

# Noise control in the wood processing industry

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## Executive summary

This survey of noise in sawmilling and the wood processing industries was commissioned by ACC and carried out by the University of Otago with the aim of assessing noise within the industry and identifying simple solutions to reducing the noise.

In general, noise levels were in the 90-100 dB range, regarded as **very noisy**. **Few workplaces in New Zealand have such consistently high levels**. Although the problem might seem insoluble, simple solutions at each stage could be identified. At the source of the noise, new designs of both band and circular saws can reduce the noise by up to 6 dB (a quarter of the noise). During sawmilling operations, a significant amount of noise came from timber handling, where damping of panels and reduction of “ringing” noise by filling rollers with sand could once again reduce the levels by 3 dB (half the noise). These are all critical points for action by the industry.

Enclosures were quite often provided, particularly with planers and “four siders”, but periodic inspection and maintenance of these is necessary: door seals deteriorate, as does insulation around infeed and outfeed openings.

Similarly, noise refuges were noisier than they should have been because of door seals and uninsulated floors.

Lastly, hearing protection is not “fit and forget”. Individuals require to be trained in their use, **particularly plugs** which can be very effective if fitted properly. Previous reports by Welch et al (University of Auckland School of Population Health) have shown that the compressible plugs are often fitted very badly (the use of the “VeriPro” or other monitoring equipment has confirmed this).

## Introduction

Noise exposure is a well known hazard in the wood processing industry, with one of the highest proportions of employees exposed to noise: in at least one study, 50% of individuals were exposed to noise levels greater than 90 dB(A).<sup>[1]</sup>

A main-stay of noise control is the provision of hearing protective devices, (hpd's). While programmes should be focussed on noise management at source, the theoretical protection provided is often much less than that found in practice, and a large survey in Alberta sawmills showed such high noise levels that noise induced hearing loss remained a significant risk.<sup>[2]</sup>

Because of the high levels of noise output of many wood working processes, noise abatement at source or during transmission, might be considered unattainable goals, but simple solutions

such as properly positioned barriers, machinery isolation, double-wall enclosures, acoustically treated infeed and outfeed tunnels, employee rotation, and machinery enclosures have been recognised for some time now<sup>[3]</sup> and although they are employed within some sawmills their use should be more universal.

The aims of this study were therefore to identify the significant sources of noise exposure, investigate “simple” control measures and assess the prevalence of noise induced hearing loss.

## **Methods**

All the sawmills who were part of an industry safety group in two New Zealand wood processing regions, South Canterbury and Hawkes Bay, were invited to participate. All of the 11 companies agreed to participate, including 6 carrying out milling only, 2 milling and further processing, and 3 further processing only.

An employer information sheet was sent to the appropriate manager at each location, who sought volunteers and distributed study information sheets to individuals at each location. On the day of the study visit, participants carrying out jobs in each main process area were selected for personal dosimetry using Cirrus Research doseBadge devices, a small unit worn by an individual which measures the sound levels and saves them using data logging software.

Appointments were made for those volunteering for audiometric (hearing) assessment. Audiograms were performed using Amplivox CA 850 and Interacoustics instruments using audiometric booths inside sound-proofed vehicles. A standard audiometric questionnaire was completed at this visit.

Area and operator position monitoring was carried out using a Brüel and Kjær (B&K) type 2260 precision sound level meter, with the microphone vertical, as close as possible to operators ears where appropriate. Calibration was carried out by B&K piston-phone. Each monitoring position was video-taped for later assessment.

## **Hazard management**

The Health and Safety in Employment Act Places obligations on employers to identify, assess and control occupational hazards in the workplace.

### **Noise identification**

Identification that noise is a hazard in the wood processing industry is not a particular problem, it is well recognised as such, with a tendency to be accepted (from discussion with industry sources) as inevitable. It should however be assessed in the general scheme of things as part of a regular review of hazards. Processes (and personnel) change, and noise is a good example where maintenance plays a significant part in the process. Other hazards such as vibration and dust often co-exist with noise exposures, so regular reviews, or “walk through surveys” of all hazards are a necessary part of a health and safety management plan.

An adequate hazard ID requires a job process review, looking at the workers' job routine, procedures and methods. Their location in relation to, and time spent in, close proximity to noise sources, methods of handling materials, and use of control equipment, will all affect exposure to noise and other hazards.

It should always be remembered that while management may know how a job *should* be done, the worker knows *how* it is done. They are also invariably aware of the sources of noise (and other exposures) and the tasks which involve the highest exposures. Noise is however, a hazard which cannot be seen but experienced, so perception of the noise hazard differs between individuals.

Exact hours and patterns of work should also be determined so that the contribution of overtime and the related prolonged exposure duration can be evaluated. Work hours in the sector often extend to 12 hours.

Worker complaints should always be taken seriously. The workers involved should always be consulted and involved in the evaluation of their work environment. They should be asked about complaints or symptoms that may be attributable to significant exposure. Their advice should even be sought on how best to proceed with an investigation, as they have the most intimate knowledge of their job.

The final aspect of the qualitative "identification" exercise is the type of controls applied - both collective and personal. The misuse or absence of personal protective equipment is both common and usually self evident: a well known example is the wearing of "beanies" with hearing protection applied over them. The effectiveness of engineering controls such as enclosures can be assessed by looking at the seals on doors, the state of repair of enclosures and noise from inadequately maintained equipment.

### **Noise assessment**

Noise assessment is a more formal process, which may involve (as in the present project) monitoring the occupational environment to characterise and assess the magnitude of noise hazards. This is the next step in making a 'diagnosis' of an 'unhealthy' work environment. It complements or confirms the information gained from the assessment made during the preliminary investigation, and provides a means of quantifying the extent of risk. The information gained provides a baseline from which to design and assess the effectiveness of control strategies.

The primary elements of the noise sampling strategy can be summarised as being those which relate to *location*, *number*, and *time* of samples.

There are essentially two choices of location of sampling on an individual worker, *personal* sampling in the worker's breathing zone, and *area* or *static* sampling in a fixed location *in the work area*.

#### **Personal sampling**

Personal noise sampling can be further subdivided into a true personal sample, where the sampling device is directly attached to the employee and worn continuously during all work and rest operations, and a sample where a second person holds a noise meter as near as possible to the worker's hearing zone. This second type of sampling

is difficult to perform, but may be useful as it provides an instantaneous readout and shows how exposure changes with tasks.

### **Area sampling**

Personal sampling is the only valid method of estimating personal noise exposure, but **area** or static sampling is the best method for obtaining information on the **sources** of noise in order to inform control efforts. Video recording of such measurements are often useful for later analysis of the noise sources.

## **Sampling strategies for personal monitoring**

The two main methods of selecting the sample to monitor are ‘worst-case’ sampling and random sampling.

### ***Worst-case sampling***

When not all individuals can be sampled, selecting the maximum risk or worst-case employees is an alternative strategy. This involves a subjective determination based on careful observation during a walk through survey. These clues include proximity to the noise source, time spent near the process when workers are mobile, and movement patterns within the workplace-particularly where the work process itself contributes to these e.g. moving machinery or product. Differences in work habits of individual workers may also have a significant effect on levels of exposure experienced, even when performing essentially the same task. For example, some workers take more care with materials handling.

The obvious advantage of worst-case sampling is the degree of certainty with which group exposures can be said to be ‘safe’ when maximum risk employees have been shown to have exposures within recognised standards.

### ***Random selection***

Where there is any doubt about the ability to select maximum risk employees to perform worst-case monitoring, then the only scientifically valid method is to select a sample in a purely random manner. Random sampling will also have application where employees have been grouped according to the similarity of exposures, and a sample from each group has to be selected for monitoring.

## **Number of samples**

There is no set rule for determining the number of replicate samples required to fully evaluate a worker’s exposure. A minimum number must, however, be taken to characterise the exposure in space and in time, and to provide the level of confidence required .

Regular monitoring is of diminishing value as exposures become further removed from the exposure limit. There is little to be gained, for example from repeated measurements of exposure when the contaminant’s concentration in the breathing zone is below one-tenth, or above twice the exposure limit. However, in either case a change of process, of materials handled, or indeed of noise control methods, would provide sufficient justification for further sampling.

As a general rule *personal sampling is the only valid method of estimating personal exposure*, and area or static sampling is the best method for obtaining information on the sources of noise emissions to direct control efforts. Also as a general rule neither method will give valid or useful information for the other purpose. The WES (85 dB(A) for 8 hours) can, strictly

speaking, only be measured by personal dosimetry when the employee performs a number of tasks.

### **Sampling for the survey**

Area sampling was also carried out for this project, the focus being on the sources of noise emissions, and samples were taken at fixed locations, usually where employees were normally present.

In this survey, the sampling was usually “worst case” a subjective determination based on careful observation during the walk through survey. Some caution is required with this approach: differences in work habits of individual workers may also have a significant effect on levels of exposure experienced, even when performing essentially the same process (the noisy and quiet worker).

Lastly, a number of samples are required but there are no set rules for doing this. There may be variations within the day, from day to day and within the season. A minimum number of samples must be taken to characterise the exposure in space and in time, and to provide the level of confidence required.

The test of whether the hazard is significant or not is, in the case of noise, whether the exposure exceeds 85 db(A), the Workplace Exposure Standard (WES) for noise. For this exposure to cause hearing loss, exposure must be for 8 hours a day, 40 hours a week for a working life-time of 45 or so years. It is not an absolute limit or “safe” limit (but is often interpreted in this way).

### **Control of Significant hazards**

Given that a Hazard Assessment has been performed, then, for significant hazards, the following three control measures have to be considered in order:

- Elimination,
- Isolation,
- Minimisation and monitoring.

Note that *it is not acceptable for Minimisation and Monitoring to be adopted as the first option*, Elimination and Isolation must be considered first.

Therefore, firstly, can the hazard be eliminated, could the task be done in some different way, for example the use of new saw technology? If the noise can't be eliminated, then the reasons why not must be stated.

If the hazard can't be eliminated, can it be isolated? Isolation means that although the hazard still exists, workers cannot come into contact with it, for example the well known solution of enclosing multi-head planers.

However, for many noisy processes, neither elimination nor isolation is possible. Consequently, the aim is to minimise and monitor exposure to the hazard.

The most common and least desirable ways to minimise exposure are the wearing of Personal Protective Equipment, Hearing Protective Devices (HPDs) and occasionally job

rotation when working from within cabins can be combined with a period on the chain, thus reducing the exposure for two workers instead of just one.

Any process of recognition and evaluation of potential hazards should be regarded as preparation for their control, and should never be performed for its own sake. Having made these assessments, there are three major areas where measures to eliminate or control hazards posed by harmful exposures, can be implemented. The first, and most effective, control alternative is to concentrate on the *source*. Effort should then be directed toward control of the *path* of the hazard, and the last alternative is to provide protection at the *receiver*.

As mentioned above there is a well-recognised hierarchy, or order of priority, of control alternatives which can also be summarised as:

### **Control at the source**

*Elimination* of the hazardous process or operation.

*Substitution* of a toxic material or hazardous process with less toxic or hazardous alternatives.

### **Control of the path**

*Isolation* of the process or substance to eliminate or minimise exposure of workers.

*Enclosure* of the process to achieve isolation from employees, or to assist other means of control such as extraction ventilation.

### **Control at the receiver**

*Personal protective* equipment to provide a barrier at the worker.

*Training and education* in methods of reducing their own exposure.

This is how noise sources were looked at in this present survey.

## **Glossary**

SPL	Sound Pressure Level. Measured in dB, with .00002 Pa as the reference level.
dB(A)	"A" weighted sound Pressure level in dB: weighting takes into account frequency sensitivity of the human ear at "normal" sound levels.
dB(C)	"C" weighted sound pressure level, used for measuring impulse noise.
LAeq,8h	The 8 hour equivalent SPL ("averaged" over 8 hours).
LAeq,t	The equivalent SPL over a period t.
L peak	The peak level of the noise.
LAFmax	The maximum "instantaneous" SPL during a period.
LAFmin	The minimum "instantaneous" SPL during a period measures what the "background" noise is, i.e. a saw running without load, and no timber handling.

## **Explanation**

There are a number of tables which represent individual noise levels measured generally at the operators position. As most sawmill operations are cyclical, 5 minutes is usually all that is required to capture what the equivalent noise will be over 8 hours. If the operation was not observed to be cyclical, longer measurement periods were used to capture a full cycle of operation.

The tables in the report give, in general, four figures: the elapsed time, the LAeq (which will be the LAeq for the elapsed time, usually around 5 minutes i.e. LAeq 5 minute); the LAFmax, which is the maximum during the period captured by a “fast” averaging in the meter and the LAFmin, which is the minimum level. In most cases the LAFmax is the noisiest thing that occurs during the 5 minutes, the LAFmin representing “no load and no handling” conditions.

In the figures, the “peak” levels of impulse (“ringing” or “explosive”) noise are captured using an even shorter average than the “fast” one (milliseconds) to capture the height of the peak. Impulse noise is generally very loud, and measured in dB(C).

The graphs show the same information. With dosimetry, the noise is measured every minute, with the blue line indicating the average during that period and the impulse levels by points above. With the area monitoring, all the levels are shown. Some spectra are shown, these represent the individual frequencies making up the overall noise.

Summary data is reported as the median (“average”) with upper and lower boundaries (the range).

# Noise sources in the wood processing industry

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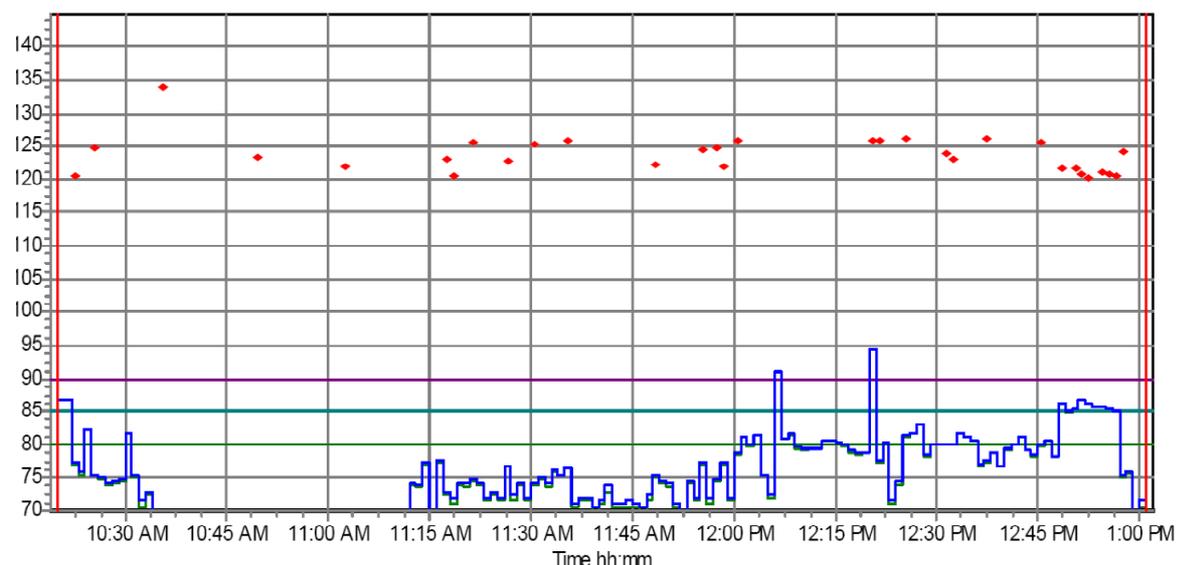
In performing a hazard ID, the most logical way to ensure that all the hazards have been identified is to look at the process from raw product in, to finished product out.

## Sawmills

The first step in the green chain is debarking.

### Debarking noise exposure

Noise levels were 85-90 dB measured outside cabins, but operators had lower exposure, in the order of 80 dB or so. If combined with other jobs (as below) such as loading, the noise exposure was around 75 dB on the loader (with cab) but 80 dB in the cabin.



**Figure 1: Debarker operator dosimetry**

### *Source*

Noise comes from the handling chain, the debarking rotor, and the associated drive and transmission systems. Logs are generally carried by chain conveyors. One or two of these were poorly designed, with inadequate diameter of sprockets, resulting in snatching of the chains. Some maintenance problems with “squealing” were also observed. Where logs were passing through transfer points, there was significant reverberation of panels transmitted through the structure of the debarker and to noise refuge cabins. Many debarker operators also carried out loading operations, but loaders have enclosed cabs.

### *Path*

Debarker operators were, without exception, outdoors and provided with cabins. In some cases these were poorly maintained. Proper design and attention to door seals (and door

closure) is essential. Most doors were actually left open, reducing their effectiveness. Anti vibration mounting of cabins, and insulating the floors can make a difference.

### ***Receiver***

None of the operators used hearing protection inside cabins, some wore them outside, but not consistently.

### **Headrig/resaw noise exposure**

The noise around headrig operations varies widely, from 94 dB to well over 100 dB. The 94 dB levels were idling, cutting obviously increases the noise but a major contribution comes from the timber handling chain.

From 6 Headrig measurements, the median was 98.5 dB(A)

### ***Source***

The Bandsaw noise is from the machine (bearings etc) and the cutting teeth. Adequate maintenance is essential. There have been some developments in saw design, for example: “A band saw blade having relatively extended pitch patterns of eight or more teeth exhibits relatively low noise and vibration during cutting operations, and substantially uniform tooth loading characteristics. The band saw blade defines set patterns within each pitch pattern, and each set pattern is defined by an unset leading tooth, followed by a plurality of offset trailing teeth. Each tooth within each set pattern defines a pitch between the respective tooth and the preceding tooth in the cutting direction of the saw blade, and an accumulated pitch between the respective tooth and the preceding tooth of like, set direction in the cutting direction of the saw blade. The ratio of pitch to accumulated pitch for each tooth within each set pattern increases from one tooth to the next in the direction opposite the cutting direction of the saw blade for substantially uniformly distributing the chip load over the teeth of the saw blade. In addition, during cutting operations, each tooth entering or exiting the workpiece defines a different pitch or forcing frequency than does every other tooth simultaneously entering or exiting the workpiece, or successively entering or exiting the workpiece, to thereby minimize noise and vibration during cutting operations.”

The following is from the UK Health and Safety executive document “noise reduction at band re-saws”<sup>[4]</sup>.

When a band re-saw is idling, vibration of the blade is usually the main source of noise. When cutting, high vibration levels in the blade caused by sawdust trapped between the pulleys and blade, and vibration of the timber being sawn are the main noise sources. How much the blade vibrates is affected by the:

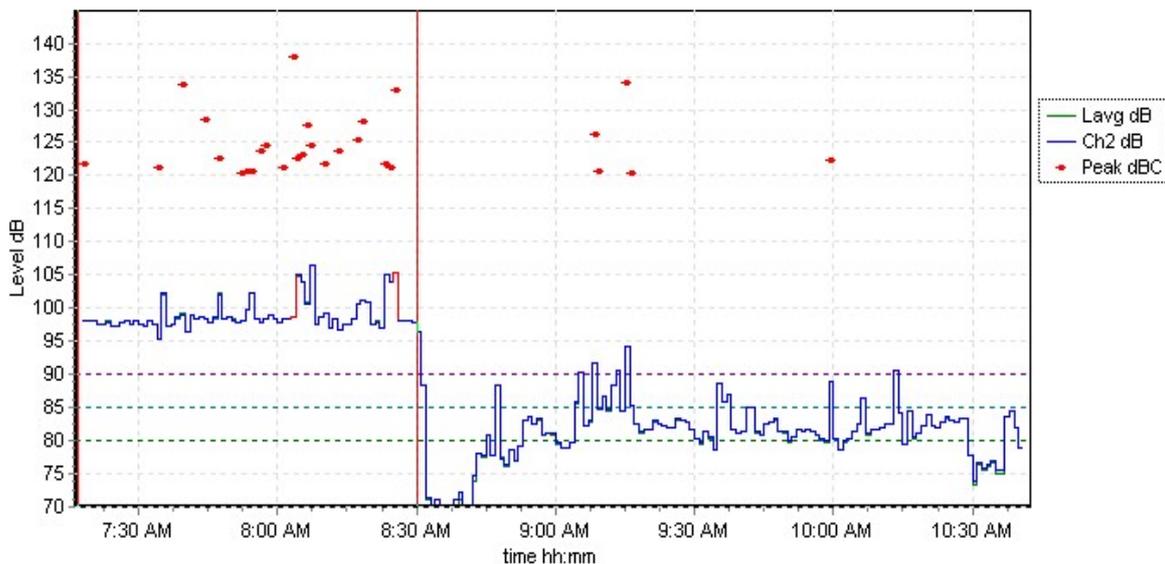
- gauge of the blade;
- condition of the saw pulley surfaces;
- effectiveness of the sawdust deflection and extraction systems;
- effectiveness of the pulley and blade scrapers/cleaners;
- effectiveness of the sawblade lubrication system;
- adjustment of the saw guides; and
- blade tension.

The condition of the sawblade, and the smoothness of the pulley faces, have been found to affect idling noise levels by as much as 10 dB. How efficient the sawdust extraction and wheel scraping/cleaning systems are, can have a similar effect. Poorly adjusted saw guides can push noise levels up by 3 dB and using an unnecessarily heavy-gauge sawblade produces a wider kerf (cut) can also produce more noise. A new 19 gauge 100 mm blade running on 900 mm diameter pulleys has been found to produce levels 5 dB higher than a new 20 gauge blade on the same machine.

In terms of handling, if the timber strikes a hard surface such as a roller or a panel, impact noise will be produced. The effect is that impact noise raises the overall levels and can be considerably increased, observed which can be up to 118 dB(A). The noise from panels on the conveyor chutes could be reduced by either stiffening or absorptive materials. Rollers, which “ring” on impact, can be filled with damping material, for example sand. The bearings are robust, and because of inertia, not much more energy will be required.

**Path**

The solution is, as applied with debarkers, to provide an operators cabin. The effect on noise exposure can be seen in the figure: average level of 98-100dB while on the mill floor, 80 dB or so in the cabin, but with peaks while outside. On leaving noise refuges in the Mill, hearing protection should always be worn. One headrig operator in the survey was not provided with a cabin.



**Figure 2: Headrig operator noise.**

**Receiver**

The control method of choice is the reduction of noise at source (engineering) or failing this, some form of interruption of the sound path between source and receiver. Protection of the receiver is mainly through the use of hearing protection, a form of personal protective equipment *which should always be considered as residual protection until further noise control measures can be implemented.* If this is the control method of choice, there needs to be a hearing conservation programme (qv). *If hearing loss continues to be a problem, then some aspect of the hearing conservation programme is likely to be at fault.* Not wearing the protection has obvious implications, see the section “reduction of effectiveness”. Poor fitting and maintenance may also be to blame.

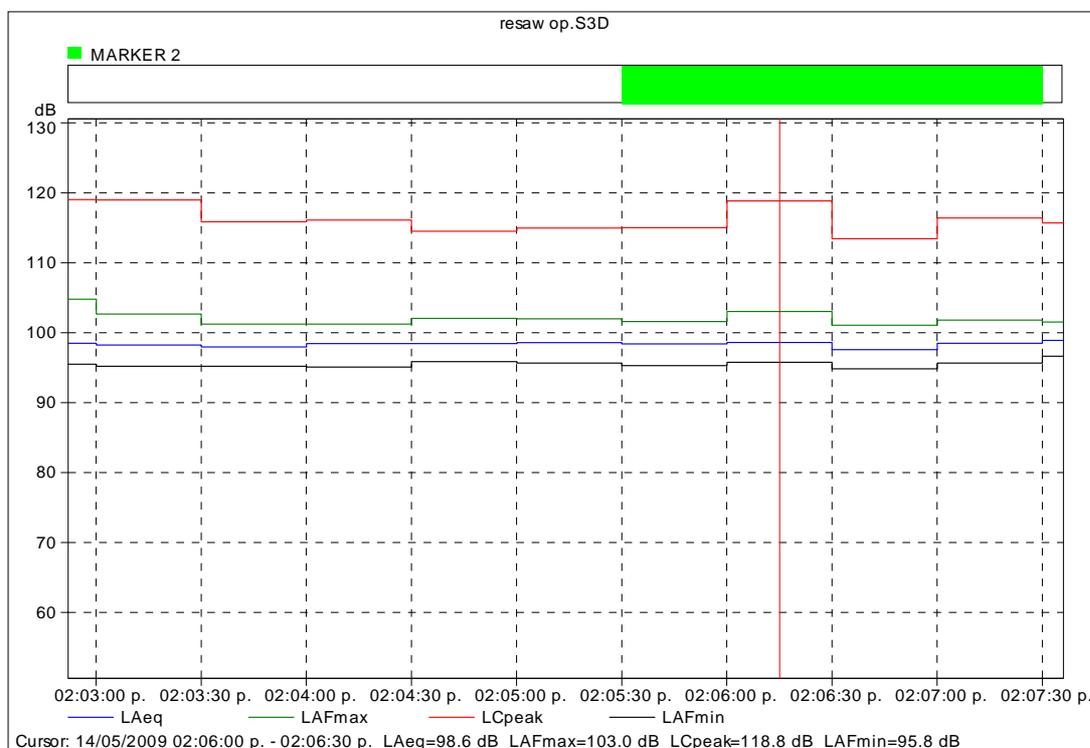
A significant point here is that one should not “over-protect”. Although class 5 might be seen as “best” in all situations, higher classes of protection *may* be bulkier and also might increase the sense of isolation if used in lower noise levels through attenuating too much “signal” noise. The Leq’s suggest that class 4 ear-muffs would be satisfactory in this area. If other personal protective equipment (PPE) is used, then **plugs may be the only option**. This includes wearing earmuffs over beanies: they will let the noise through.

Plugs, *if well fitted* can be very effective, but they are difficult to fit properly. **Each individual should therefore have their technique checked.** The plugs should be held in the ear for **one minute** to allow them to expand. Class 4 or 5 hearing protection will be effective, and there are a number of choices available in the DoL guideline. Note that, if hearing protection is used, base-line (pre noise exposure) and monitoring (post noise exposure) audiograms are required by the DoL code of practice. This requires the employees hearing to be measured *during the shift*. If there is a shift in hearing between base-line and monitoring tests it indicates that there may be a problem with wearing of the protection *which should be investigated*.

### Re-saw and edger noise exposures

**Re-saw (band saw) measurements were 98.6 dB(A), with a range from 96-100.**

Resaw and edging operations are similar to headrig operations. Noise here is around 98 dB (blue line), but the peaks in the noise (red line) are mostly due to timber handling.



**Figure 3: Re-saw.**

Source

While most re-saws and edgers are band saws, several circular re-saw operations were observed.

The following is from the IFA (Institut fuer Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung) web site:[5]

“In the case of the circular saw, the blade's excitation of vibration is particularly strong because the blade is of thick steel, which has practically no damping effect. With damped, noise-reduced saw blades, it is possible to effectively reduce the excitation and hence the propagation of sound. Other factors that have an effect on the saw blade's excitation of vibration (e.g. hardness of the material or saw tooth geometry) can only be modified to a limited extent. The feed rate and saw blade projection, i.e. the distance the saw blade projects from the table, have a major effect on the sound level. It is advisable to always keep the saw blade projection as low as possible. Significant noise reductions, 6-10 dB, are thought to be possible.”

There are two types of noise-reduced saw blades.

Saw blades that have a "sandwich design", i.e. consisting of two sheets of metal and a damping film in between.

Saw blades incorporating laser incisions that inhibit the generation of natural vibration and, thanks to the friction in the incisions, achieve better damping.

Either is suitable for sawmill application. An additional advantage of these saw blades is that their higher quality and the low-vibration operation result in an increased capacity and precision, and hence better results. These two points compensate for the on average 30% higher cost of purchasing these products. Low-noise saw blades are thus a highly cost-effective way of reducing noise from the use of circular saws

### ***Path and receiver***

As previously.

### **Handling chain noise exposure**

Handling chain noise exposures (13 measurements) had a median exposure of 94 dB(A), range 87-96.

The noise exposure on the handling chain depends on whether there are other significant noise sources such as docking saws, or on the proximity to the main mill operations. Stacker operations tended to be similar.

Some examples are shown below.

**Table 1: Handling chain noise exposure****Docking**

	<b>Start time</b>	<b>Elapsed Time</b>	<b>Overload [%]</b>	<b>LAeq [dB]</b>	<b>LAFmax [dB]</b>	<b>LAFmin [dB]</b>
Value			0	<b>94.9</b>	109.6	89.4
Time	2:04:26 p.m.	0:03:20				
Date	18/05/2009					

**Sticking**

	<b>Start time</b>	<b>Elapsed Time</b>	<b>Overload [%]</b>	<b>LAeq [dB]</b>	<b>LASmax [dB]</b>	<b>LASmin [dB]</b>
Value			0	<b>87.3</b>	92.8	81.9
Time	1:02:17 p.m.	0:03:32				
Date	14/05/2009					

**Stacker**

	<b>Start time</b>	<b>Elapsed Time</b>	<b>Overload [%]</b>	<b>LAeq [dB]</b>	<b>LASmax [dB]</b>	<b>LASmin [dB]</b>
Value			0	93.7	102.2	87
Time	1:32:52 p.m.	0:04:40				
Date	14/05/2009					

**Sorter**

	<b>Start time</b>	<b>Elapsed Time</b>	<b>Overload [%]</b>	<b>LAeq [dB]</b>	<b>LASmax [dB]</b>	<b>LASmin [dB]</b>
Value			0	95.3	102.4	90.7
Time	1:42:45 p.m.	0:04:52				
Date	14/05/2009					

**Sorter out-feed**

	<b>Start time</b>	<b>Elapsed time</b>	<b>Overload [%]</b>	<b>LAeq [dB]</b>	<b>LASmax [dB]</b>	<b>LASmin [dB]</b>
Value			0	95.1	99.1	90.8
Time	1:51:48 p.m.	0:02:44				
Date	14/05/2009					

**Source**

The sources have been briefly described. Any point at which logs or timber strikes a part of the conveyor system, such as at transfer points between conveyors, and also at “drop outs”, has the capacity to produce impact noise. The amount of noise produced depends on the weight of the timber, tending to be worse at the headrig, and on the surface being struck. The length of the drop will also influence the amount of energy released.

When the object struck is a roller, there is a tendency for “ring” which may be prolonged. Striking a panel also causes this effect. The solution for rollers may be to fill them with an

absorptive material such as sand. The bearings are robust enough to withstand this, and due to inertia not much more energy will be needed.

Panels can either be faced with sound absorptive material, or have stiffening or supporting members retrofitted.

### ***Path and receiver***

Sound absorption, especially at transfer points, would provide benefits in terms of sound transmission to other areas.

## **Further processing operations**

The further processing operations were involved with general timber processing for the furniture and building trade and also various manufactured timber products (laminated building products, also pallets, cable drums and bins).

All of the standard wood process operations were included: conversion (band saws, docking saws etc); component making (machining operations, moulding, finger jointing) assembly (lamination) and final finishing and packing.

## **Conversion operations**

### **Band saws**

Six measurements of bandsaws in further processing gave a median of 95 db(A), with range 90-96 db(A).

Band Saws used in further processing conversion are on a scale of magnitude smaller than those in the mills. They do tend to be slightly less noisy at the operators position, but not much more so. Average levels are still in the order of 95 dB, with quieter minimum, around 90 dB.

### ***Source***

The same criteria apply to reduction of noise at source from conversion saws.

### ***Path***

In further processing, the work area tends to be open plan, as this facilitates the work flow. As a result, noisy items of machinery plant and equipment tend to affect bystanders, those working “quieter” machines nearby, for example. Sound barriers will absorb some of this noise and can reduce reverberation, thus lowering the noise by up to 3 dB, which is half the sound energy.

### ***Receiver***

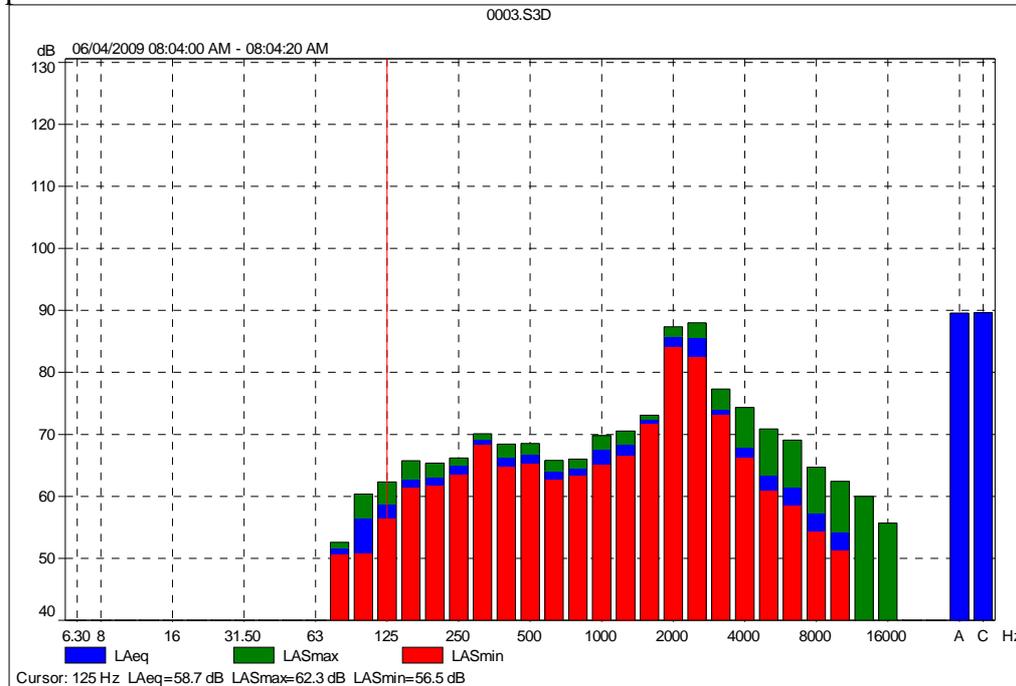
As previously.

### **Docking saws**

Docking saws were not much in use within further processing: the one example had a noise output of 89 dB(A). It was, however, a special case.

### Source

Docking saws are circular saws with guards. Care must be taken with these, which because of the enclosures become, in effect, miniature sirens. This can be seen in the figure below where there are peaks in the noise spectrum at 2 and 3 kHz, audible as a high pitched whine. Re-design of the enclosure will reduce this noise signature, which is audible right through the production area.



**Figure 4: Noise spectrum, docking saw.**

### Path

As in all areas from which high noise levels originate, it helps if the sound can be contained or absorbed by baffles or barriers. This will stop sound transmission.

### Component making

#### Multi head machines

Out of 8 measurements, a median of 92, minimum 83 maximum 103. This reflects the range of enclosures (the 103 db(A) example with no enclosure).

### Source

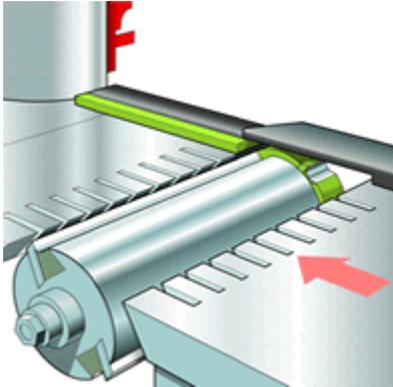
The noise from multi-head machines comes from a number of sources:

1. Idling noise generated aerodynamically by the rotating cutter heads.
2. Cutting noise generated by the impact of the knives on the timber.
3. Noise created by the transmission of vibration along the timber length.
4. Poorly designed and sited chip extraction systems.

The following is from the UK Health and Safety Executive web site.<sup>[6]</sup>

<http://www.hse.gov.uk/noise/goodpractice/planingmoulding.htm>

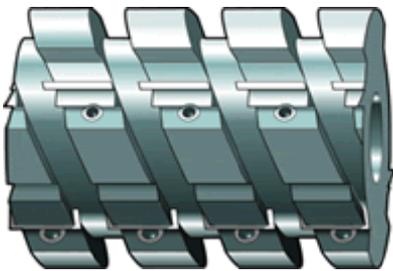
[extracted from L108 “Controlling noise at work” p 57]



**Figure 5: Slotted table lips on a planer reduce air turbulence and noise.**

When any rotating part such as a fan blade or a woodworking cutter block passes close to a stationary part of the machine, noise is produced. If the distance between the rotating part and the stationary part is increased, the noise level will be reduced. Also if cutter blocks are fitted with helical blades, the smooth transition of the curved cutting edge next to the stationary table instead of the abrupt impact of a normal blade, will reduce the noise considerably.

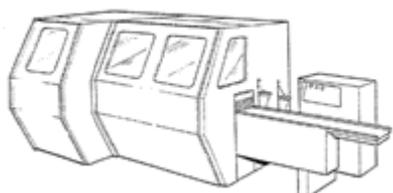
**CAUTION:** Gaps between stationary and rotating parts of machinery are dangerous. You should not alter gaps without ensuring that the machinery can be used without risks to safety.



**Figure 6: Reduced-noise cutter block.**

When air flows past an object or over sharp edges, turbulence is caused which produces noise. Also when air flows over cavities or voids, a noise tone can be produced (similar to blowing over a milk bottle). Making edges as smooth as possible and removing voids or rounding the edges can reduce the level of noise created. Similarly, air flowing smoothly through ducts and pipes will produce less noise.

### **Methods of noise reduction at source**



**Figure 7: Integral enclosure – close fitting round feed area with controls outside and overlapping strips across opening.**

Planing and straightening heads often produce most of the idling noise. This can be reduced by up to 10 dB by using smoother profile blocks with low blade projection. Slotted or perforated table lips can reduce idling noise levels by more than 5 dB at the bottom first head (straightening cutter).

Helically bladed cutter blocks can significantly reduce cutting noise when planing. However, this type of cutter is not readily available for moulding machines. Segmented blocks (which are more widely available) can reduce in-feed noise levels by 5 dB if used at the bottom first head.

Reductions in cutting noise can also be made by reducing the cutter's rotational speed, and increasing the number of knives on the cutter – without detriment to the finish.

Correct design of chip extraction systems can reduce idling noise levels significantly, where the system is not part of a noise enclosure.

Design of high speed drive motors should embody up-to-date noise reduction techniques.

***Path***

Interruption of the path can be achieved by enclosure: The attached DoL guide gives guidance on this. The points outlined should be addressed if possible, although this is likely to cause some access problems in feeding and outfeeding.

In two instances, a four sider was not provided with an acoustic enclosure at all because of access requirements and the need for manual feeding of smaller off cuts of timber and was by far the noisiest single item of machinery on site. Some form of acoustic barrier (or isolation) would provide benefit in terms of sound transmission to the rest of the plant.

If an enclosure is provided, maintenance is still important, for example the seals around doors. These should obviously be kept closed for maximum effect (which was not always the case).

***Receiver***

As previously

## Assembly

**The lamination process (2 measurements) had median 96 dB(A) with minimum 94 and maximum 98**

The major sources are “donging” down the laminates with a wooden sledge or donger and the rattle gun used to compress the laminates during the cure. The peak noise levels can reach 133 dB(C).

### Source

The noise of the impact wrench comes from the turbine vanes on the air motor, the impact of the hammer on the anvil when it strikes, and the exhaust air noise. Not all wrenches produce the same noise, and it pays to “buy quiet” where possible. Some wrenches have the air exhaust in the handle, which helps.

The impact noise from donging down will be difficult to deal with at source.

## Fabrication: Drum, pallet and crate manufacture

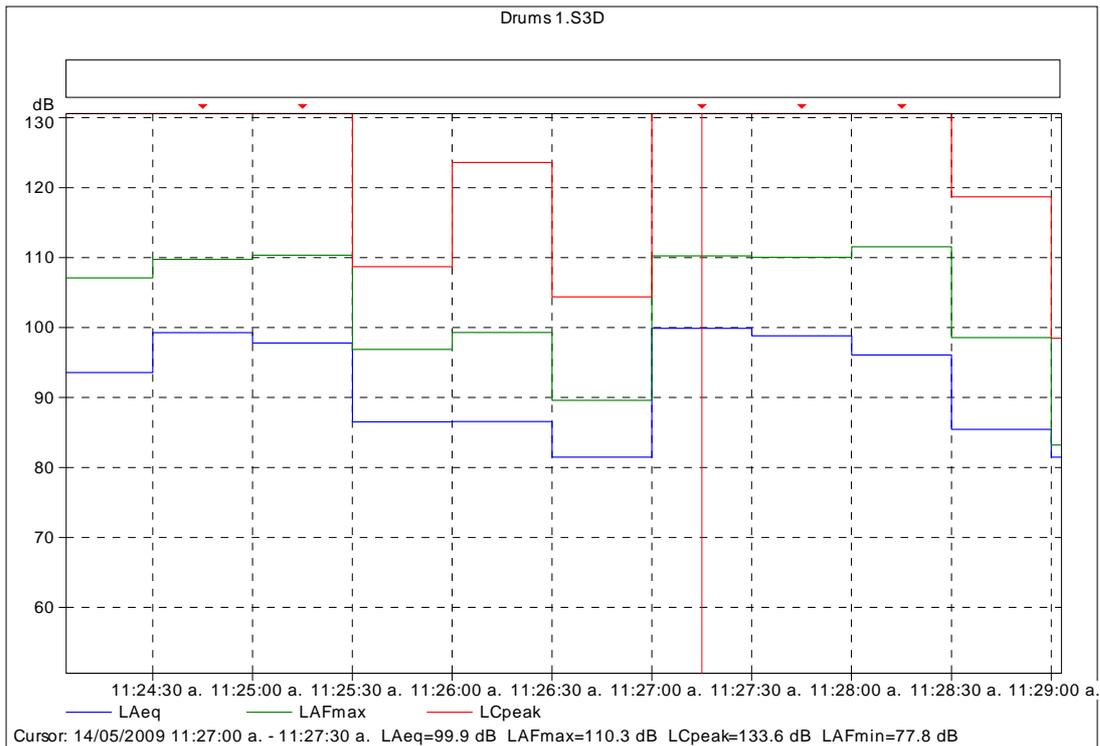
A total of 3 measurements of fabrication were made, median 99 dB(A), range 96-102. Two specific examples were drum and pallet making.

**Table 2: Drum making noise exposure**

	<b>Start time</b>	<b>Elapsed time</b>	<b>Overload [%]</b>	<b>LAeq [dB]</b>	<b>LASmax [dB]</b>	<b>LASmin [dB]</b>
Value			0.01	95.9	106.2	78.3
Time	11:24:04 a.m.	0:04:59				
Date	14/05/2009					

A noise level of 96 dB(A), with a maximum of 106 dB(A) The noise is from the nail guns, a combination of mechanical impact noise (piston assembly and front bumper) and jet exhaust from the compressed air. The diagram below shows a recording of the noise profile: the blue line is the average noise level, the green the maximum level and the red the “peak” or impulse noise.

The impulse noise reaches 134 dB(C), which is not in excess of the 140 dB  $L_{peak}$  DoL criterion.



**Figure 8: Noise from nail guns.**

**Source**

The two major sources of noise are the impact of the piston assembly with the front bumper, and the compressed air exhaust. An attached PDF shows how the noise can be reduced by fitting a muffler and fitting an additional, more resilient, bumper. These should be design features of nail guns, and it helps to “buy quiet”. Not all nail guns have the same sound output.

**Path**

As in all areas from which high noise levels originate, it helps if the sound can be contained, or absorbed, by baffles or barriers. This will stop sound transmission.

**Receiver**

As previously.

**Table 3: Pallet manufacture noise**

	Start time	Elapsed time	Overload [%]	LAeq [dB]	LASmax [dB]	LASmin [dB]
Value			0	98.7	101.4	93.2
Time	11:51:18 a.m.	0:02:42				
Date	14/05/2009					

The noise here is higher at 99 dB(A) during the period measured. This is due to the higher cycle rate of the nail gun during pallet manufacture. A further sample had an even higher cycle rate in a more “production line” process. The same comments apply, however in production line processes, job rotation may be helpful in reducing exposures.

## **Hearing loss**

Hearing tests were carried out on site using pure-tone audiometry carried out by either an occupational physician or a hearing therapist. This was carried out in a sound-proofed booth. The tests were “monitoring” tests according to the Code of Practice for the Management of Noise in the Workplace,<sup>[7]</sup> in other words they were carried out during the work day when noise exposure had occurred. All the individuals were, however, asked to wear their hearing protection before the test.

A total of 213 hearing tests were carried out during the project, the majority of subjects being male, median age of 39 years and with a median time of employment with their current employer of 5 years. A standard questionnaire was used to ask about risk factors, including service in the military, use of firearms, suffering a head injury and participation in noisy hobbies.

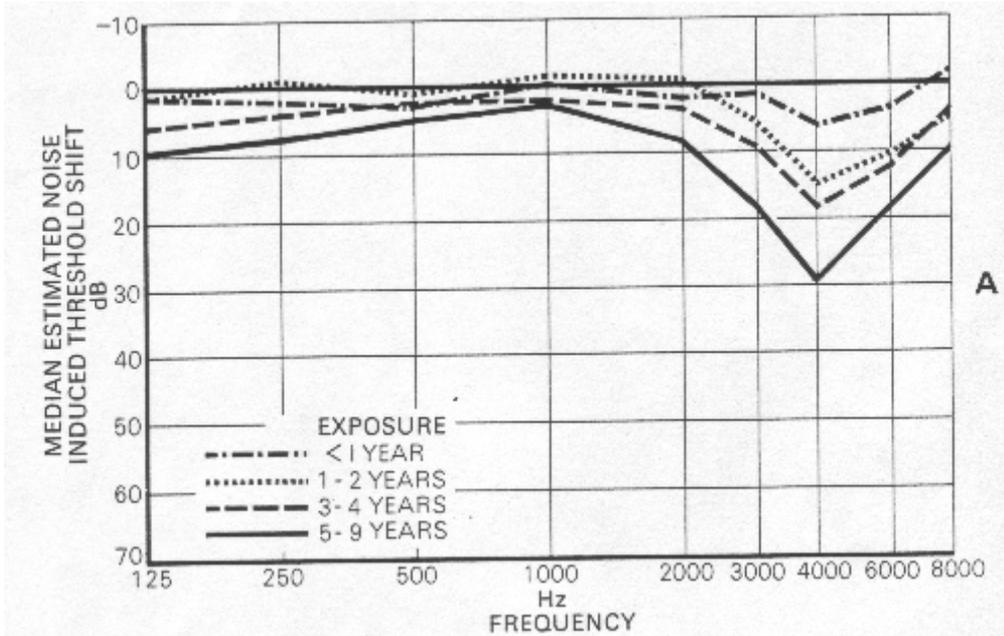
There are two main forms of hearing loss, the first is “nerve” deafness or sensorineural hearing loss due to damage to the sensory organ (the cochlea). This occurs with age, noise and illnesses (for example mumps). Conductive hearing loss occurs when there are problems with the structures which conduct the sound from the ear drum (tympanic membrane) to the cochlea. This may be due to childhood ear diseases such as otitis media.

The audiogram is a measure of hearing ability and shows how loud a pure tone sound (like a tuning fork) needs to be in order to be heard. The “average” young person can hear a sound pressure of .00001 Pascal, and this is the “reference” level of 0dB Hearing Level (HL). Some individuals will be better than, and worse than, this average.

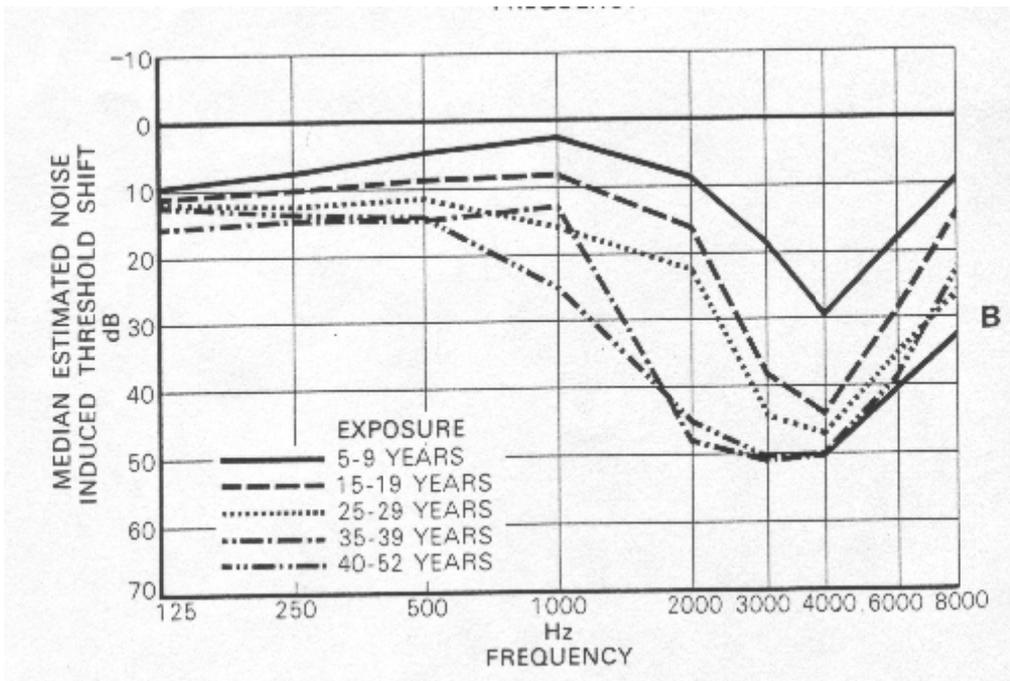
In addition, many individuals may have had ear infections (or other problems) in childhood or later which may or may not be remembered. If this happens, the hearing will be slightly worse than these “normal” levels.

Comparison databases allow the calculation of how much hearing loss can be expected for age and noise. They are available for both groups “screened” and “unscreened” for prior ear disease: the latter takes into account conductive and other losses.

With age, the hearing gets worse at the high frequencies (4 6 and 8 Khz, the high pitches) and noise accelerates this, typically appearing as a notch or dip in the audiogram which gets deeper and wider as the noise continues. This indicates noise induced hearing loss (NIHL).

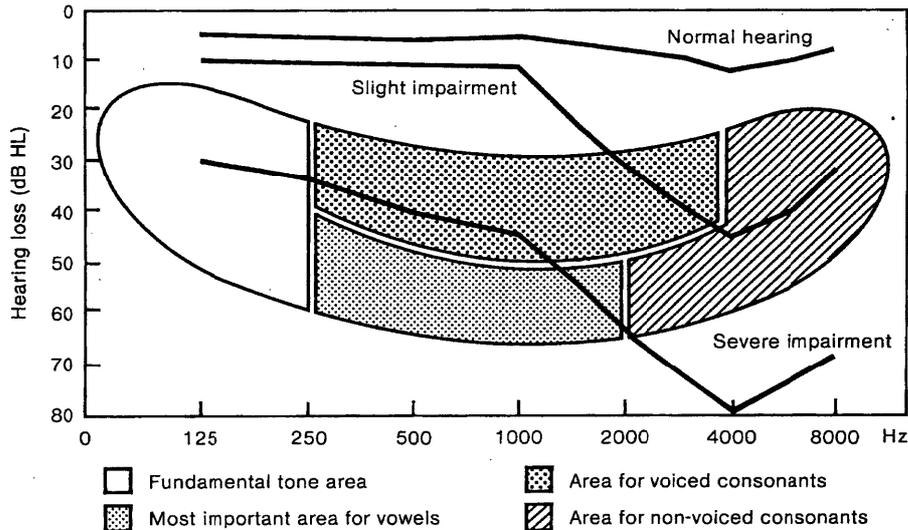


**Figure 9: Estimated noise induced threshold shift as median values for audiometric frequencies from 125 Hz-8 kHz and duration of exposure from 1-9 years.**



**Figure 10: Estimated noise induced threshold shift as median values for audiometric frequencies from 125 Hz-8 kHz and duration of exposure from 1-9 years.**

These are “average” levels, and individuals may obviously be better or worse than this. How this relates to impairment is shown in Figure 11.



**Figure 11: Hearing loss and impairment.**

As the hearing at the high frequencies rises above an average of 27 dB HL, hearing disability becomes noticeable.

We therefore looked at disability in a number of ways. Firstly, in order to identify possible causes of disability, we looked at hearing impairment defined, according to the International Standards Organisation (ISO) criterion as a threshold of at least 27 dB hearing level at the mean of the 1, 2 and 4 kHz audiometric frequencies.<sup>[8]</sup>

We then defined two measures of probable noise induced hearing loss, a notch in the audiogram and an age-adjusted measure of “excess” hearing loss, the Health and Safety Executive (HSE) categorization.<sup>[9]</sup> This identifies individuals who have more hearing loss than expected for their age.

The presence of a notch may indicate NIHL, but many notches are not typical, and asking individuals to classify audiograms as to whether or not a notch is present is not reliable.<sup>[10]</sup>

We therefore selected a computer algorithm of a threshold at 4 kHz of at least 30 dB hearing level which was at least 15 dB worse than the 2 kHz threshold with an improvement at the 6 kHz threshold. This is the Department of Labour criterion for noise induced hearing loss.<sup>[7]</sup>

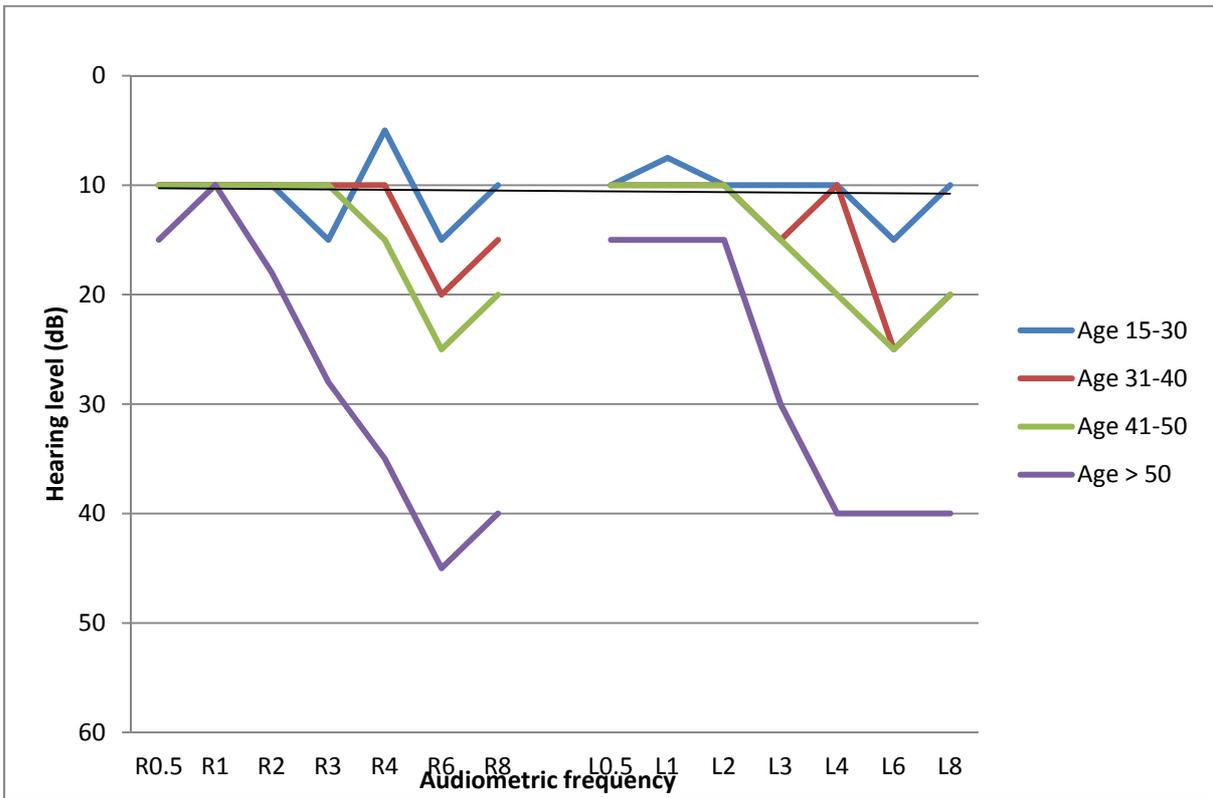
In keeping with the concept, that noise induced hearing loss is often asymmetrical, all these criteria would have identified the worse hearing ear.

For reference populations we used the ISO 1999 model<sup>[8]</sup> to predict the expected hearing in an otologically normal population, those screened to be free of evidence of ear disease. The tables in Robinson<sup>[11]</sup> for a typical “unscreened” population were used as a comparison as a population with some degree of hearing loss due to previous ear troubles.

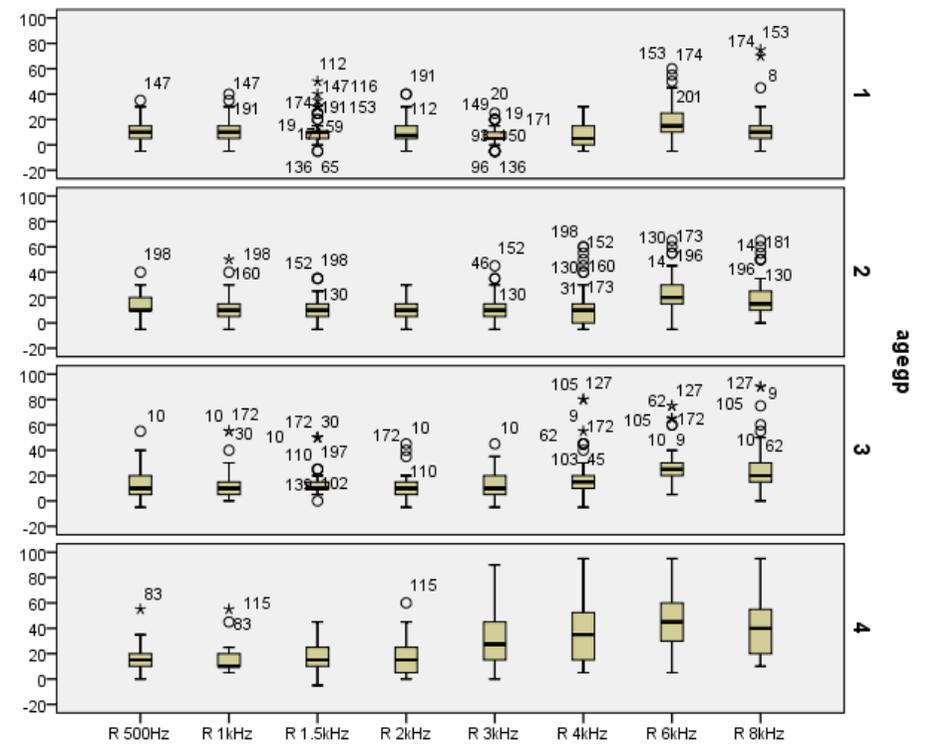
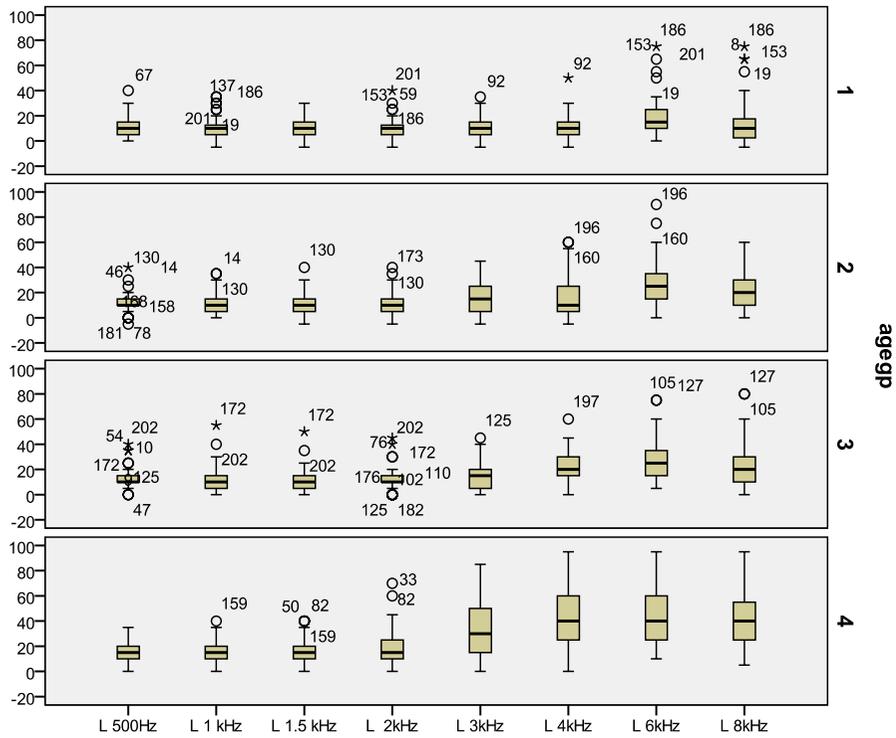
There were a total of 213 valid hearing tests carried out, 133 within wood processing (mean age 41, length of service (LOS) 9 years) and 80 within saw milling (mean age 37 years, LOS 7.5 years). The group was divided into age groups for the analysis, group 1 aged 18-30 (n=68, group 2 ages 31-40 (n=41) group 3 aged 41-50 (n=45) and those aged more than 51 (n=50).

The overall average hearing levels of the study group are shown in Figure 12 by age group. As expected, hearing does get worse with age. There is a “dip” in the audiogram at 6 kHz in all the age groups.

These average levels do not show those who are better or worse than expected (Figure 13). This spread or distribution is best represented by way of “box-plots”. The top and bottom of the box are the 25<sup>th</sup> and 75<sup>th</sup> percentiles (25% of individuals have hearing worse than the top and bottom limits), with the median (“average”) depicted by the bar within the box. These are “usual” levels. The ends of the whiskers are the lowest and highest datum points that contains 1.5 times the inter-quartile range. These are more “unusual”. Outliers are indicated by the numbered points, and represent levels more extreme than the rest. There appear to be more outliers in the right ears.



**Figure 12: Overall hearing levels.**



**Figure 13: Variability in hearing levels by age group.**

It is also useful to look at the hearing levels in comparison with reference values. Figures 10a-d show the hearing levels at the 2, 3 4 and 6 kHz, those most likely to be affected by age and noise. The hearing is shown by age group. At all frequencies except 4 kHz the hearing is worse than expected for both screened and unscreened groups.

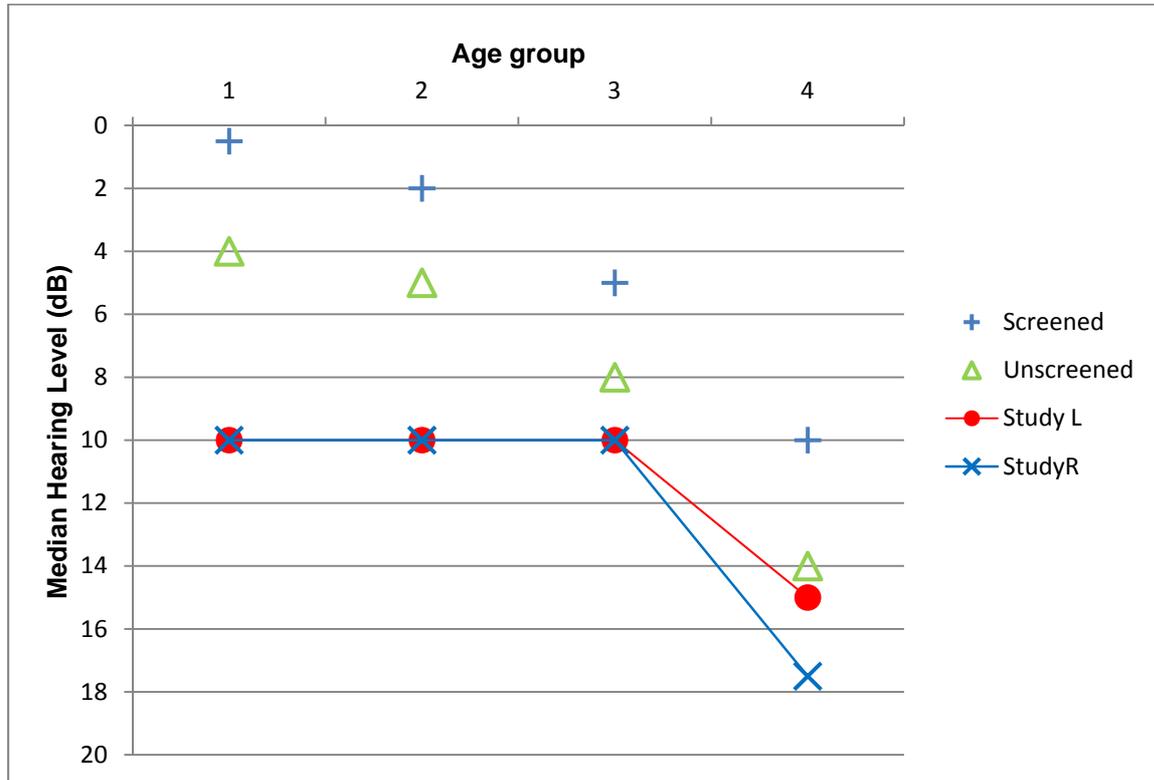
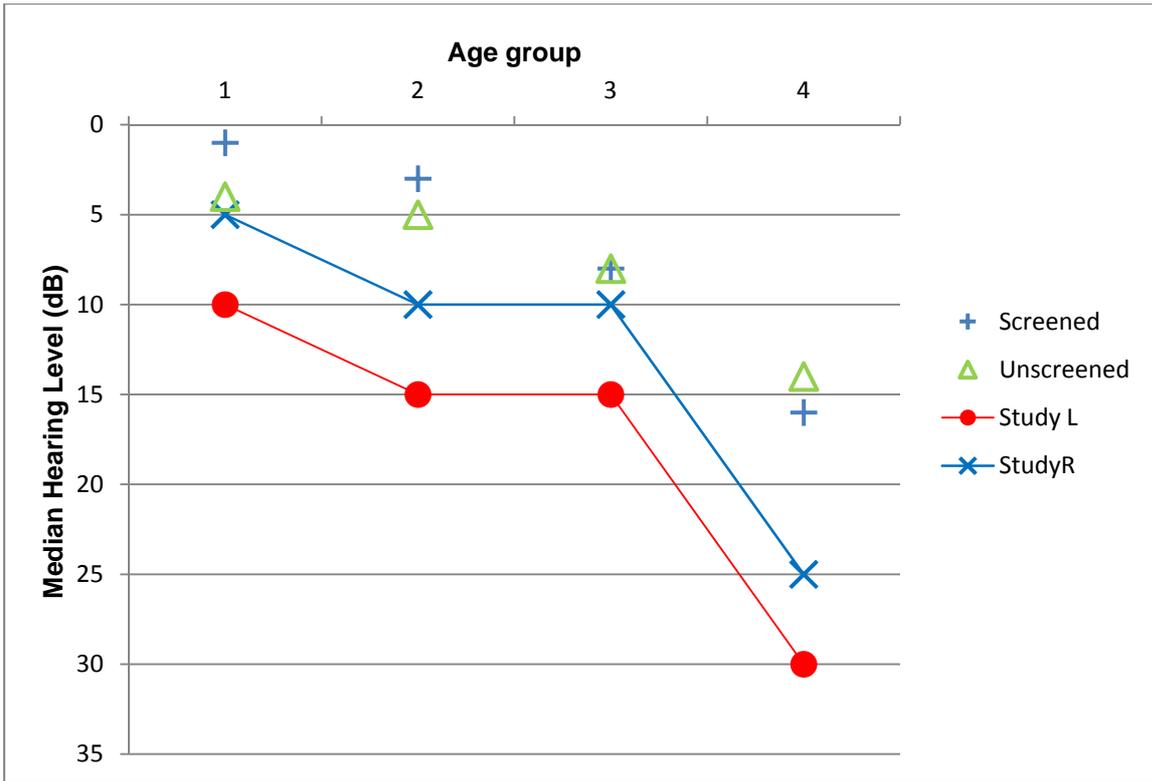
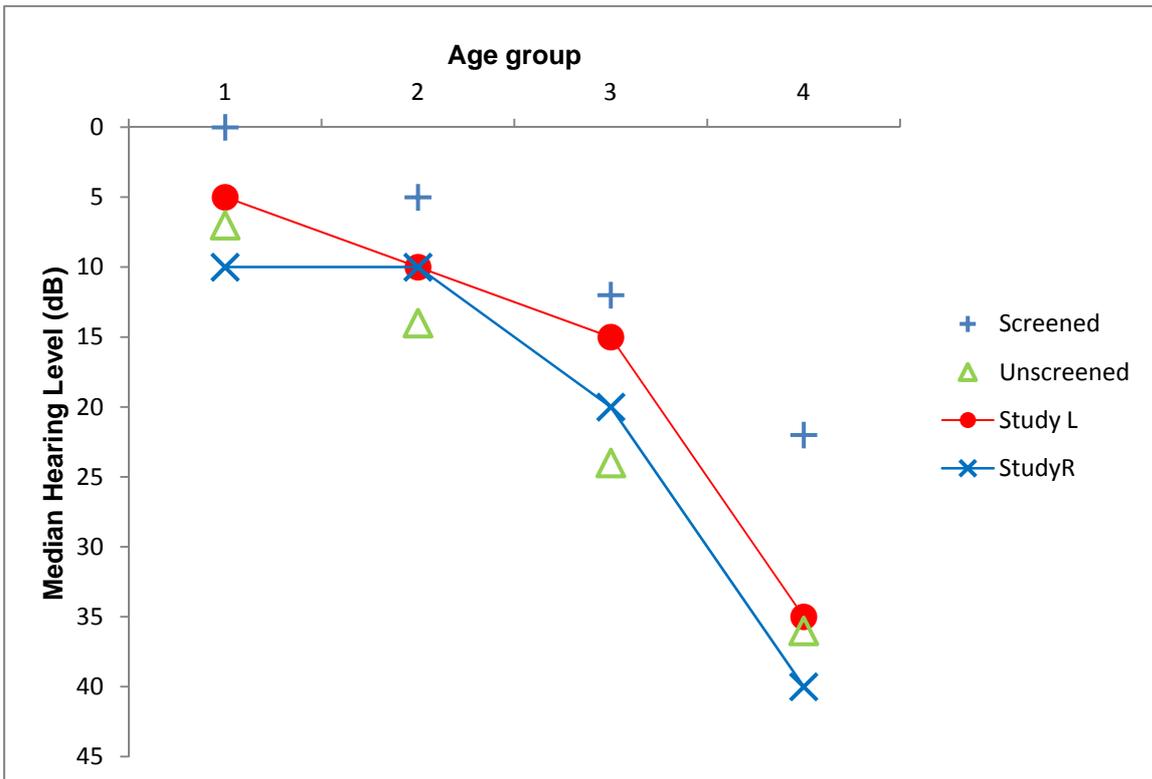


Figure 13a: Median hearing level at 2kHz



**Figure 13b: Median hearing level at 3Khz**



**Figure 13c: Median hearing level at 4Khz**

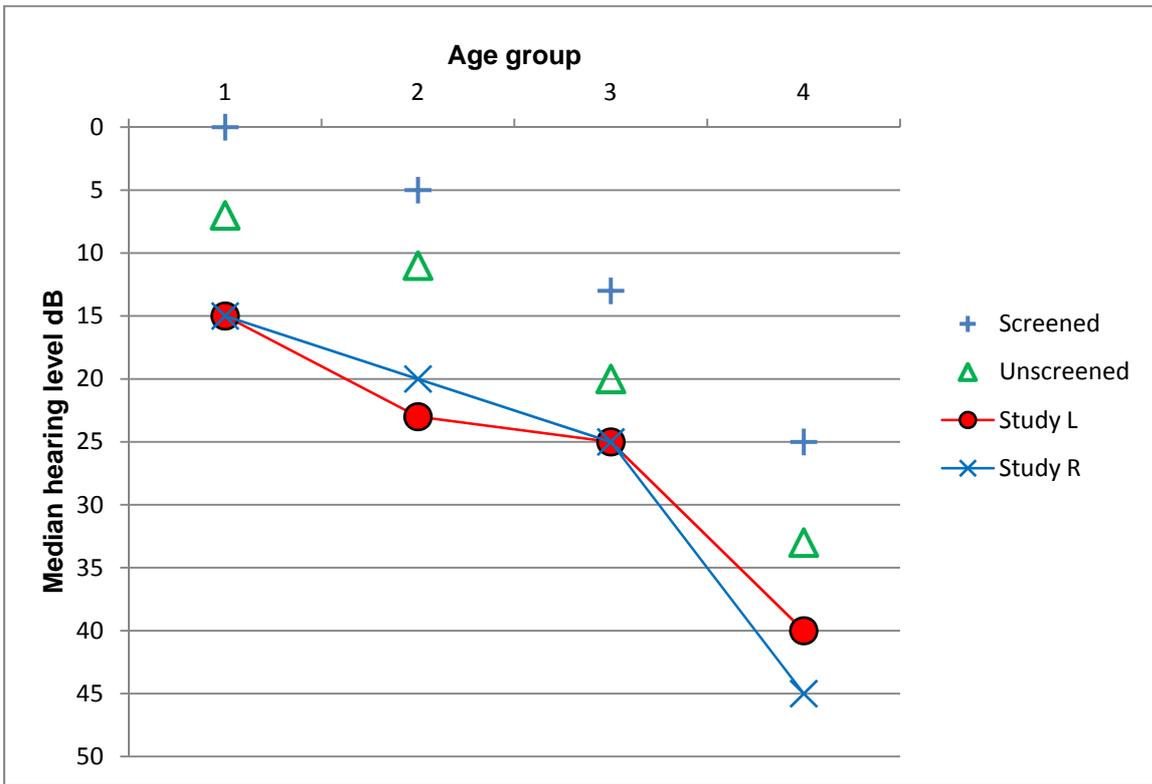


Figure 13d: Median hearing level at 6 kHz.<sup>1</sup>

<sup>1</sup> Age group 1=18-30, group 2=31-40, group 3 41-50, group 4= 51+

Hearing loss according to the three criteria chosen are shown in Table 4.

**Table 4: Hearing loss according to the three criteria.**

Age group	Disability	HSE	Notch
1	4 (1.9)	29 (13.6)	0 (0)
2	7 (3.3)	22(10.3)	6 (2.8)
3	7 (3.3)	20 (9.3)	5 (2.3)
4	24 (11.3)	39 (18.3)	15 (7.0)
Total (row %)	42 (19.7)	110 (51.6)	26 (12.2)

There were no statistically significant differences between processing and milling between any of these criteria, although those in sawmilling were 34% more likely to have a high frequency loss and 60% more likely to have disability.

There were also no significant differences in any of the other risk factors when looking at these categorical (hearing loss, either yes or no) variables.

Looking at the hearing levels as continuous variables, either as the means of the low (0.5,1,2) or high (3,4,6) frequencies did show that firearms use was associated with an increased loss in the left ear at the high frequencies only (one way ANOVA,  $p=.011$ ). This was significant at both L4 and L6 Khz. ( $p=.008$  and  $.040$  respectively). In these 62 individuals, who were shooters, the levels were worse in the left ear by 9.8 (4kHz) and 7.8 dB HL (6 kHz) respectively.

None of the other variables showed any significant differences.

### **Discussion of hearing levels**

The overall hearing patterns shown in figure 9 show that the younger age groups had, on average, relatively good hearing. On average those in the oldest age groups had hearing which was starting to fall into the “slight impairment” category. Some individuals are better or worse than average and figure 13 shows, in the distribution of hearing levels, that some individuals in each age group will have severe impairment. This is obviously greater in the oldest age group, who had a mean age of 57 years with an average length of service of 16 years.

Figure 13 shows that the hearing in the study group was worse than of a screened group at all the frequencies. When compared with an unscreened group, the hearing is, in general, also worse except at 4 kHz, which is supposedly the most noise sensitive frequency.

It is therefore difficult to say how much of the hearing loss in this group, is due to age and how much due to additional “ear disease” factors. The latter includes conductive losses (stiffness in the ears due to previous infection) and nerve conduction loss. The other factor that gives rise to hearing loss in this group is of course noise. For example, at 3 kHz, the median hearing loss is about 28 dB in the oldest age group. This is much more hearing loss than would be expected for age in both normal ears and those with some ear trouble in the past. It is also possible to calculate how much hearing loss would be expected for age and noise exposure.

The median length of service in this group was 15 years with a median age of 55. Noise exposure at 92 dB(A) over the 15 years would have given a “noise loss” of 12.5 dB HL, and an age loss of 15.5 dB, a total of 28 dB HL. This accounts for the 28 dB HL loss at 3 KHz. In an unscreened group, the age loss of 27 dB accounts for almost all of the loss.

At 4 kHz the median hearing loss is about 38 dB HL. In an unscreened group, this hearing would have been achieved by exposure at 92 dB(A) over the period. The expected loss in an unscreened group is 36 dB HL, accounting for almost all of the loss.

At 6 kHz, the average loss is about 43 dB HL. In an unscreened group this would have required an exposure of 100 dB(A), or about 92 dB(A) in an unscreened group (10 dB HL due to noise, 33 dB HL due to age and other ear factors).

It is therefore difficult to say how much hearing loss in this group is due to age and noise because of the largely unknown level of ear disease. There is however evidence that noise exposure has taken place at a level of over 90 db(A). This is consistent with studies of US construction industry workers showed protection factors of only 6-7 dB.<sup>[12]</sup>

The leisure noise findings, that only gunfire was having an effect on hearing in the larger group, was consistent with previous studies. A British study of 4000 people (some of whom listened to music for more than 6 hours a week) showed no effects of “average” amounts of listening, going to concerts or clubs. The occupational noise exposure was more important.

On the other hand, gunfire may have had an effect: this was greatest in the left ears and were more than in a study of 9778 locomotive engineers in the US, where the losses were about 5 dB at the average of the high frequencies. Our results were about twice this.

The levels of “significant” hearing loss can be compared with those found in a group of New Zealand farmers and farm workers exposed between 85 and 90 dB(A). In comparing farmers with wood processing workers, 8.5% v 19.7% had disability, 57 v 51.6 had excess high frequency hearing loss and 12.2 v 12.6% had “notches”.

The weaknesses of the study were that the audiograms were “monitoring” tests, measured during a work shift, and may have included the temporary effects of noise. On the other hand, all participants were asked to wear their hearing protection prior to the test. The major difficulty was that we could not establish the true proportion of those with ear disease. This requires specialised examination.

## **Acknowledgements**

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