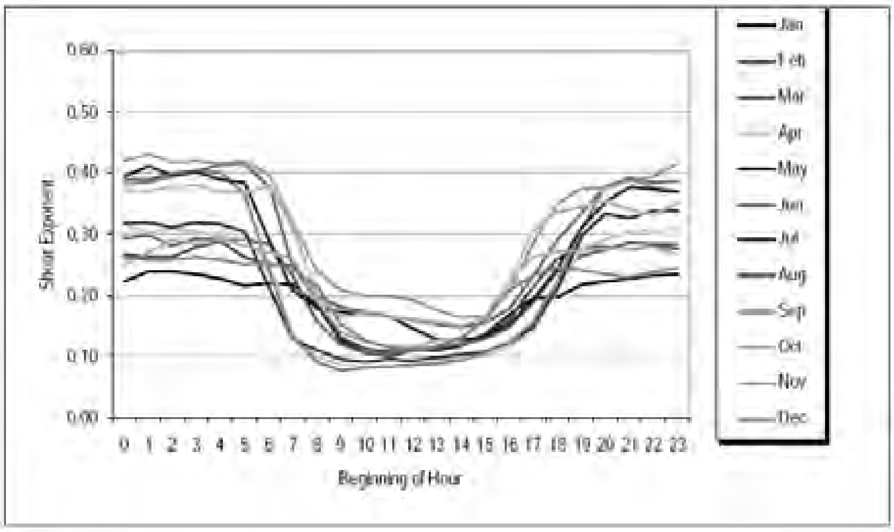

Figure 2. Wind Shear Exponent, α. Defined by V1/V2 = (H1/H2) $^{\alpha}$. Source: (Author, 2010)

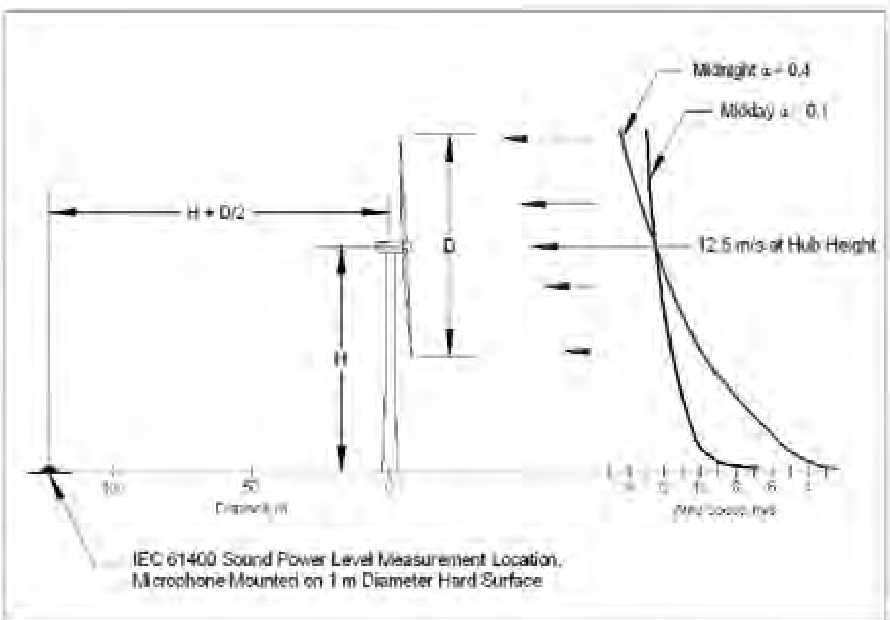

Figure 3. Typical Wind Profiles for Day and Night Periods and Measurement Location for IEC 61400.

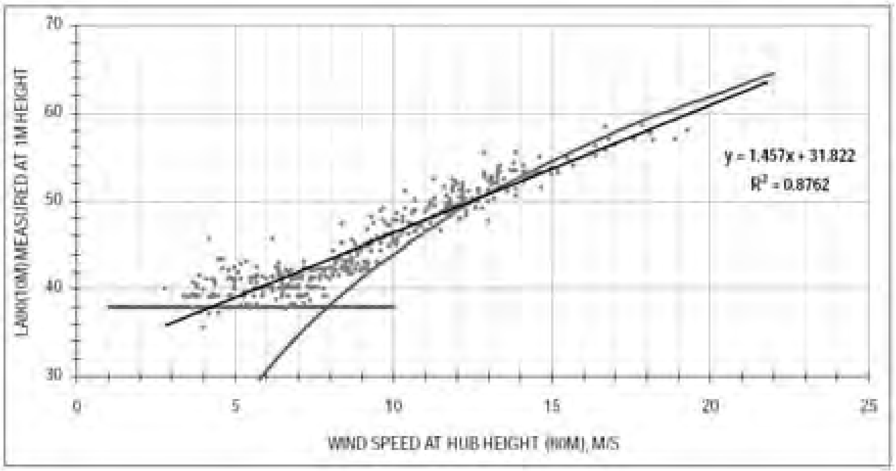

Figure 4. Typical LA90 Measurement as a Function of Wind Speed at Hub Height. Source: (Author, 2010).

3.0 Noise Limits From The Literature

3.1 World Standards and Guidelines

The World Health Organization (WHO) published the following 1999 guidelines[5] for community noise in residential environments:

- 55 dBA Leq Daytime Levels: "Serious Annoyance, daytime and evening"
- 50 dBA Leq Daytime Levels: "Moderate Annoyance, daytime and evening"
- 45 dBA Exterior/30 dBA Interior Leq Nighttime Levels: To avoid sleep disturbance issues.

The nighttime sleep disturbance threshold has recently been reexamined by the WHO (2009)[6] and has been lowered from 45 dBA to 40 dBA outside of residences. No inside value is specified. The level is expressed as a design target to protect the public. Considering this guideline, nighttime sound levels from wind developments outside of residences should be generally targeted at 40 dBA as an ideal design goal to avoid sleep disturbance issues.

Wind turbine development in European countries and in other parts of the world has been proceeding for some time now while widespread development has only really started in the United States within the last 5 years or so. Thus, the question of allowable limits specifically for wind turbines has already been addressed by a number of other countries. Storm[7] presents a summary of world standards in Tables 3 and 4 of his paper, the core of which is reproduced in this work.

The consensus (arithmetic average) for daytime and nighttime limits is 45 and 40 dBA, respectively.

3.2 U.S. Federal Standards

The U.S. Federal government issues no standards for industrial noise but does promulgate noise regulations for major transportation systems. These regulations by the Federal Aviation Authority (FAA) and the Federal Highway Administration (FHWA) are fundamentally predicated on the idea that some noise annoyance is justified or offset by the public good provided by the systems. Generally, acceptable regulatory levels in the 60 to 65 DNL (day night sound level) range have been shown to "highly annoy" approximately 10 to 20% of affected residential receptors. However, these published standards are not particularly useful for wind turbine noise emissions, since the public good of a new power plant or industrial facility is not obvious to its immediate neighbours, and conscientious owners would ideally want no annoyed neighbours.

The U.S. EPA Office of Noise Abatement was unfunded in the late seventies but did issue a landmark report suggesting guidelines for environmental noise in residential communities from all environmental sources. The report[8] is often referred to as the "Levels" document for short and has become a de-facto standard for such organizations as the World Bank and others. Unfortunately, this report is often misused and the cited recommended level of DNL = 55 dBA for residential land use is commonly interpreted as an acceptable criterion level for new noise sources in any type of residential environment - whereas the intent was to provide a guideline, or national goal for total environmental noise (ambient noise including all industrial and transportation sources). The report acknowledges that no cost-benefit analysis was performed.

In addition, the report clearly indicates that the level of DNL = 55 dBA is applicable to an urban residential background and must be normalized to the specific environments under consideration to obtain an acceptable level of correlation between DNL and community response. Without background normalization, correlation is very poor based on the analysis presented in the levels document and elsewhere. This is no surprise since a level of DNL = 55 dBA cannot be expected to be satisfactory at the same time in both a very quiet rural and noisy urban residential setting. Schomer[9] suggests that an adjustment of 10 dBA should be subtracted for quiet rural environments and perhaps another 5 dBA if the project is newly introduced into such a long-standing quiet setting.

Table 1 Typical Worldwide Wind Turbine Noise Limits. Source: (Author, 2010)

LOCATION	CRITERIA VALUE(S)	METRIC	FEATURES
ALBERTA, CANADA	50D/40N	dBA	
QUEBEC, CANADA	45D/40N	dBA	
ONTARIO, CANADA	45D/40N	dBA	
MANITOBA, CANADA	60D/50N	MAX dBA	MAX ACCEPTABLE
MANITOBA, CANADA	55D/45N	MAX dBA	MAX DESIRABLE
DENMARK	40	Leq dBA	DAY AND NIGHT
GERMANY	50D/45N	dBA	
NETHERLANDS	40D/30N	Leq dBA	
NEW ZEALAND	40	L90 dBA	PRIMARY, WHICHEVER
NEW ZEALAND	AMBIENT + 5	L90 dBA	IS GREATER
UK	43N	dBA	
UK	35-40	dBA	FOR LOW NOISE ENVIRONMENTS
UK	AMBIENT + 5	dBA	DAY AND NIGHT
UK	35	dBA	AVOIDS AMBIENT STUDY
ARITHMETIC AVERAGE	45D/40N		

Table 2 Tabulation of State Nighttime Noise Regulations and Siting Standards. Source: (Author, 2010)

STATE	NOISE LIMIT AT RESIDENTIAL RECEPTORS "A" WTD. EMISSIONS LEVEL	COMMENTS
MARYLAND	55	EMISSION LIMIT, ANY AMBIENT
DISTRICT OF COLUMBIA	55	EMISSION LIMIT, ANY AMBIENT
DELAWARE	55	EMISSION LIMIT, ANY AMBIENT
ILLINOIS	51	EMISSION LIMIT, ANY AMBIENT-EQUIVALENT A-WTD LEVEL FROM SPECIFIED OCTAVE BANDS
CONNECTICUT	51	EMISSION LIMIT, ANY AMBIENT
MINNESOTA	51	EMISSION LIMIT, ANY AMBIENT
NEW JERSEY	50	EMISSION LIMIT, ANY AMBIENT
OREGON	50	L50 IN ANY ONE HOUR IN "QUIET" ENVIRONMENTS
COLORADO	50	EMISSION LIMIT, ANY AMBIENT
MAINE	45	50 dBA WHEN AMBIENT LEQ>35 dBA, 45 dBA BELOW (USE Leq=33 dBA)
MASSACHUSETTS	40	MAXIMUM OF 5 TO 10 dBA ABOVE LOWEST L90 AMBIENT (USE MIN L90=33 + 7 dBA)
WASHINGTON	39	EMISSION LIMIT DEPENDING ON RURAL (39) OR RESIDENTIAL (42) ZONING
CALIFORNIA	38	MAXIMUM OF 5 dBA ABOVE L90 AMBIENT (FOUR QUIETEST CONSECUTIVE HOURS, USE MIN L90=33 dBA)
NEW YORK	38	MAXIMUM OF 5 dBA ABOVE UNDEFINED AMBIENT (USE MIN L90 OR Leq =33 dBA)
MEAN STATE NIGHTTIME LIMIT:	50	
AVERAGE STATE NIGHTTIME LIMIT	47.7	

Table 3 Summary of Existing Guidelines and Standards Relevant to Typical Wind Projects. Source: (Author, 2010)

Source	Effective Limits	Comments
WHO	40 dBA Night	Sleep Disturbance Threshold
Consensus of Int'l Limits Specifically on Wind Turbine Noise	45 dBA Day / 40 dBA Night	Arithmetic Average of all Standards
U.S. EPA	45 dBA Day / 35 dBA Night	DNL=45 dBA
State Standards	38 to 40 dBA Night	Based on the 3 States using an Ambient-Based Approach

For a steady source, which a wind turbine could be broadly considered, a level of 39 dBA would be equivalent to DNL = 55 dBA if reduced by 10 dBA; or 34 dBA if reduced by 15 dBA to compensate for a very quiet rural setting.

The EPA did conclude in the levels document that an outside sound level of 45 dBA at night (10 p.m. to 7 a.m.) is adequate to preclude sleep-interference issues. This was based on a typical noise reduction of 10 dBA with open windows that would result in an interior bedroom level of 35 dBA. The much later work by the WHO mentioned above now recommends an exterior background level of 40 dBA to avoid sleep issues.

Considering the EPA guidelines as published in the seventies and later analysis, DNL levels from wind developments outside of residences should ideally be targeted at DNL = 45 dBA, or preferably 5 dBA less. A DNL level of 45 dBA is equivalent to 45 dBA day/35 dBA night or a steady 24 hour level of 39 dBA. A 45 dBA CNEL (Composite Noise Equivalent Level with a 5 dBA evening weighting) would be even more ideal at 45, 40 and 35 dBA for day, evening and nighttime levels, respectively.

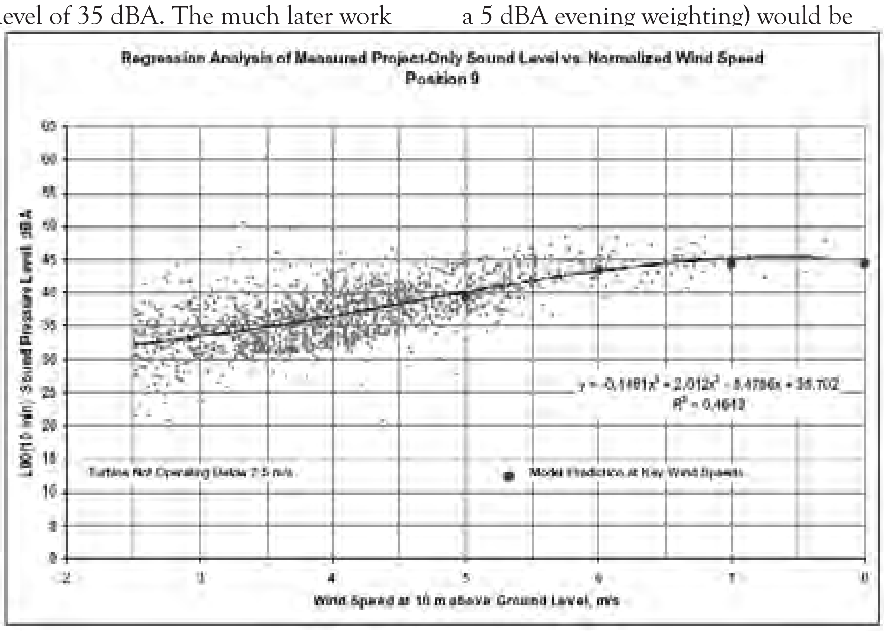

Figure 5. Measured vs. Modeled Sound Levels at a Typical On-site Receptor. Source: (Author, 2010).

3.3 State Standards

Just over a dozen states have codified regulations, zoning guidance or siting standards that fundamentally have the same result as regulations for industrial noise. Most allow a higher limit for daytime hours. The nighttime limits for industrial noise sources are tabulated below for thirteen states. For the three states using an ambient based limit (CA, MA and NY), we use a representative background level of 33 dBA as an approximate, if somewhat conservative, design datum.

Clearly, there is a large variance, ranging from 38 dBA to 55 dBA, in what is considered "acceptable" for nighttime noise emissions at sensitive receptors. Not all can possibly be appropriate.

Eight states use absolute 'maximum emission limits' for daytime and nighttime hours that are applicable at residential receptors regardless of the acoustic environment in those areas. While simple to codify and enforce, it is illogical that the same level could be satisfactory for any residential environment ranging from noisy urban to quiet rural residential locations. The state of Maryland[10] acknowledges this and has found that fully 50% of excessive noise complaints occur in situations where the noise source is in compliance with the State's regulations. Maine and Washington acknowledge differing ambient environments by including a clause that reduces the allowable emission limit for "quiet" areas in Maine and "rural" areas in Washington.

The states of New York, Massachusetts and California use ambient-based emission levels, i.e. the allowable emission level is calculated based on a prescribed increase to the existing ambient, or background sound level. An ambient-based method is based on the perception of the new sound in the specific residential community. A perception-based method is clearly a better approach than a single absolute limit, and, in fact, many years of experience have shown that this approach is working well in these three states. Based on an assumed generic background level of 33 dBA for rural areas where wind projects are usually sited, the effective design level for a new project would range from 38 to 40 dBA in these three states.

3.4 Local Standards

Finally, it should be mentioned that countless counties and local municipalities have enacted noise laws and ordinances specifically with respect to wind turbine projects – usually in response to a proposed project. Most commonly an absolute limit of 50 dBA is prescribed. Field experience, which is discussed in further detail in Section 4.0, indicates that such a limit is insufficient to avoid annoyance from wind turbine noise if the actual project sound level closely approaches this limit.

3.5 Summary of Existing Guidelines and Standards

Table 3 summarizes the general noise limits and guidelines from all known existing entities domestic and foreign that would be relevant to typical wind turbine projects in rural areas.

4.0 Direct Experience And Previous Annoyance Studies

It is only through field experience testing newly operational wind projects that the actual community reaction can be directly compared to the sound levels produced by a project. Over the last few years we have had the opportunity to conduct sound surveys at 8 new operational wind turbine sites, of which 7 may be considered representative of the typical U.S. domestic project in the sense that a fairly large number of turbines (50 to 100) are sited over a large area within which there is a fairly uniform distribution of farms and homes; i.e. the turbines and residences are thoroughly intermixed. Out of these 7 typical project sites long-term sound monitoring surveys were carried out at 5, usually over a 2 to 3 week period. The principal objective of these surveys was to determine whether the projects were compliant with the applicable regulatory noise limit (usually 50 dBA) but they also afforded important opportunities to quantify the sound levels produced exclusively by the project at a number of the closest homes and to compare these measurements with model predictions. In addition, the community reaction to each project could be generally discerned because monitors were deliberately placed at the homes of all those who were known to have complained or otherwise expressed concern about noise, whether participating in the project or not. Monitoring stations were also set up at other homes where no complaints had been received but where maximum project sound levels were expected based on modelling. Informal discussions about the resident's subjective reaction to project noise occurred at most monitoring positions.

In general, these studies involved continuous monitoring in 10 minute increments over at least a 14 day period at numerous on-site positions supplemented by a number of off-site monitors generally 2 miles beyond the project perimeter recording the likely concurrent background sound level without any project noise. In this way it was possible to reasonably correct the on-site sound levels for background noise contamination (which is often very significant during windy conditions) thereby deriving the project-only sound level at each position – the quantity predicted by analytical models.

As an example, Figure 5 is a typical plot that shows the corrected project-only sound level as a function of wind speed rather than time. The scatter in the data, which is typical and expected, is due to fluctuations in the project sound level at the observation point due to variations in atmospheric conditions (path effects) and fluctuations in the aerodynamic noise produced by the rotor due to inevitable inconsistencies in wind speed, gradient or direction (source effects). More importantly, this figure shows the essentially universal result from all positions in all the surveys that the model predictions at integer wind speeds agree extremely well with the mean trend through the measured performance, thus demonstrating that ISO 9613-2[11] (assuming a moderate 0.5 ground absorption coefficient) is a perfectly valid methodology for predicting wind turbine sound levels, recognizing that path and source effects will lead to levels that vary by about +/- 5 dBA about the predicted mean .

In terms of noise impact, the results of these studies indicate that the actual degree of adverse impact, defined as the number of serious complaints relative to the total number of households in the project area (within 2000 ft. of the project perimeter), was fairly small at about 4%. The specific numbers associated with each project are tabulated in Table 4.

Just because the total number of complaints is fairly small in each case one should not be dismissive of these people, because there were usually one or two at each site that were profoundly disturbed by project noise. However, it must also be said that the vast majority of people apparently had no objections to noise, even people who consistently experienced turbine sound levels in the 45 to 50 dBA range. Based on discussions with non-participating and participating residents at more or less randomly selected monitoring positions in close proximity to turbines, the most common reaction was generally that operational noise was certainly audible, particularly during certain wind conditions or times of day, but that it was to be expected and they didn't pay any real attention to it. Of course, this general assessment is not the result of a rigorous scientific study on wind turbine annoyance; that was never the objective of the surveys, but a milder than anticipated reaction was observed at each site.

Table 4 Number of Observed Complaints Relative to the Total Number of Households in Close Proximity to Turbines. Source: (Author, 2010)

Project	Total Households in the Site Area (Approx.)	Number of Complaints as a Function of Project Sound Level (dBA) (1)			Total Number of Complaints	Percentage Relative to Total Households
		< 40	40 - 44	45 or Higher		
Site A	107	0	2	1	3	3%
Site B	147	0	3	3	6	4%
Site C	151	0	3	0	3	2%
Site D	268	0	2	4	6 (2)	2%
Site E	91	1	1	4	6	7%
					Overall Average:	4%

(1) Sound levels expressed as long-term, mean values
(2) There were only 3 reported complaints at this site but others may have existed that we were not made aware of; hence a total number of 6 were assumed

The low apparent rate of adverse reaction to projects where numerous residences were exposed to relatively high sound levels (up to 55 dBA in some cases) was surprising because it stood in stark contrast to the results of previous annoyance studies; in particular, the extensive work carried out from 2000 to 2007 in Sweden and the Netherlands by Pedersen[12] and Persson Waye[13] . These studies generally predict an annoyance rate ranging from 10 to 45%, or more, for wind project sound levels in the 40 to 45 dBA range. For example, the earliest study (Pedersen 2004), based on questionnaire responses collected in 2000 from residents living in proximity to five small wind projects in Sweden, found the annoyance rate as a function of sound level plotted below in Figure 6.

This steeply rising curve apparently indicates that a sound level of 40 dBA, for instance, leads to a 26% annoyance rate, implying that out of the study population of 513, 133 were highly annoyed. However, this is not at all the case. On further analysis it turns out that the response curve percentage is not related to the overall study population – i.e. the total number of households within the project area with a predicted sound level of 30 dBA or more, whether they responded to the survey or not -but rather to the percentage of people exposed to a particular sound level that reported annoyance due to that sound level (see Table V of the paper). Now it must be pointed out that only 351 of the 513 individuals forming the study population returned the questionnaire, so the views of the missing 32% are not known, but in the 37.5 to 40 dBA category, for example, 20% of the 40 respondents exposed to that sound level range reported being highly annoyed - which is just 8 people. Viewed in terms of the overall population of 5[13] that is equivalent to a highly annoyed response of just over 1% for that particular sound level range (37.5 to 40 dBA). In general, across all sound level ranges the total number of people responding that they were highly annoyed was 31, or 6% of the total number of households. In contrast to the alarmingly steep response rate curve in Figure 6, this 6% figure agrees much more closely with the 4% complaint rate (based on the total number of households) observed during our own field studies of projects in the United States.

A further and much larger questionnaire study modelled on the 2000 study was performed in the Netherlands in 2007 and reported in 2009 (Pedersen[14]). This study is the most representative of current projects with large turbines and essentially flat topography. In this study out of 1948 queries sent out 708 were received. Across all sound level categories a total of 29 respondents (back-calculated from the results expressed as percentages in Table II) reported being very annoyed. If only the 708 respondents are assumed to make up the pool of potentially affected residences in the project area (rather than 1948), this equates to a 4% rate of high annoyance.

On the other side of the coin, the number of individuals concerned about or annoyed by noise at each of the sites we studied may not have been definitive, since the number represents those who were troubled enough to call in and complain, as reported by project management, and any others we may have learned of indirectly in discussions with neighbours. The possibility that others were annoyed certainly cannot be ruled out and, in fact, seems likely but it appears that the actual rate of serious annoyance to noise from wind projects may not be nearly as high as previously supposed.

5.0 Low Frequency Noise And Adverse Health Effects

Harmful, or at least disturbing levels of low frequency or infrasonic noise and potential adverse health effects are almost always feared, based largely on internet misinformation, and cited as major reasons why proposed projects should not go forward. However, the fact of the matter is that wind turbines do not produce significant or even remotely problematic levels of low frequency noise and that a link between health complaints and turbine noise has only been asserted based on what is essentially anecdotal evidence without any valid epidemiological studies or scientific proof of any kind. The latter assertions are all the more suspect in that they are often predicated on or directly associated with the assumed existence of high levels of low frequency noise.

It is well outside the scope of this paper to go over the basis for these conclusions but readers are referred to a recent review by a panel of independent doctors on wind turbine health effects[15] and some extensive testimony by the leading experts in the field (now public record) regarding potential low frequency noise impacts recently filed in conjunction a proposed wind project in Wisconsin[16].

Because low frequency noise from wind turbines, essentially irrespective of distance, is well below the point where it might begin to be audible or initiate perceptible vibrations (windows or dishes rattling, for example) there is no actual need for a design goal or regulatory limit. However, if one is desired just to be on the safe side, so to speak, a limit of 65 dBC might be used. In over 30 years of investigating countless genuine low frequency noise complaints, usually associated with simple cycle combustion turbines, there was only one outlier below 65 dBC. A maximum regulatory limit of 70 dBC is recommended if one must have a low frequency limit.

Having said that, it must be strongly cautioned that C-weighted sound levels do not mix well with wind turbine applications because it is extremely difficult to accurately measure C-weighted sound levels in the presence of any kind of wind[17]. Self-generated, false signal noise, which occurs in the low frequencies, from wind blowing through even sophisticated windscreens and over the microphone tip will drastically elevate the apparent C-weighted sound level and, by extension, the apparent low frequency sound level. Consequently, it would be a significant technical challenge to accurately field verify the C-weighted performance of a wind turbine project. Any casual measurement in a windy field will ostensibly yield a relatively high C-weighted sound level, possibly in excess of the 65 to 70 dBC levels suggested above, whether a wind turbine is present – or not.

6.0 Recommended Design Goals And Noise Limits

Based on the existing guidelines and limits outlined in Section 3.0, combined with our direct experience summarized in Section 4.0, the following design goals and regulatory limits are recommended.

The nighttime level of 40 dBA is suggested as an ideal design goal rather than a firm regulatory limit because a legal limit must reasonably protect the public from legitimate annoyance and, at the same time, not stand completely in the way of economic development, which 40 dBA would tend to do in some instances. Because the actual number of complaints observed at sites where the project sound level exceeded, or even substantially exceeded, 40 dBA is small at 4%, a sound level of 45 dBA at residences, as an ordinance or legal limit, appears to balance the desire on everyone's part to avoid complaints and annoyance on the one hand with practical constructability on the other. Sound levels of less than 45 dBA would theoretically lead to a very low complaint rate of 2% based on the data in Table 4.

It is important to note that both of the levels above are mean, long-term values and not instantaneous maxima. Wind turbine sound levels naturally vary above and below their mean or average value due to wind and atmospheric conditions and can significantly exceed the mean value for brief periods. As illustrated in Figure 5 above, project sound levels commonly fluctuate by roughly +/- 5 dBA about the mean trend line but short-lived (10 to 20 minute) spikes on the order of 15 to 20 dBA above the mean are occasionally observed (less than 1% of the time) that are ostensibly attributable to turbine noise – although the possibility exists that some or all are extraneous noise events. Because it would be completely impractical to design any project so that all such spikes would remain below the 40 and 45 dBA, these values are expressed as long-term mean levels, or the central trend line through the data scatter as shown in Figure 5.

Some degree of dissatisfaction due to audibility is largely inevitable. The very definition of noise is unwanted (audible) sound. For example, in isolated incidences we are familiar with complaints have been engendered by wind project sound levels as low as 23 and 34 dBA. Therefore an objective of completely eliminating the possibility of any negative response is largely impractical and the imposition of extremely low regulatory noise limits or of vast minimum setbacks - as championed by James and Kamperman[18], for instance – would not necessarily eliminate all adverse impact but would, in fact, make most projects impossible to build, even in sparsely populated areas of the country.

6.1 Options for Meeting the Recommended Limits

During the design phase of a wind project, particularly for projects where the turbines are interspersed amidst a number of homes, there are several options, outlined below, that are available for mitigating potential project noise and bringing the project, hopefully, into conformance with one or both the recommended noise levels.

Site Layout Optimization

The most useful and effective method by far is the optimization of the site plan through iterative noise modelling. This technique, which has been successfully applied to a number of projects, involves developing a baseline model of the project as initially conceived in terms of a sound contour map and then hypothetically relocating or removing certain units in order to ideally place all of the potentially sensitive receptors within the site area outside of the 40 dBA contour line.

The baseline layout is usually driven by where participating land parcels are in general and where the wind resource is best on those parcels in particular, rather than by noise concerns. Consequently, some degree of improvement, i.e. a reduction in the predicted sound levels at residences, can almost always be realized - so long as it is early enough in the design process that significant changes can be made. In fact, the best time to start evaluating potential noise impacts is when a project has just begun to coalesce and is considered generally viable, even if only a hypothetical or estimated turbine layout is all that is available for modelling. All too often noise is only considered at the eleventh hour just prior to submittal of the permit application, or even construction, when the flexibility to move turbines has been utterly lost.

Because of the numerous other constraints that always exist on exactly where turbines can be built, it is often necessary to go through several iterations of noise modelling to find the optimal arrangement that minimizes noise and still satisfies all other concerns.

Low Noise Operating Modes

If physical changes to the turbine site plan cannot be made or are still insufficient to realize the desired performance, further targeted reductions can sometimes be made by operating specific units in low noise operating mode – something that can also be evaluated prior to construction through iterative modelling. While still not universally available as an option on all turbine makes and models, there now appears to be a trend towards incorporating this capability into most new units or retrofitting it on existing models. Noise reductions of up to 5 dBA relative to normal performance (it is claimed by some manufacturers) can nominally be achieved primarily through electronic manipulation of the blade pitch. Although this operating mode could theoretically be employed at all times, it adversely affects power production at higher wind speeds so it not desirable, or in some cases even economically unfeasible, to permanently de-rate the turbines; consequently, this option is more appropriate for use as a temporary measure under certain weather conditions or times of day, mostly likely during the critical nighttime hours when noise is typically more of an issue.

Operational Curtailment

Curtailment of operation, or temporarily shutting down specific turbines, is obviously onerous to the economics of a project that clearly involves a large capital investment, but it may be less devastating than first thought. The temporary shutdown of just one unit (overnight, for instance)

Table 5 Recommended Regulatory Noise Limits and Design Goals for Wind Turbine projects . Source: (Author, 2010)

	Sound Level, dBA (1)	Applicable	Time of Day
Regulatory Limit:	45	Outside Residences	Day and Night
Design Goal:	40	Outside Residences	7 p.m. to 7 a.m.

(1) Long-term, mean project sound level (normally measured in terms of the L90(10 min) statistical sound level)

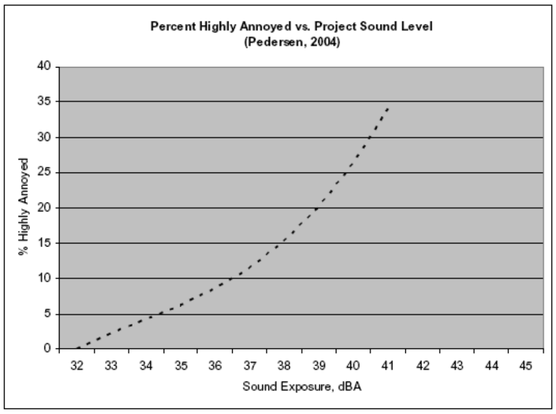

Figure 6. Response Analysis from Pedersen 2004.

can sometimes make a dramatic difference in the sound level at a particular point of interest. Depending on the geometry of the situation, model simulations taken from actual projects indicate that noise reductions from 2 to 8 dBA can be achieved by shutting down only the single nearest turbine to a particular house.

7.0 Conclusions

Measurements of operational wind turbine projects indicate that turbine noise is usually most perceptible relative to the background level at night suggesting that design goals and regulatory limits should either be focused on nighttime conditions or have differing goals for night and day Existing guidelines and regulatory limits, interpreted within the context of the quiet rural environments in which wind projects are normally sited, generally point to a design goal sound level of 40 dBA at night and 45 dBA during the day.

Experience in measuring the sound levels produced by newly operational wind projects and comparing those levels to actual community reaction indicates that the number of complaints relative to the total number of potentially affected households within a given project area is fairly low at roughly 4% in cases where project sound levels exceed or even substantially exceed 40 dBA at residences. This finding was also found to generally agree with previous European research but only when the number of questionnaire responses reporting high annoyance is similarly viewed relative to the overall number of potentially affected households rather than by exposure levels.

Field surveys of operational projects also generally indicate that complaints engendered by wind turbine sound levels below 40 dBA are very rare therefore suggesting that new wind projects should use a nighttime sound level of 40 dBA as an ideal design goal at all residences to minimize the probability of annoyance and complaints with a higher level of 45 dBA applicable during the day. However, the low (2%) rate of complaints observed in the studies when the project sound level was below 45 dBA points to this value (45 dBA) as an appropriate regulatory limit, irrespective of time of day, since it appears to strike a balance between the reasonable prevention of annoyance and what is generally achievable in terms of project sound levels at typical project sites.

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A More Than Minor Debate: The Correct Use of Effects Terminology

Francelle Lupis, Senior Solicitor, and Kate McDonald, Solicitor; Russell McVeagh

Introduction

We should all be proud pedants when it comes to our choice of words. Words are the primary medium through which your ideas and opinions can be conveyed. Words mean what they say, and if you want to say what you mean, then you must choose your words with great care. With that in mind, how many times have you somewhat aimlessly written or thought "the effects will be no more than minor" or "the effects are de minimis"? Be honest. It happens. A lot. These phrases have become somewhat of a mantra, trotted out automatically without a great deal of thought being given to exactly what is meant in any particular situation, or any thought being given to whether it is appropriate to use this phraseology at all. As a result, the Court still finds it necessary to remind experts and lawyers that the "no more than minor" assessment is solely a threshold test for otherwise non-complying activities under a district or regional plan.

Experts frequently give evidence, with the endorsement of legal counsel, to confirm that controlled or discretionary activities, for example, will have effects on the environment that are "no more than minor", despite this test being relevant only to whether a non-complying activity might be allowed through the section 104D "gateway":

(Upland Landscape Protection Society v Clutha District Council EnvC Christchurch C85/08, 25 July 2008, Smith J at [93]):

- Generally we note that ... evidence reached conclusions as to whether effects were more or less than minor. This test appears to be derived from the threshold test under section 104D. However such a test is irrelevant to the substantive evaluation that must be undertaken under 104(1)(a) and under Part 2 of the Act.

Council decisions often reflect the same misuse of the threshold test, no doubt as presented to them in evidence or pre-hearing reports:

(McKinlay Family Trust v Tauranga City Council EnvC Auckland, A119/08, 29 October 2008, Smith J at [9]):

- We note that the Hearings Panel refer to effects more than minor as a ground for declining consent. Given than the applications are for discretionary activities, this test arising under section 104D is not relevant.

So why are we still getting it wrong? "No more than minor effects" is a phrase that has evidently found popularity with lawyers who are wary of over-emphasising adverse effects when advocating for a client's proposal to the Court, and experts who are cautious of speaking in absolute terms. The Court does not have the same admiration for the phrase and is more often seeking clarity as to what is really meant when an effect has been described in that way. When it is used as an evaluative measure, rather than as a simple threshold test, it appears to do little to assist the Court's understanding of the significance of a particular adverse effect. Simply put, outside of its proper context, it seems to lose its meaning altogether.

This article will examine what experts can do instead to introduce shades of meaning to their analysis, and will ask whether "no more than minor" has crept into our resource management vernacular in place of a proper evaluation of the impacts of an activity: namely, what are the actual and potential effects on the environment and does the activity, on balance, promote sustainable management?

The only other area in the RMA where the more than minor test is applied with real meaning is with respect to decisions regarding public or limited notification. Section 95A provides a consent authority with the discretion to publicly notify a resource consent application if it considers that the activity will have or is likely to have adverse effects that are more than minor. Where public notification is not required, limited notification must be given to those individuals who are affected by the adverse effects of an activity in a minor or more than minor way (but not less than minor). These notification provisions have their own peculiarities, not least the inability for a consent authority to consider both positive and adverse effects when making a decision to notify. For that reason the "more than minor" notification test is beyond the scope of this particular article and will not be discussed further.

Section 104D: A threshold test

The "no more than minor" descriptor is derived from the threshold test for non-complying activities under section 104D of the Resource Management Act 1991. That section provides that a consent authority may only grant consent for a non-complying activity if it is satisfied that either the adverse effects on the environment will be minor, or that the activity is one that will be not be contrary to the objectives and policies of the relevant plan or plans.

For all applications (including those non-complying applications that have passed through the section 104D "gateway"), section 104 sets out that a consent authority must, subject to Part 2, have regard to any actual or potential effects on the environment, any relevant provisions of any relevant environmental standard, regulation, policy statement or plan, and any other matter deemed relevant by the consent authority. The "test" in section 104 is therefore simply whether the activity meets the singular purpose of the Act set out in Part 2 - does it achieve sustainable management? In considering whether the application meets that test, a consent authority must consider each and every actual and potential effect, including positive effects, regardless of their scale or degree.


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• Novahush Bafflestack
• Novahush Panel Absorber
Metal Ceiling Systems
• Renhurst Ceiling Systems
• I.C.E. Metal Acoustic Tiles
• Linear Coruline Perforated Metal Ceiling System
• ACS Linear Look Metal Ceiling Systems
• Lindner Metal Systems Acoustic Tiles
• Armstrong Metalworks Acoustic Tiles
Mineral Fibre Ceiling Systems
• Armstrong range of acoustic ceiling tiles
• Armstrong Ceiling Grid
Soft Fibre Ceiling Systems
• Eurocoustic range of acoustic ceiling tiles
• Parafon range of acoustic ceiling tiles
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Rondo
• Quiet Stud Friction fitted acoustic wall system
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There is therefore no requirement for a consent authority determining an application, other than a non-complying application under section 104D, to first consider whether the adverse effects of allowing the activity will be minor. The test of "no more than minor" is simply not relevant to the consideration of other types of activities, unless it can be shown that particular evaluation of the level of adverse effect provides a useful clarification for the Court or consent authority during the balancing exercise required by section 104. So, does it?

Defining no more than minor - a helpful descriptor?

On the face of it, the "no more than minor" test should provide a helpful descriptor of the degree of relevant effects for a decision maker who is considering granting consent for an activity. But what does it actually mean?

While the RMA defines other terms important to the section 104 assessment, such as "effect" and "environment", there is no corresponding definition of the concept of minor. In King v Auckland City Council [2000] NZRMA 145 the Court stated that a minor effect will be "at the lower end of a scale including major, moderate and minor effects but must be something more than de minimis". Various other decisions have followed that interpretive theme.

Effects that are "no more than minor", then, will register somewhere on a scale. That might serve a purpose in the context of a threshold or gateway test, but is it useful when describing effects that are to be assessed in the round? A decision maker undertaking a broad section 104 assessment is not necessarily concerned with effects which register on a scale of de minimis to moderate, but whether the effects are indeed significant enough to be considered adverse in the context of a particular proposal and, if so, whether or not they are counter-balanced by a suite of conditions, mitigation measures and positive effects that will also flow from the application in question.

If the test of "no more than minor" effects is irrelevant to the assessment of anything but a non-complying activity, what is the relevant test? The RMA is not a "no effects" statute - in other words, it is not about preventing any or all effects on the environment or only allowing activities with a certain scale of effect. As section 104(1)(a) is concerned with all actual and potential effects, there can be no requirement to classify effects on a scale or more or less than minor. Whatever their magnitude, the effects should properly be considered by the Court or decision maker as part of their overall assessment.

There are very few applications that would not generate any effects or any adverse effects. It is obvious that whether or not an application would result in adverse effects is not the ultimate test. Applications for resource consent which would generate very significant effects can, and often are, granted by the Court.

The Environment Court has helpfully described the issue in this way:

(Upland Landscape Protection Society EnvC Christchurch C85/08 at [94])

- Case law clearly establishes that activities with very significant effects may be granted consents, while others without such particular effects may be refused consent. The scale of effect is clearly a matter which will go into the evaluation necessary under Part 2 of the Act but is not determinative of it.

So the scale or significance of effects will not necessary preclude a resource consent from being granted, but will simply factor in the overall evaluation and balancing of the application against Part 2 of the RMA. What the decision maker needs to know then is, on balance, how much weight should be given to the effects in question when undertaking the balancing exercise. Are the effects greater than de minimis? Are they significant or moderate? What are their impacts on the various affected parties/receptors/the environment?

It is clear then that outside of its section 104D context, an assessment of an adverse effect as more or less than minor is of little assistance to the Court. As a threshold test it has value, but as an evaluative tool it loses its meaning in the face of other, more balanced assessments.

So why is "no more than minor" so attractive?

As we have noted above, it is often said that the RMA is not a "no effects" statute. Why is it then that expert witnesses loathe to describe any proposal as having an adverse impact on the environment? Why do practitioners find comfort in the safety net of "no more than minor"? This ability to assess adverse effects in the round when undertaking a proper balancing exercise means that experts (and lawyers) should have confidence in acknowledging adverse effects when they are in fact likely to occur. But is there a perceived risk in doing so?

We suggest there are a number of reasons which, cumulatively, are responsible for the regular use of the "no more than minor" terminology in an improper context.

The first, and most obvious, is that the phrase has fallen into popular use. Experts and practitioners are used to saying it, used to hearing it, and feel like they are using "RMA language" when describing an effect in that way. This is understandable. On the odd occasion the use of the phrase appears to crop up when evidence has, from appearances, been worked up on the basis of a template document for a previous activity - one that was in fact non-complying. This is less excusable. Experts should be encouraged to always start from scratch when preparing evidence, and to give careful thought to how best to describe a particular effect.

The qualification as "no more than minor" must also have an inherent level of comfort for those giving an evaluative judgment. The effects have been acknowledged, there can be no question about that, but have been assessed as no more than minor, or nothing to worry about. This, then, is an assessment that covers all the bases. There is no element of controversy - for example by suggesting there are no effects or no adverse effects. (As any practitioner will know, an expert will seldom accept that there will be absolutely no effects - in science, that is an unlikely proposition, as even the smallest proposal is likely to create a measurable impact, if your degree of measurement is small enough!)

A further reason for the popularity of the description could be that it is used by experts who want to describe effects as being very minimal indeed. However that concept has been encapsulated by the description of effects as de minimis

- a term that has been very strictly confined in case law:

(Rea v Wellington City Council [2007] NZRMA 449 at [10])

- The term de minimis has survived… since there is no equally convenient and pity English alternative. It is a shorthand way of expressing the full Latin maxim "de minimis non curat lex". This is usually translated as "the law is not concerned with trifles." In the present context, it means that an adverse effect …is so trifling that the law should regard it as of no consequence. That is a much more stringent test than whether the adverse effect is minor.

If the de minimis definition is not available but the expert wants to acknowledge some level of adverse effect, albeit one that does not give cause for any alarm, then "no more than minor" might appear to fit the bill.

Another explanation may be that experts are nervous about how their message will ultimately be conveyed and understood by the decision maker. Experts could fear that the shades of meaning in their assessment may not be immediately apparent and, unless they are questioned in detail by the Court or by opposing counsel (giving rise to an opportunity to provide a detailed justification), their evidence might not be given the appropriate weighting by the Court when the time comes to undertake the balancing exercise.

Alternatively, experts may fear that the positive effects of any given proposal will not be given sufficient weight, so that any acknowledged adverse effect at all may be enough to tip the scales against the proposal seeking consent. If a proposed activity does not find sufficient favour with a decision maker (with respect to the enabling purpose of the Act), then a lesser degree of adverse effect may represent ample justification for declining consent.

The obvious solution here is for lawyers and experts alike to ensure that the positive effects of any given proposal are illustrated carefully for the benefit of the decision maker. Often applications are framed in such as way as to minimise or justify the adverse effects, and the positive effects of the activity are only added as an afterthought. These should be emphasised up front as they are a crucial aspect of the Part 2 balancing exercise. To undersell the positive effects of a proposal is to run the risk of the acknowledged adverse impacts assuming greater significance in the round.

Reminders for experts and lawyers

What then can, or should, be kept in mind when drafting (or reviewing) expert evidence? Should experts and lawyers ensure that the language used in expert evidence and submissions accurately matches the statutory tests for the particular activity? The answer is yes, to the extent possible. Although is the Court that has the final responsibility to assess the effects against the relevant statutory tests, both lawyers and expert witnesses have a duty to assist the Court as much as possible in undertaking this evaluation.

Ultimately it is for the expert witness to decide how to set out his analysis for the court and lawyers should be wary of suggesting changes which impact on the meaning that the expert is trying to convey. In saying that, it is the lawyer's job to remind themselves of the relevant statutory tests and, when reviewing expert evidence, ensure experts are aware of the correct terminology and/or are prepared to justify their conclusions to the Court in a way that will be easily understood.

What a decision maker really needs to hear from an expert witness is, on balance, what weight should be given to effects relevant to any given area of expertise when undertaking a holistic assessment of the resource consent application. Experts may like to consider employing language which still provides an adequate detail of scale but avoids importing an irrelevant statutory threshold. For example, expert witnesses could explain adverse effects that are nothing to worry about as "nominal", "insignificant" or "negligible". It is also important that, if an expert witness does consider that there are no relevant adverse effects arising from the activity, he or she does not feel precluded from saying so in the simplest possible terms. While this may be scary, an expert witness should be prepared to be tested by the Court and to explain how they arrived at that conclusion.

If adverse effects are more serious, but can be appropriately mitigated through conditions and other measure, it may be more accurate to describe them as "acceptable", all things considered. This is a term that has found favour with the Court in the past:

(McKinlay Family Trust EnvC Auckland, A119/08 at [55]):

- We would only alter the words of their decision more than minor to read unacceptable.

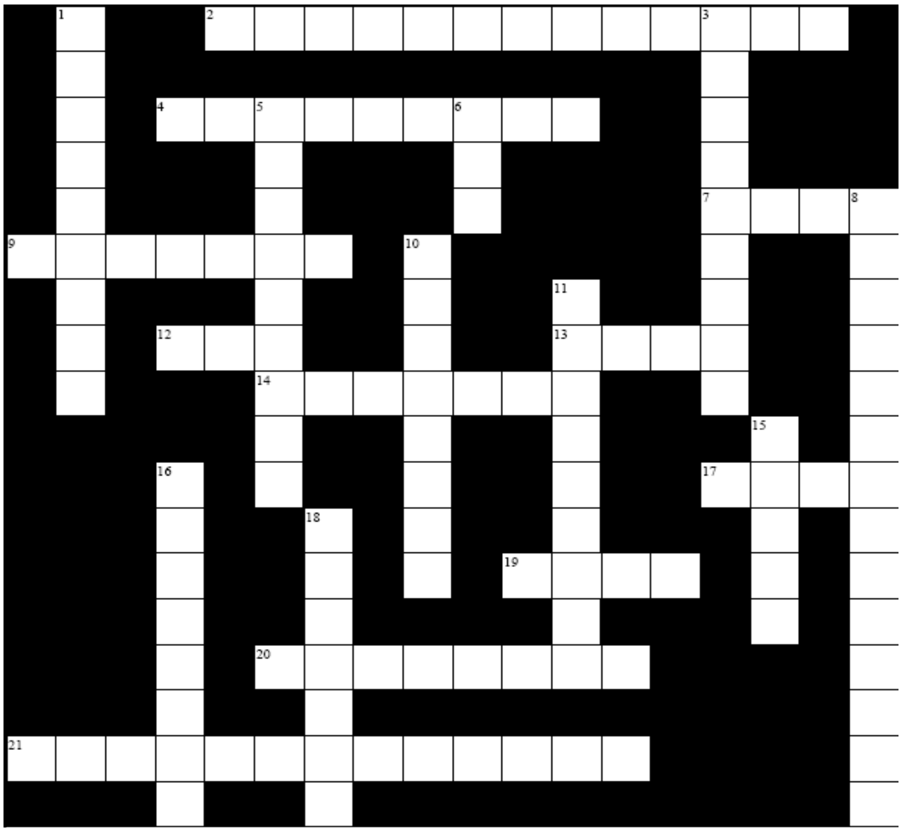
Although the use of "no more than minor" out of its proper context will not necessarily detract from the Court's final evaluation, it does put a decision maker to an unnecessary task. When selecting appropriate evaluative language to be used in evidence and in legal submissions, it is plain that lawyers and experts can greatly assist the Court by being accurate and precise.

Conclusion

Judicial comment on the use of section 104D language when assessing activities other than non-complying has sparked a more than minor debate. Although it is ultimately for the Court, and not experts and lawyers, to undertake the final evaluation of the activity under the RMA, practitioners and witnesses have a responsibility and a duty to appropriately employ the relevant statutory tests and RMA terminology. Whatever the language used in the final product, experts should be prepared to explain their conclusions and reasoning in such a way that will add value to a decision maker's overall assessment under Part 2.

Ultimately adverse effects will be considered in the round, weighed up against the positive effects of a proposal and any conditions or mitigation measures that lessen the impact of the proposal. Experts and lawyers alike should have confidence in this balancing exercise and adopt a brave and up-front approach where adverse effects are concerned, forgoing the safety blanket of "no more than minor" once and for all.

Acoustic Crossword #3



CLUES ACROSS

2. Vegan tribe err in making sound (13)
4. By which arthritis increases its frequency? (9)
7. A number of equalizers needed for HSE assessments? (4)
9. Bed lice are confused by this scale (7)
12. A bad mix up of levels in the by-law (3)
13. Note produces a special audible characteristic (4)
14. A squinty type halving the sampling frequency? (7)
17. A vibration pattern in a reshaped dome (4)
19. An enquiry is heard about power (4)
20. Boney stalactites found in the middle ear? (8)
21. An alternative to a private PO Box for communicating? (6,7)

CLUES DOWN

1. Suze and her vulva create lots of noise at the football (9)
3. Made into an island is it protected? (9)
5. A mischievous little fellow with electronic movement to music shows a complex ratio of pressure and velocity (9)
6. It senses close proximity without direction (3)
8. How walls are indexed in ISO 717? (5,9)
10. Half a semolina dish served in the uppermost part of the house without tea, we hear its audible (8)
11. Mid morning (or at bedtime) I hear you consumed to reduce the level (9)
15. We hear it is OK in wind and limb (5)
16. A place for a hirsute custodial sentence is capable of producing a neural response? (4,4)
18. By which the insulation for church services is regulated? (4,3)

Crossword submitted by:

Dogged Doer

2011

3 November, Holiday Inn, Surfers Paradise. 41st Annual General Meeting of the Australian Acoustical Society. Commencing 6.00pm.
http://www.acoustics.asn.au

10 - 13 November, Detmold, Germany. International Conference on Spatial Audio (ICSA2011)
http://www.icsa2011.org/vdt/modules.php?file=content/icsa2011/index&sl=en

16 - 18 November, Cardiff, Wales, UK. Reproduced Sound
http://www.ioa.org.uk

24 - 25 November, Valencia, Spain. International Seminar on Virtual Acoustics
http://www.upv.es/contenidos/ACUSVIRT/indexi.html

2012

20 -25 March, Kyoto, Japan. IEEE International Conference on Acoustics, Speech, and Signal Processing.
http:// www.icassp2012.com

13 - 18 May, Hong Kong, China. Joint meeting of the 183rd meeting of the Acoustical Society of America, 8th meeting of the Acoustical Society of China, 11th meeting of Western Pacific Acoustical Conference and Hong Kong Institute of Acoustics.
http://acoustics2012hk.org

02 - 06 July, Edinburgh, UK. 11th European Congress on Underwater Acoustics
http://www.acua2012.com

19 - 22 August, New York, N.Y., USA. Internoise 2012.
http://www.internoise2012.com.

19 - 24 August, Beijing, China. 23rd International Congrss of Theoretical and Applied Mechanics (ICTAM2012).
http://www.ictam2012.org/

09 - 13 September. Portland, Or. USA. Interspeech 2012.
http://interspeech2012.org

Solutions to Crossword #2

Across:

1. Taps; 3. Phew; 7. Reverberant; 9. Clef; 10. SPL; 11. Mach; 14. Threshold; 17. Stands; 20. Sine; 22. Hum; 24. Path; 25. Integration; 27. Beat; 28. Near

Down:

1. Trees; 2. See; 3. Pitch; 4. Woofer; 5. Temporary; 6. Data; 8. Rest; 12. Flute; 13. Vibration; 15. Sub; 16. QRD; 18. Seal; 19. Superb; 20. Shift; 21. Note; 23. Motor; 26. Gun.

Damage From Noise Occurs Long Before Hearing Loss Is Perceived

AHRF-funded researchers Qiong Wang, PhD, and Steven Green, PhD, both at the University of Iowa, have found that damage caused by exposure to loud noises in the inner ear may occur long before changes in hearing are perceived. They have also identified a chemical factor that may aid in restoring hearing loss due to noise exposure. Their findings were published in the May 25, 2011 issue of The Journal of Neuroscience.

The researchers studied intact cochlear cultures consisting of hair cells and spiral ganglion neurons (SGNs) taken from mice. Hair cells are structures within the cochlea that pick up sound and translate it into signals carried by auditory nerves (the SGNs) to the brain, where the signals are interpreted as sound.

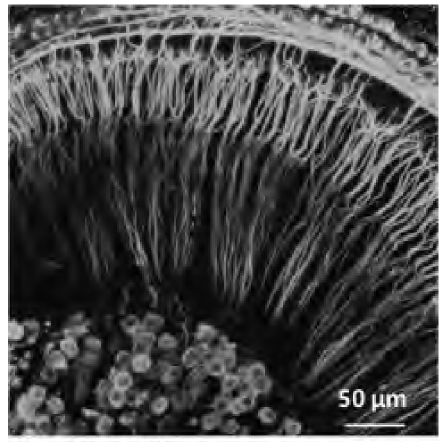
Exposure to very loud noise can kill the hair cells and cause hearing loss, a phenomenon that has been well known for many decades. Much more recent research has revealed another, even more insidious consequence of noise. Noise levels too low to kill hair cells are still able to cause irreversible damage to the cochlea, damage that may not be immediately evident but that results in accelerated hearing loss over the following decades of life. This is a particular problem in young people exposed to moderately high noise, such as constantly listening to mp3 players at high volume, or attending loud concerts.

"Most people who think they have normal hearing are probably living with some level of hearing damage- they just don't notice it," says Wang. "Just being exposed to some of the sounds of everyday life, over time, can have an effect on the inner ear, especially loud or prolonged exposure to noise."

"Exposure to lots of loud noise when you are young does lead to accelerated age-related hearing loss later in life," Wang says, "indicating that the damage from noise early in life continues to have deleterious effects over time." She believes this may be due to lost connections between hair cells and SGNs that never recover.

The research helps shed light on the complex chemical communication between hair cells and SGNs and hints as to how it may be harnessed for therapeutic interventions to treat acoustic trauma in the future. Dr. Green adds that "it is a long road from these initial observations to therapy and the best advice for now is to turn down the volume when using earbuds!"

© Adapted from an article proposed for the National Foundation for the Deaf website: http://www.nfd.org.nz/



Wang & Green, 2011

Spiral Ganglion Neurons

Hair Cells

Charging Phones with Speech

For mobile phone users, a flat battery or a lost charger are among the frustrations of modern life. Now new research suggests a way to recharge phones using the power of the human voice. A group of Engineers have developed a new technique for turning sound into electricity, allowing a mobile to be powered up while its user holds a conversation.The technology would also be able to harness background noise and even music to charge a phone while it is not in use. However, there could be a downside to the innovation, if it gives people a new reason to shout into their phones as they attempt to squeeze in every extra bit of power they can. Dr Sang-Woo Kim, who has been developing the design at the institute of nanotechnology at Sungkyunkwan University in Seoul, South Korea, said: "A number of approaches for scavenging energy from environments have been intensively explored. "The sound that always exists in our everyday life and environments has been overlooked as a source. This motivated us to realise power generation by turning sound energy from speech, music or noise into electrical power. "Sound power can be used for various novel applications including sound-insulating walls near highways that generate electricity from the sound of passing vehicles.

"The latter development would have the additional benefit of reducing noise levels near highways by absorbing the sound energy of vehicles." A prototype of the technology was able to convert sound of around 100 decibels to generate 50 millivolts of electricity.

"This is not enough to charge a phone properly, but Dr Kim and his colleagues hope that by altering the material the wires are made from they will be able to produce more energy at lower sounds levels. He said: "Our current output performance can be applied to various electronic devices with low-power consumption such as self-powered sensors and body-implantable tiny devices. We believe that we can realise more efficient sound-driven nanogenerators."

Researchers and some manufacturers have already started looking at using 'energy scavenging' as a way of powering portable electronic devices. Scientists have developed devices that can use the heartbeat to power MP3 players, while Nokia has filed a patent for a device which harvests energy from movement, much like a kinetic energy powered watch.

© Adapted from: http://http://www.telegraph.co.uk/technology/news

Richard Gray, Science Correspondent

Auckland

215, Dominion Rd	(1)	★★★★½
Andrea (form. Positano), Mission Bay	(1)	★★★
Aubergine's, Albany	(1)	★★★★½
Backyard, Northcote	(1)	★★
Bask, Browns Bay	(1)	★★★
Bay (The), Waiake, North Shore	(1)	★★★★★
Bolero, Albany	(1)	★★★★
Bosco Verde, Epsom	(1)	★★★★½
Bouchon, Kingsland	(1)	★★
Bowman, Mt Eden	(1)	★★★★½
Bracs, Albany	(1)	★★★★
Brazil, Karangahape Rd	(1)	★★★
Buoy, Mission Bay	(2)	★★★★½
Byzantium, Ponsonby	(1)	★★★
Café Jazz, Remuera	(1)	★★★★½
Carriages Café, Kumeu	(1)	★★★★
Charlees, Howick	(1)	★★★★★
Cibo	(1)	★★★★★
Circus Circus, Mt Eden	(1)	★★
Cube, Devenport	(1)	★★
Del Fontaine, Mission Bay	(1)	★★★★★
Deli (The), Remuera	(1)	★★★★
Delicious, Grey Lynn	(1)	★★★★★
De Post, Mt Eden	(1)	★★
Dizengoff, Ponsonby Rd	(1)	★★
Drake, Freemans Bay (Function Room)	(1)	★★
Eiffel on Eden, Mt Eden	(1)	★★
Eve's Cafe, Westfield Albany	(1)	★★★½
Formosa Country Club Restaurant	(1)	★★★★★
Garrison Public House, Sylvia Park	(1)	★★★★½
Gee Gee's	(1)	★★★
Gero's, Mt Eden	(9)	★★★
Gina's Pizza & Pasta Bar	(1)	★★★½
Gouemon, Half Moon Bay	(1)	★★
Hardware Café, Titirangi	(1)	★★★★★
Hollywood Café, Westfield St Lukes	(1)	★★½
IL Piccolo	(1)	★★★★
Ima, Fort Street	(1)	★★★★
Jervois Steak House	(1)	★★★
Kashmir	(1)	★★★★
Khun Pun, Albany	(2)	★★★★★
Kings Garden Ctre Café, Western Springs	(1)	★★
La Tropezienne, Browns Bay	(1)	★★
Malaysia Satay Restaurant, Nth Shore	(1)	★★★★★
Mecca, Newmarket	(1)	★★★★★
Mexicali Fresh, Quay St	(1)	★★
Mezze Bar, Little High Street	(16)	★★★★
Monsoon Poon	(1)	★★★★★
Mozaike Café, Albany	(1)	★★
Narrow Table (The), Mairangi Bay	(1)	★★★★½
One Red Dog, Ponsonby	(1)	★★★
One Tree Grill	(1)	★★★
Orbit, Skytower	(2)	★★★★
Patriot, Devonport	(1)	★★★½
Pavia, Pakuranga	(1)	★★★★★
Prego, Ponsonby Rd	(2)	★★
Remuera Rm, Ellerslie Racecourse	(1)	★★★★★
Rhythm, Mairangi Bay	(1)	★★
Rice Queen, Newmarket	(12)	★★★★
Sails, Westhaven Marina	(2)	★★★★★
Scirocco, Browns Bay	(1)	★★★
Seagers, Oxford	(1)	★★★★
Shahi, Remuera	(1)	★★★½
Shamrock Cottage, Howick	(1)	★★
Sidart, Ponsonby	(1)	★★★★½
Sitting Duck, Westhaven	(1)	★★★½
Sorrento	(1)	★★½
Stephan's, Manukau	(1)	★★★★★
Tempters Café, Papakura	(1)	★★★★★
Thai Chef, Albany	(1)	★★★★★
Thai Chilli	(1)	★★★★★
Thai Corner, Rothesay Bay	(1)	★★★★★
Tony's, High St	(1)	★★★
Traffic Bar & Kitchen	(1)	★★
Umbria Café, Newmarket	(1)	★★★★½
Valentines, Wairau Rd	(1)	★★★★★
Vivace, High Street	(2)	★★½
Wagamama, Newmarket	(1)	★★★★½
Watermark, Devonport	(1)	★★
Woolshed, Clevedon	(1)	★★½
Zarbos, Newmarket	(1)	★★
Zavito, Mairangi Bay	(1)	★★ ★

Arthur's Pass

Arthur's Pass Cafe & Store	(1)	★★★½
Ned's Cafe, Springfield	(1)	★★★★

Ashburton

Ashburton Club & MSA	(1)	★★★★½
Robbies	(1)	★★★
RSA	(1)	★★★★

Readers are encouraged to rate eating establishments which they visit by completing a simple form available on-line from www.acoustics.ac.nz, or contact the Editor.
Repeat ratings on listed venues are encouraged.

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

Tuscany Café & Bar	(1)	★★★

Bay of Plenty

Alimento, Tauranga	(1)	★½
Imbibe, Mt Maunganui	(1)	★½
Versailles Café, Tauranga	(2)	★★

Blenheim

Raupo Cafe	(1)	★★

Bulls

Mothered Goose Cafe, Deli, Vino	(1)	★★

Cambridge

GPO	(1)	★★★★★

Christchurch

3 Cows, Kaiapoi	(1)	★★★★
Abes Bagel Shop, Mandeville St	(1)	★★★★
Alchemy Café, Art Gallery	(1)	★★★★★
Anna's Café, Tower Junction	(1)	★★★★
Arashi	(1)	★★
Azure	(2)	★★★
The Bog	(1)	★★★★★
Becks Southern Ale House	(11)	★★★★½
Buddha Stix, Riccarton	(1)	★★★★
Bully Haye's, Akaroa	(1)	★★
Café Bleu	(1)	★★★
Cashmere Club	(1)	★★★★★
Chinwag Eathai, High St	(8)	★★
Christchurch Casino	(1)	★★
Christchurch Museum Café	(1)	★★★★
Cobb & Co, Bush Inn	(1)	★★★
Coffee Shop, Montreal Street	(1)	★★
Cookai	(3)	★★½
Costas Taverna, Victoria Street	(1)	★½
Coyote's	(6)	★★★
Decadence Café, Victoria St	(1)	★★★★★
Drexels Breakfast Restaurant, City	(1)	★★★★½
Drexels Breakfast Restaurant, Riccarton	(1)	★★★★
Elevate, Cashmere	(1)	★★★
Fava, St Martins	(1)	★★
Foo San, Upper Riccarton	(1)	★★★½
Fox & Ferrett, Riccarton	(1)	★★★★★
Freemans, Lyttleton	(9)	★★★½
Gloria Jean's, Rotheram St	(1)	★★★★
Golden Chimes	(1)	★★★★★
Governors Bay Hotel	(1)	★★★★
Green Turtle	(1)	★★★★
Harpers Café, Bealey Ave	(1)	★★★★★
Hari Krishna Café	(1)	★★★
Holy Smoke, Ferry Rd	(1)	★★
Indian Fendalton	(2)	★★
Joyful Chinese Rest., Colombo St	(1)	★★★★★
Kanniga's Thai	(1)	★★★
La Porchetta, Riccarton	(4)	★★½
Little India	(2)	★★★★★
Lone Star, Riccarton Road	(6)	★★★
Lotus Heart, Colombo Street	(1)	★★★★
Lyttleton Coffee Co, Lyttleton	(1)	★★★★
Manee Thai	(6)	★★½
Mexican Café	(6)	★★★
Myhanh, Church Corner	(4)	★★★½
Number 4, Merivale	(2)	★★★★
Oasis	(1)	★★★★½
Old Vicarage	(2)	★★★½
Phu Thai, Manchester Street	(1)	★★★
Portofino	(3)	★★★★★
Pukeko Junction, Leithfield	(1)	★★★★
Red, Beckenham Service Centre	(1)	★★★★
Red Elephant	(1)	★★★★
Retour	(1)	★★★
Riccarton Buffet	(2)	★★★★½
Robbies, Church Corner	(2)	★★★★½
Route 32, Cust	(1)	★★★★
Salt on the Pier, New Brighton	(6)	★★★½
Santorinis Greek Ouzeri	(1)	★★
Scarborough Fare	(1)	★★
Speights Ale House, Tower Junction	(1)	★★★★
Tap Room	(9)	★★★
The Bridge, Prebbleton	(1)	★★★★★
The Bicycle Thief	(1)	★★★★½
The Sand Bar, Ferrymead	(2)	★★★½
The Vault, Cashel Mall	(1)	★★★★
Tokyo Samurai	(1)	★★★★★
Tutto Bene, Merivale	(2)	★★
Untouched World Cafe	(1)	★★★★★
Wagamama, Oxford Terrace	(6)	★★★
Waitikiri Golf Club	(1)	★★
Waratah Café, Tai Tapu	(1)	★★★

Clyde

Old Post Office Cafe	(1)	★★★★★

Dunedin

A Cow Called Berta	(1)	★★★½
Albatross Centre Cafe	(1)	★★★★★
Bennu	(1)	★★★★
Bx Bistro	(1)	★★★★
Chrome	(1)	★★★★½
Conservatory, Corstophine House	(1)	★★★★★
Fitzroy Pub on the Park	(1)	★★★★★
High Tide	(2)	★★
Nova	(1)	★★★★★
St Clair Saltwater Pool Cafe	(1)	★★★★½
Swell	(1)	★★
University of Otago Staff Club	(1)	★★

Feilding

Essence Cafe & Bar0	(1)	★★★★

Gore

Old Post	(1)	★★★
The Moth, Mandeville	(1)	★★★★★

Greymouth

Cafe 124	(1)	★★★

Hamilton

Embargo	(1)	★★★★★
Gengys	(1)	★★
Victoria Chinese Restaurant	(1)	★★★★★

Hanmer Springs

Laurels (The)	(2)	★★★★★
Saints	(1)	★★★★½

Hastings

Café Zigliotto	(1)	★★★

Havelock North

Rose & Shamrock	(1)	★★★½

Levin

Traffic Bar & Bistro	(1)	★★

Masterton

Java	(1)	★★

Matamata

Horse & Jockey	(1)	★★★★★

Methven

Ski Time	(2)	★★★

Napier

Boardwalk Beach Bar	(2)	★★★★★
Brecker's	(1)	★★★★★
Café Affair	(1)	★★
Cobb & Co	(1)	★½
Duke of Gloucester	(1)	★★★★½
East Pier	(1)	★★
Estuary Restaurant	(1)	★★★★★
Founder's Cafe	(1)	★★★★★
Napier RSA	(1)	★★★★★
Sappho & Heath	(1)	★★

Nelson/Marlborough

Allan Scott Winery	(1)	★★★★★
Amansi @ Le Brun	(1)	★★★★★
Baby G's, Nelson	(1)	★★★★★
Boutereys, Richmond	(1)	★★★★
Café Affair, Nelson	(1)	★★
Café on Oxford, Richmond	(1)	★★★
Café Le Cup, Blenheim	(1)	★★★
Crusoe's, Stoke	(1)	★★★
Cruizies, Blenheim	(2)	★★★★½
Grape Escape, Richmond	(1)	★★★★★
Jester House, Tasman	(1)	★★★★★
L'Affaire Cafe, Nelson	(1)	★★
Liquid NZ, Nelson	(1)	★½
Lonestar, Nelson	(1)	★★★★
Marlborough Club, Blenheim	(1)	★★
Morrison St Café, Nelson	(1)	★★½
Oasis, Nelson	(1)	★★★★★
Rutherford Café & Bar, Nelson	(1)	★★★★★
Suter Cafe, Nelson	(1)	★★
Verdict, Nelson	(1)	★★
Waterfront Cafe & Bar, Nelson	(1)	★★★
Wholemeal Trading Co, Takaka	(1)	★★★★★

New Plymouth

Breakers Café & Bar	(1)	★★★
Centre City Food Court	(1)	★★★★
Elixer	(1)	★★★★
Empire Tea Rooms	(1)	★★★★½
Govett Brewster Cafe	(1)	★★
Marbles, Devon Hotel	(1)	★★★
Pankawalla	(1)	★★★★★
Simplicity	(1)	★★★
Stumble Inn, Merrilands	(1)	★★★
Yellow Café, Centre City	(1)	★★★
Zanziba Café & Bar	(1)	★★★

Oamaru

Riverstone Kitchen	(1)	★★★★★
Star & Garter	(1)	★★★
Woolstore Café	(1)	★★★★

Palmerston North

Café Brie	(1)	★★★
Café Esplanade	(2)	★★★★
Chinatown	(1)	★★★★
Coffee on the Terrace	(2)	★★★
Elm	(1)	★★★★½
Fishermans Table	(1)	★★★★★

Gallery	(3)	★★★★
Rendezvous	(1)	★★½
Roma Italian Restaurant	(1)	★★★
Rose & Crown	(1)	★★
Tastee	(1)	★★★
Thai House Express	(1)	★★★★★
Victoria Café	(1)	★★★★

Queenstown

Bunker	(1)	★★★★
The Cow	(1)	★★★
Sombreros	(1)	★
Tatler	(1)	★★★★
Winnies	(1)	★★★★★

Rotorua

Cableway Rest. at Skyline Skyrides	(1)	★★★★★
Lewishams	(1)	★★★
Woolly Bugger, Ngongotaha	(1)	★★★
Valentines	(1)	★★★★★
You and Me	(1)	★★★★★
Zanelli's	(1)	★★

Southland

Lumberjack Café, Owaka	(1)	★★★★★
Pavilion, Colac Bay	(1)	★★
Village Green, Invercargill	(1)	★★★★★

Taihape

Brown Sugar Café	(1)	★★★★½

Taupo

Burbury's Café	(1)	★★★
Thames		
Thames Bakery	(1)	★★★
Waiheke Island		
Cortado Espresso Bar	(1)	★★★★
Cats Tango, Onetangi Beach	(1)	★★★★

Timaru

Fusion	(1)	★★★★★

Wanganui

3 Amigos	(1)	★★★½
Bollywood Star	(1)	★★★½
Cosmopolitan Club	(1)	★★★★
Liffiton Castle	(1)	★★½
RSA	(1)	★★★½
Stellar	(1)	★★★★½
Wanganui East Club	(1)	★★★★

Wellington

162 Café, Karori	(1)	★★★★★
180o, Paraparaumu Beach	(1)	★★
88, Tory Street	(35)	★★
Anise, Cuba Street	(1)	★★
Aranya's House	(1)	★★★★★
Arbitrageur	(2)	★★★
Arizona	(1)	★★
Astoria	(2)	★★★
Backbencher, Molesworth Street	(1)	★★★
Bordeaux Bakery, Thorndon Quay	(1)	★★
Brown Sugar, Otaki Railway Station	(1)	★★★
Buzz, Lower Hutt	(1)	★★½
Brewery Bar & Restaurant	(5)	★★★★
Carvery, Upper Hutt	(1)	★★★★★
Chow	(1)	★½
Cookies, Paraparumu Beach	(1)	★★★½
Cosa Nostra Italian Trattoria, Thorndon	(1)	★★★★
Gotham	(6)	★★★½
Great India, Manners Street	(2)	★★★★★
Habebie	(1)	★★
Harrisons Garden Centre, Peka Peka	(1)	★★★★
Hazel	(1)	★★
Katipo	(1)	★★★★★
Kilim, Petone	(4)	★★★★½
Kiss & Bake Up, Waikanae	(1)	★★★
La Casa Pasta	(1)	★★★★½
Lattitude 41	(3)	★★★★
Legato	(1)	★★
Le Metropolitain	(1)	★★★★★
Loaded Hog	(5)	★★★★½
Manhatten, Oriental Bay	(1)	★★★★
Maria Pia's	(1)	★★★
Matterhorn	(1)	★★★
Mungavin Blues, Porirua	(1)	★★★★★
Olive Cafe	(1)	★★★★★
Olive Grove, Waikanae	(1)	★★★½
Original Thai, Island Bay	(1)	★★★★
Palace Café, Petone	(1)	★★½
Parade Café	(1)	★★
Pasha Café	(1)	★★★★
Penthouse Cinema Café	(2)	★★★½
Pod	(1)	★★½
Rose & Crown	(1)	★★★★★
Shed 5	(1)	★★
Siem Reap	(1)	★★
Speak Easy, Petone	(1)	★★
Speights Ale House	(1)	★★
Sports Bar Café	(1)	★★★★
Stanley Road	(1)	★★★
Stephan's Country Rest., Te Horo	(1)	★★★★★
Wakefields (West Plaza Hotel)	(1)	★★★
Windmill Café & Bar, Brooklyn	(1)	★★
Yangtze Chinese	(1)	★★★★½
Zealandia Café, Karori Sanctuary	(1)	★★★½

NOISE CONTROL SERVICES LTD

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