



The AS/NZ standard for building interiors [9] recommends a reverberation time (T60) of 0.4-0.6 seconds in classrooms and learning spaces. For young children, who are immature listeners, and for those experiencing hearing loss and auditory processing difficulties, a reverberation time of 0.4 seconds creates the optimum acoustic conditions.

## Noise Induced Hearing Loss

One of the most common forms of hearing loss is that caused by prolonged exposure to excessive noise. This is referred to as noise-induced hearing loss (or noise-induced permanent threshold shift) which is usually of gradual onset and irreversible. Noise-induced hearing loss begins as a result of the degeneration of the hair cells in the inner ear (organ of Corti) in the frequency region of 3,000-6,000 Hz.[10,11]

In normal healthy hearing, the hearing threshold level does not fall below 20 dB across the audible frequencies. A typical audiogram indicating noise-induced hearing loss shows the characteristic dip or V shape in the frequency range of 3,000 to 6,000 Hz (see Figure 2).

## Experimental

The study and analysis was planned with the following three research questions:

1. What are the typical sound exposure levels experienced by early childhood centre staff?
2. What is the hearing status of New Zealand early childhood teaching staff?
3. What is the typical acoustical quality of early childhood centre learning spaces in New Zealand.

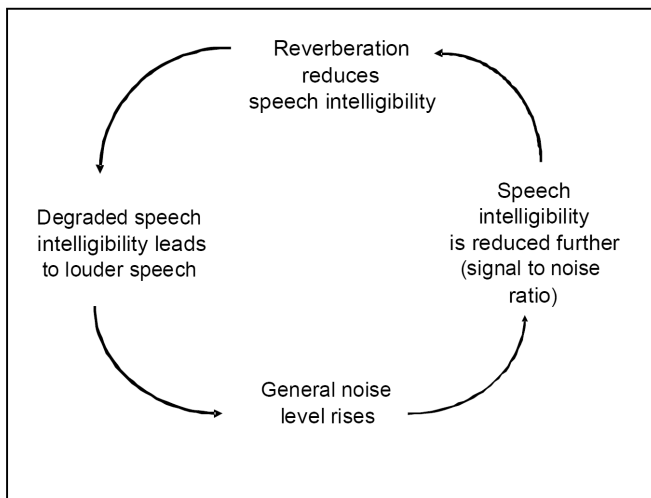


Figure 1. Cyclic interrelationship of noise levels and acoustical quality. Adapted from Oberdorster and Tiesler (2008).

### Personal sound exposures of staff

In addressing the first research question, three daily sound exposure categories were formulated. Those of less than 50% of the maximum permitted dose do not present any concern because they are well below the permitted maximum of 100%. The second category (50-100% dose) still complies with the legislation but is approaching the maximum permitted level and finally the third category (greater than 100%) is of major concern because it transgresses the legal requirement.

As length of exposure is a critical factor in determining the levels of sound exposure, the participating early childhood centres were selected according to the licensing categories of the former legislation (in force at the time the investigations were carried out) [12] which included a selection of sessional centres (kindergartens) and all-day centres. In general, children will be enrolled in kindergarten at 3-years of age and attend 2-hour sessions in the afternoon for three days a week.

Children 4-5 years of age attend 3-hour sessions in the morning for five days a week. All-day centres principally provide childcare for working parents and those who choose full time early education. This sector caters for all preschool children from new-born babies right up to age 5. Centres were licensed as required by the legislation [12] as either all-day centres (Part 1) or sessional centres (Part 2). Within each part, there are separate licensing sub-categories for children under 2-years old (all under 2) and those 2-years old and over (all 2 or over). There is an additional licensed category for mixed ages which in effect combines the two age subcategories allowing children from new-born to 5 years of age to be present in the same centre. This mixed age licence will only be granted where the Secretary (of Education) is satisfied that sufficient care and protection is provided for children less than 2-years old (Regulation 37) [12].

Daily sound exposures of individual teachers were recorded using Cirrus



Nigel Lloyd, phone 04 388 3407, mobile 0274 480 282, fax 04 388 3507, nigel@acousafe.co.nz

lightweight dose Badges and personal sound exposure meters (dosimeters) for teaching and contact staff. A total of 73 staff members (45 participants from 20 all day centres and 28 participants from 12 sessional centres) had been evaluated. All the centres except one were established in buildings converted from a previous use and had no acoustical treatment such as acoustically rated wall and ceiling panels. The personal sound exposure equipment recorded the following relevant data:

- A-frequency weighted time-average level ( $L_{Aeq,t}$  dB) for the entire work period
- Daily sound exposure expressed as pascal squared hour or % dose. A noise dose of 1.0 Pa<sup>2</sup>hr= 100% does and equivalent to an A frequency weighted time-average level of 85 dB over an 8 hour day or equivalent energy to this amount.
- C weighted Peak level ( $L_{Cpeak}$  dB)
- Time history for each event.

### Pure tone audiometric testing

The second research question involved the hearing status of the teaching staff. Audiometric testing was carried out before work began. This part of the study originated from a number of requests from early childhood centre staff expressing concern about their hearing status and requesting the research team for assistance. Despite the number of requests received, the work culture of long hours and rosters made the conducting of testing very difficult. Tests were scheduled between 5am to 7am to allow enough time for all participants to be tested before work and again after each worker had finished for the day. This meant that only the two large centres that were located close to Massey University could be considered. While it is ideal that testing be done in an approved hearing test booth, no unit was available.

The 20 participants' age range was 20 – 60 years old. The age categories and numbers in each are given in Table 1.

Audiograms were taken with the current standardised procedure for presentation of tones prior to the start of the working day to establish the normal hearing threshold of each participant (Research question two). A screening audiometer

(GSI17) was used and audiometric testing was done either at Massey University or at the particular early childhood centre.

Participation was completely voluntary but all the staff that were present at the testing times wished to participate. The necessary ethics committee approvals were obtained and the conditions of approval and the requirements of the Health and Safety in Employment Act 1992 [5] for testing of workers were strictly applied.

Background noise presented major issues in conducting the audiometric testing as no audiometric booth was available. Staff from the first centre elected to have their hearing tested before the start of work at Massey University. Even though the Massey University space was normally very quiet, the noise of heavy rain on the roof and water running down gutters became a major source of distraction. There were major difficulties in detecting the tones in the lower frequencies probably due to masking effects. Staff from the remaining centres wished to have their evaluations done at their premises, but with no quiet space a number of the tests had to be done while children were present with the noise presenting a major source of distraction. In addition, time was constrained with staff having limited time available before commencing duties. The noisy testing conditions and time constraints compromised reliability. However the

results were useful as many participants had not had their hearing tested before and were able to gain an approximate status of their hearing.

In addressing the third research question, reverberation times were measured in 30 early childhood centres. Measurements were taken with an 01 dB Solo Master sound level meter mounted on a tripod (1.2-1.5 metres from the floor) and set to T60 mode with a trigger activation level of 90 dB. The sound source was provided by a starter gun with powder caps.

Many of the centres had no form of acoustical treatment of internal surfaces. Three centres had acoustical treatment retrofitted enabling the effect on acoustical quality to be monitored. One new purpose-built centre was professionally designed to meet the criteria for learning spaces of the Australian and New Zealand Standard [9] and had full acoustic treatment applied as part of the construction.

## Results

### Daily sound exposures of teachers

The daily sound exposures (or daily noise doses) recorded in the study together with the number of participants are presented in Table 2.

### Peak levels

The highest level permitted under the Health and Safety in Employment Regulations 1995 is 140 dB.

**Table 1. Participants in hearing tests**

Number of participants	Age category
6	Less than 20
8	20-30
3	30-40
2	40-50
1	Over 50

**Table 2 Daily sound exposures and teacher numbers**

Daily sound exposure	All day centres	Sessional centres	Total 73
(% dose)	45 centres in total (% of total)	28 in total (% of total)	(% of total)
<50%	31 (69%)	23 (82%)	54 (74%)
50-100%	9 (20%)	4 (14%)	13(18%)
>100%	5 (11.0%)	1 (4%)	6 (8%)

- In all day centres 19 participants of 45 in total (42%) recorded at least one peak level exceedance over 140 dB.
- In part time sessional centres, 11 participants of 28 in total (39%) recorded at least one peak level exceedance over 140 dB
- In all day centres and part time (sessional) centres combined, 30 participants of 73 in total (41%) recorded at least one peak level exceedance over 140 dB.

Due to limitations of the equipment, further information on the numbers of exceedances, when they occurred or the peak levels received could not be determined.

### Hearing status of participants

While the effects of difficult test conditions cannot be discounted, half of the participants tested showed the likelihood of developing noise-induced hearing loss, which is characterised by an increase in the threshold values in the 3000- 6000 Hz frequency range (or the 'characteristic dip' at these frequencies as shown in Figure 2).

In the younger teaching staff (20-25 years of age), noise induced-hearing-loss was not evident from their audiograms. The audiograms of several participants in the 30-35 age-bracket presented a small notch or V shape in the 3,000-6000 Hz region, which is characteristic of noise-induced hearing loss. This trend continued with a noticeable increase in the level of noise-induced hearing loss as age increased. The two participants in the 40-50 age group both showed significant hearing loss, and the participant in the over 50 age bracket experienced the highest level of hearing loss. The audiogram is given in Figure 3. This participant would be classified as presenting with moderately severe hearing loss.

Further investigation is urgently needed to determine the extent of hearing loss, which exists in teachers of the early education sector and the amount that can be reasonably attributed to occupational exposure.

### Acoustical quality of learning spaces

Of the 30 early childhood centres chosen most had reverberation

times between 0.6-0.8 seconds in the important frequencies of 500, 1000, and 2,000 for speech production and intelligibility. Three existing centres complied with the criteria of 0.4-0.6 seconds in the important frequencies. The new purpose built centre with full acoustic treatment met the optimum conditions for young children of 0.3- 0.4 seconds in the important frequencies. This centre was fitted throughout with acoustic wall vertiface composition panels (NRC =0.4, NRC = Noise Reduction Coefficient; an NRC of 0.4 means a 40% reduction of reverberated noise) and the acoustic ceiling tiles (NCR=0.8). The centre was

also insulated to mitigate noise intrusion from noise generating activities outside the centre.

Two centres following the initial evaluation, decided to undertake professional acoustical treatment. Descriptions are given as Cases 1 and 2 below.

### Case 1

A sessional centre with a staff of two and an enrolment of 30 children carried out acoustical treatment of the walls. These surfaces, except for some upper areas were covered with New Zealand manufactured vertiface composition

## Easy to use compact design with comprehensive features

Rion's priorities for on-site measurements are speed, ease of use, quality and reliability.

The New NA-28 is the top of the Rion range of sound level meters and analyzers. It combines cutting edge technology with excellent quality and unrivalled ease of use.

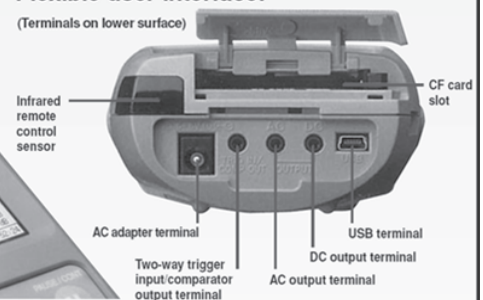
### Key Features Include:

- Ease of use – main functions on dedicated, backlit keys.
- Superb high-contrast backlit TFT-LCD colour display.
- Simultaneous measurement and display of 1/1 and 1/3 octaves.
- One keystroke to switch between sound level meter and analyzer display.
  - Massive storage capacity using text files stored to CompactFlash memory cards (CF card).
  - Flexible and simple PC connectivity (CF card and USB Virtual Disk)
  - Exceptional battery life using standard alkaline batteries, approx. 16 hours.



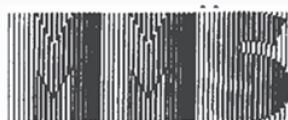
### Flexible user interface.

(Terminals on lower surface)



↑ Colour TFT-LCD Display.

← New Sound Level Meter and 1/3 octave band real-time analyzer NA-28.



## Machinery Monitoring Systems

3/355 Manukau Road, P.O. Box 26 236, Epsom, Auckland  
Tel: 09 623-3147 Fax 09 623-3248 Email: mamos@clear.net.nz

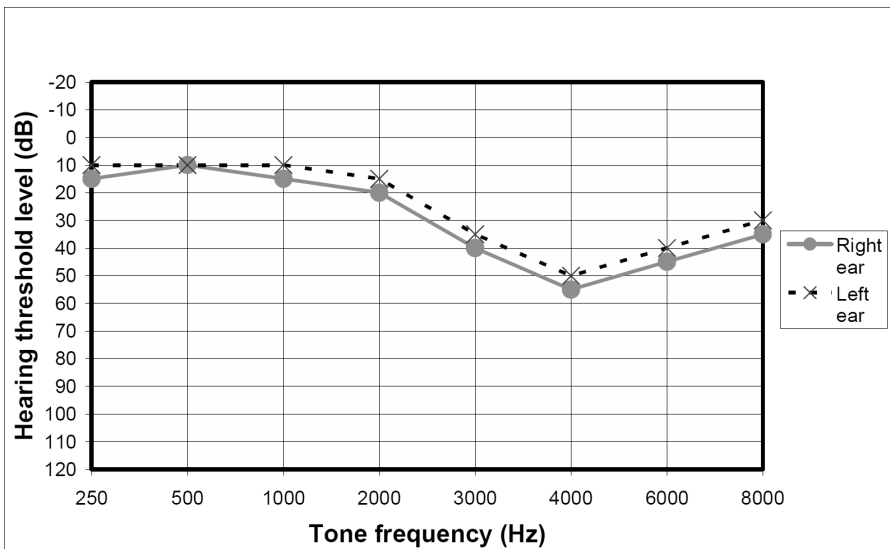


Figure 2. Audiogram showing a typical noise-induced hearing loss in both ears. Adapted from Occupational Safety and Health (1994) [10].

acoustic wall covering (NRC = 0.4). The walls were covered fully from the floor to the underside of the sill of the upper windows. The reverberation times before the treatment and after the installation are presented as a graph in Figure 4.

There has been a noticeable improvement in reverberation times as a result of the vertiface composition wall panel application with reductions of up to 0.3 seconds in the important frequencies. This centre now complies

with the recommended reverberation times (T60) of 0.4-0.6 seconds for classrooms and learning spaces.[9] These times could be further reduced by fitting acoustic tiles to the ceiling.

#### Case 2

This sessional centre had generated many complaints from staff. The reverberation times were the highest recorded of any centre. Acoustic treatment was applied to the walls with

vertiface composition wall covering (NRC = 0.4) and an acoustic blanket (NRC = 0.8) attached to the underside of 50% of the ceiling surface.

As can be seen in Figure 5, acoustical treatment of the walls and 50% of the ceiling area resulted a 0.3 second improvement in reverberation times in the important frequencies (500, 1000, 2000 Hz). While these times are still above the recommended reverberation times of 0.4-0.6 seconds [9], this treatment resulted in a substantial improvement in acoustical quality. If the acoustic treatment were to be applied to the complete ceiling area, it is likely to reduce the reverberation times to 0.4-0.6 seconds.

#### Discussion

The first research question investigated the typical sound exposures for early childhood centres staff. Six participants out of a total of 73 participants (8%) recorded daily sound exposures well in excess of 100% dose, the maximum permitted level under the legislation.[3] A further 13 participants (18%) received daily sound exposures of 50-100% and 54 participants received exposures less than 50% dose. While there has been

## Potter Interior Systems and AMF a sound Partnership



Can I have your **ATTENUATION!!**

AMF performance Ceilings are putting the CAC into your NRC and Coefficiently Increasing your Absorption.



AMF performance Ceiling Call 0800 POTTERS or [info@potters.co.nz](mailto:info@potters.co.nz) if you want to hear less.

[www.potters.co.nz](http://www.potters.co.nz)

AUCKLAND WELLINGTON CHRISTCHURCH

an improvement on the levels reported earlier in the progress study by McLaren and Dickinson [13] with an increased sample size, it is still of concern that a significant number of teachers recorded levels in excess of the maximum permitted daily sound exposure. A similar study by Grebenikov [14] in Sydney of 25 full-time teaching staff using similar equipment and the same criteria as adopted by the New Zealand legislation, had one staff member with a daily sound exposure in excess of 100% and three staff members close to the maximum.

The second research question investigated the hearing status of a small group of early childhood workers. Despite the problems with the testing environment, three of the workers showed significant hearing loss and a further seven showed clear signs of a developing hearing loss with the characteristic V shape in their audiograms beginning to form. While likely contributions from non-work activities such as noisy leisure activities have not been investigated in this study, it is of concern that half those who participated either showed significant levels of hearing loss or showed a risk of developing significant levels of hearing loss during their working lives.

The excessive personal sound exposure rates recorded on staff suggests that this may be an important occupational issue for teachers in early education environments. A comprehensive study is needed to examine the temporary threshold shifts in hearing of a cross section of early childhood education staff and relate this to the levels of noise exposure. In particular, investigation of staff members who receive noise exposures greater than the maximum permitted dose of 100%, is justified. Furthermore, a dedicated study is now needed to establish the hearing status of teachers and contact staff in the early education sector and to establish the extent of hearing loss due to occupational exposure when compared to other noise contributing activities outside work.

The third research question revealed that few of the existing childcare centres in the study had any form of acoustic treatment. Reverberation times were above those prescribed by the Australian

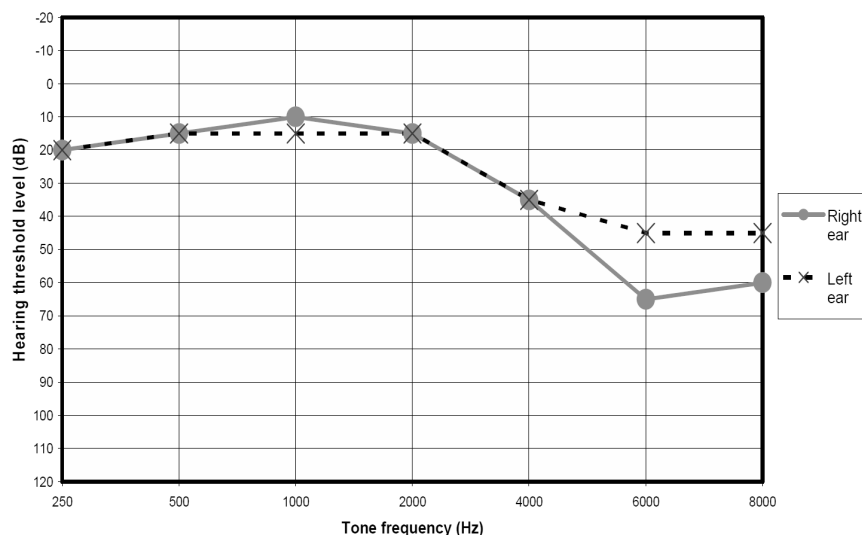


Figure 3.: Audiogram of a staff member aged 60-65 years.

### Reverberation times ( $T_{60}$ ) before and after acoustic treatment

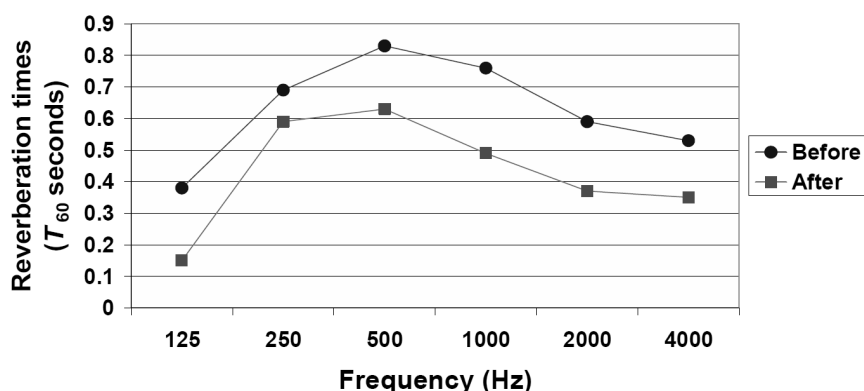


Figure 4 Reverberation time as a function of frequency (Case 1).

and New Zealand Standard. On the other hand, one of the few new purpose-built centres with full acoustic treatment incorporated, was shown to meet the optimum acoustical quality. However, the retrofitting of acoustic wall and ceiling coverings to those centres not meeting the criteria prescribed by the standard, was shown to significantly improve the acoustical quality. Due to scarce resources in this sector, it is not possible for many centres to engage professional advice to carry out acoustic treatment. Low cost solutions and DIY (do it yourself) options could be explored which may result in improvement even if they do not meet the optimum level.

The development of a resource kit could be implemented giving a wide range of

solutions to improve acoustical quality of learning spaces.

The Department of Labour has not considered this sector of workers as being at-risk from excessive noise exposure at work, and this now needs immediate attention. It is of considerable importance to investigate thoroughly the extent of occupational noise exposure with this group of workers, and if a significant risk is established, to implement regular testing programmes as is done with other at-risk work places. It may be necessary, based on establishing the level of risk among these workers, to propose amendments to address occupational noise issues in the legislation and the associated code of practice as applicable to this profession.

## Reverberation times ( $T_{60}$ ) before and after acoustic treatment

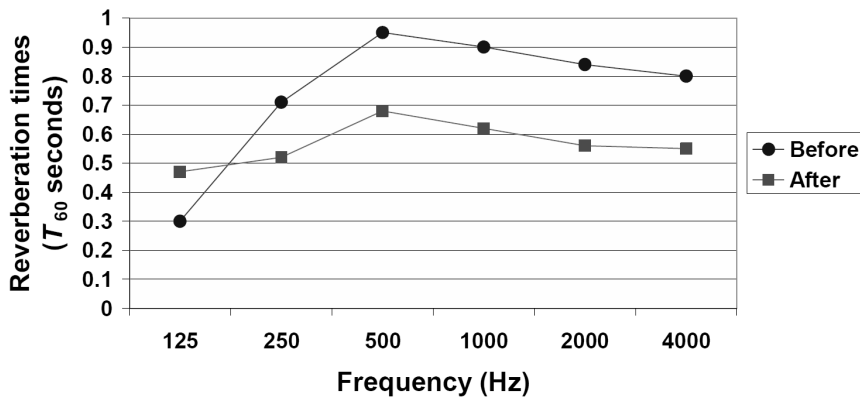


Figure 5. Reverberation time as a function of frequency (Case 2)

### Recommendations

The following recommendations are proposed:

- A wide ranging national study be undertaken of teachers and assistants across the early education sector to establish levels of excessive noise exposure and hearing loss attributable to the work environment.
- The Department of Labour and the Ministry of Education ensure that regular testing programmes are introduced for occupational hearing loss and noise exposure among early childhood staff.
- A resource kit be developed to give a range of options for early childhood centres to manage and mitigate noise levels.

### References

- 1 Education (Early Childhood Services) Regulations 2008 (New Zealand legislation)
- 2 Licensing Criteria for Early Childhood Education and Care Centres 2008 (New Zealand Legislation).
- 3 Health and Safety in Employment Regulations 1995 (New Zealand Legislation)
- 4 Occupational Safety and Health. "Approved code of practice for the management of noise in the workplace." (Department of Labour, Wellington, 2002). (Retrieved 1 August 2008, <http://www.osh.govt.nz/order/catalogue/15.shtml>).
- 5 Health and Safety in Employment Act 1992 (New Zealand Legislation)
- 6 Lombard, E. "Le signe de l' elevation

de la voix". Ann Maladies Oreille Larynx Nez Pharynx 37 101109 (1911).

7 M. Oberdorster, G. Tiesler. "Acoustic Ergonomics of School: Research report Fb 1071" (Federal Institute for Occupational Safety and Health, Dortmund, Germany, 2006)

8 M. Oberdorster, G. Tiesler. Noise in Educational Institutions. (Federal Institute for Occupational Safety and Health, Dortmund, Germany, 2008) pp 21-35

9 Australian and New Zealand Standard, AS/NZS 2107:2000, Acoustics: Recommended sound levels for building interiors. Standards New Zealand, 2000.

10 Occupational Safety and Health. "Noise-induced hearing loss of occupational origin: A guide for medical practitioners." Department of Labour, Wellington, 1994) pp 17-19

11 W. Melnick, "Hearing characteristics". in Handbook of acoustical measurements and noise control 3rd ed. C. M. Harris editor. (Acoustical Society of America, New York, 1988) pp 18.1-18.19

12 Education (Early Childhood Centres) Regulations 1998 (former New Zealand Legislation now repealed)

13 S. McLaren, P. Dickinson. "Noise in early childhood centres and how safe is the level of noise". New Zealand Research in Early Childhood Education, 8, 71-79 (2005)

14 L. Grebennikov, "Preschool teachers' exposure to noise". International Journal of Early Years Education, 14(1), 35-44. (2006)

sound weighted standardized impact sound pressure levels structure born sound low frequency noise octave band time weighting sabin speech intelligibility noise reduction engineering sound level environment spectrum resource management SIL ambient sound insulation vibration rumble sound level meter noise map silencer emission speaker amenity value

reverberation time noise reduction coefficient Dntw speech transmission index dBA frequency band noise Hertz or Hz far field octave airborne sound impact sound pressure level immission plane wave SEL line source random incidence sound reduction index.

R best practical option frequency spectrum noise exchange rate logarithm live room limiter calibration room criterion curves habitat structure sound power sound.

pressure level hiss free field Ctr articulation class ambience Bel acoustics environment assessment structural analysis apparent sound reduction index resonance natural frequency flow kinetic measurement prediction signal processing threshold shift shadow zone transducer wavelength narrow band overtone reflection percentile level impedance directivity fresnel number harmonic echo ambient active noise control attenuation coverage angle coincidence hearing point abatement temperature diffusion indoors reflections concave node anti-node wind

## Malcolm Hunt Associates

Noise and Environmental Consultants

www.noise.co.nz - email mha@noise.co.nz