European Agency for Safety and Health at Work

EUROPEAN WEEK FOR SAFETY AND HEALTH AT WORK

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Reducing the risks from occupational noise

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Reducing the risks from occupational noise

European Agency for Safety and Health at Work

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TABLE OF CONTENTS

TABLE OF CONTENTS

Foreword

Despite being a well-known hazard, noise at work is still a risk to workers at the start of the 21st century. It is difficult to estimate how many people may be harmed by noise, but with 20 % of workers in Europe being exposed to loud noise (about 40 million workers) the human and economic cost of this hazard is very great.

The Administrative Board of the European Agency for Safety and Health at Work designated noise as the theme for the European Week for Safety and Health at Work 2005. The campaign, simply titled 'Stop that noise', has set out to raise awareness that:

- noise at work is an issue not only in heavy fabrication industries, but also in a wide range of sectors from education to entertainment, agriculture to the service sectors;
- noise can cause more harm than hearing loss; it can be a causal factor in work-related stress, work-related voice disorders loss, and can be a factor in workplace accidents;
- in 2006, a new noise directive comes into force in Member States.

This report gives an overview of noise control methods, based on the European noise control policy as formulated in the relevant directives on workplace health and safety and in the supporting international standards. The report also contains details of interventions in workplaces to examine and prevent the risks arising to workers from noise.

European Agency for Safety and Health at Work
September 2005

Executive summary

Key points

- European directives exist that set out how to deal with noise in the workplace
- Manufacturers have requirements under European directives to ensure that machinery is designed and constructed to reduce noise emissions
- Standards exist to complement the directives, giving detailed information on topics, from noise measurement to acoustics

Every day, millions of employees in Europe are exposed to noise at work and all the risks this can entail. While noise is most obviously a problem in industries such as metal manufacturing and construction, it can also be an issue in a wide range of other workplaces, from airports to farms, call centres to concert halls. The European Agency for Safety and Health at Work has looked at how the European directive structure and the standards that complement it work to ensure that risks to workers from noise are addressed to reduce the high personal, social, and economic cost of ill health, stress and accidents arising from noise exposure.

European directives exist to protect workers from harm caused by exposure to noise. The 'framework directive', together with other workplace-orientated directives such as the 2003 noise directive, the PPE directive, and the pregnant workers' directive, provide a structure for dealing with all risks (not just the risk of noise-induced hearing loss) to all workers from noise. The framework directive sets out the general principles of prevention and then the more specific directives, of which the 2003 noise directive is the most significant for noise, give greater detail.

The general principles of prevention

- Avoiding risks
- Evaluating the risks which cannot be avoided
- Combating the risks at source
- Adapting the work to the individual, especially as regards the design of workplaces, the choice of work equipment, and the choice of working and production methods
- Adapting to technical progress
- Replacing the dangerous by the non-dangerous or the less dangerous
- Developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors related to the working environment
- Giving collective protective measures priority over individual protective measures
- Giving appropriate instructions to the workers

Employers are required to control risks at source, eliminating or reducing noise risks to a minimum, taking account of technical progress and of the availability of preventive measures. Workers should be consulted and participate in the risk assessment and risk elimination/reduction process, and in the choice of individual hearing protection. There should not be a reliance on personal hearing protection (such as earplugs) when there are other measures available to remove or control the risk. The 2003 noise directive identifies factors to consider when controlling noise risks:

- working methods that require less exposure to noise;
- the choice of appropriate work equipment, taking account of the work to be done, emitting the least possible noise;

- the design and layout of workplaces and work stations;
- adequate information and training to instruct workers to use work equipment correctly in order to reduce their exposure to noise to a minimum;
- noise reduction by technical means;
- appropriate maintenance programmes for work equipment, the workplace and workplace systems;
- noise reduction by better organisation of work;
- limiting the duration and intensity of the exposure and/or by organising appropriate work schedules with adequate rest periods.

The requirements in the machinery directive ([1]) and outdoor machinery directive ([2]), for manufacturers to provide noise information about the machinery, and for some machinery to limit emissions, should help the employer to have an effective procurement policy.

These directives also make clear that prevention through design is vitally important in dealing with occupational noise. 'Machinery must be so designed and constructed that risks resulting from the emission of airborne noise are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at source' ([3]).

Standards have a key role in the prevention of occupational noise exposure. The 2003 noise directive refers to ISO 1999:1990 for the assessment of workers' exposure, and many standards prepared by the technical committees of the European Committee for Standardisation (CEN) contain provisions on noise to support the essential safety and health requirements on noise in the machinery directive.

([1]) Directive 98/37/EC of the European Parliament and of the Council of 22 June 1998 on the approximation of the laws of the Member States relating to machinery.

([2]) Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors.

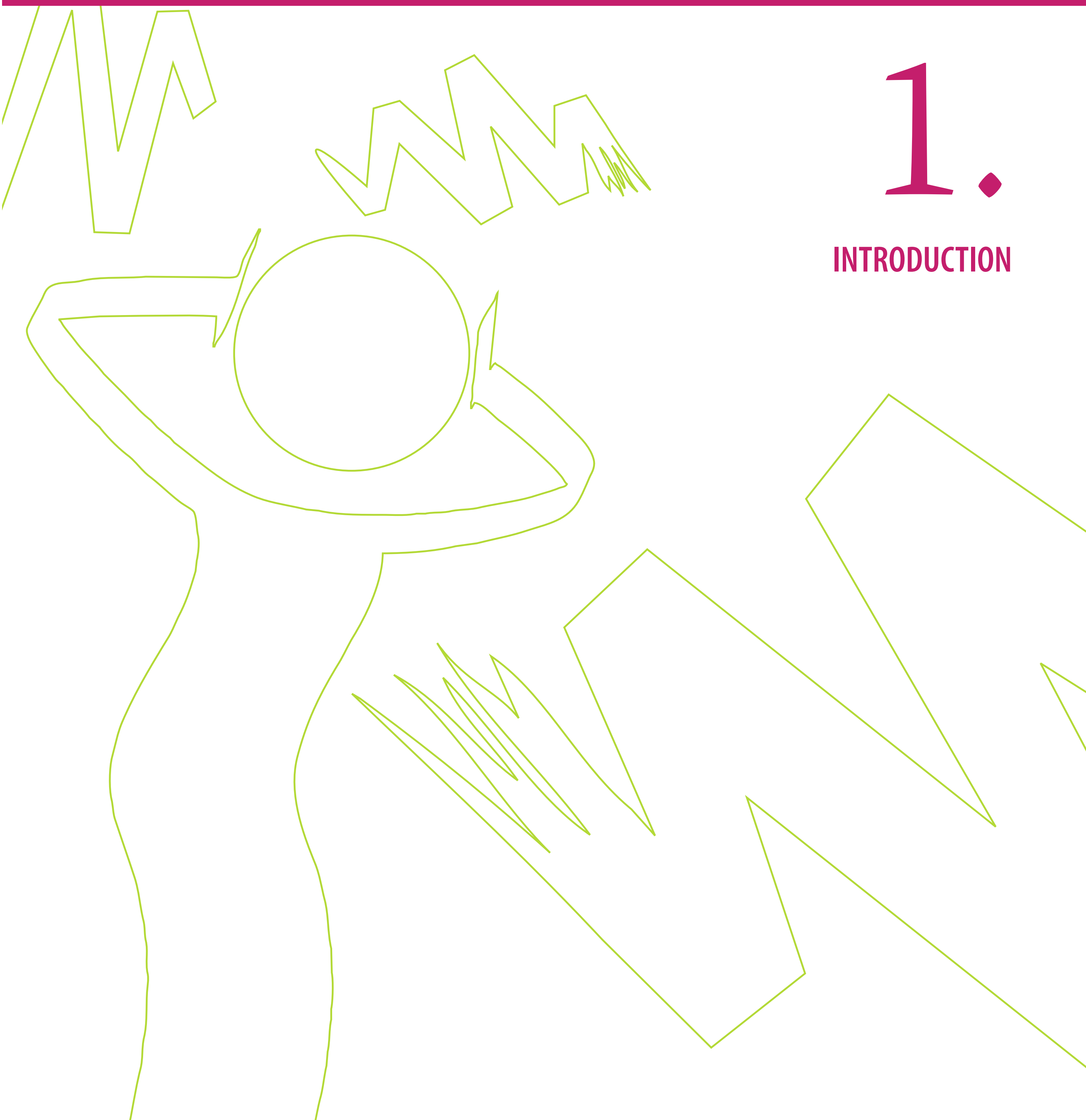
([3]) Machinery directive essential health and safety requirements, Annex 1, Section 1.5.8.

European Agency for Safety and Health at Work

EUROPEAN WEEK FOR SAFETY AND HEALTH AT WORK

1.

INTRODUCTION



Key points

- Occupational noise is a global problem
- Noise is a problem in many work areas, including the manufacturing, construction, and service sectors
- Noise is a costly problem, but the exact cost is difficult to calculate as many of the losses are hidden

The World Health Organisation states 'noise-induced hearing loss is insidious, permanent, and irreparable. In a developed country, exposure to excessive noise is at least partially the cause in more than one third of those in the population who have hearing loss. Noise-induced hearing loss is the most prevalent irreversible industrial disease, and noise is the biggest compensable occupational hazard' ([4]).

'Noise can cause hearing impairment, interfere with communication, disturb sleep, cause cardiovascular and psycho-physiological effects, reduce performance, and provoke annoyance response and changes in social behaviour' ([5]). In short, noise is a problem.

According to the *Third European survey on working conditions 2000* ([6]), about 20 % of European workers are exposed to noise so loud that they would have to raise their voice to talk to other people. Exposure to noise is particularly common in construction and the manufacturing sectors. The same source notes that about 7 % of European workers consider that their work affects their health in the form of hearing disorders. A crude extrapolation to get EU-25 figures gives a figure of just under 40 million workers exposed to loud noise ([7]) and over 13 million believing that work is affecting their health in the form of hearing disorders.

The 1999 labour force survey ad hoc module ([8]) reported 0.1 % of respondents suffering from a hearing problem that according to their own judgment was caused or made worse by work. A crude extrapolation to the EU-25 would give a figure of just under 300 000 workers ([9]).

While the immediate effects of noise might be few, its physical and psychosocial long-term effects can be significant. Moreover, because noise is usually found with other hazards (e.g. dangerous substances, vibration, extreme working temperature), it can have additive effects to health and well-being, performance and safety. Yet when the risks of these other hazards are assessed, noise and its combined effects can go unnoticed.

The European Union has a common policy to control risks from the exposure of workers to noise. However, the harmonised legal requirements concentrate on the avoidance of hearing impairment. This is because the role of the long-term exposure to noise in causing hearing loss has long been recognised and research has progressed to where dose–response relationships have been derived. Other issues relating to noise, such as physiological stress reactions due to moderate intensity noise, have yet to be fully addressed.

The reduction of noise at source is perhaps the crux of the European Union policy to control risks from noise at work. It is a requirement not only of Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the

([4]) Speech by Dr R. H. Henderson, Assistant Director-General, World Health Organisation, at 'Prevention of noise-induced hearing loss', informal consultation held at the World Health Organisation, Geneva, 28–30 October 1997.

([5]) *Factsheet 258*, 'Occupational and community noise', World Health Organisation, revised 2001.

([6]) The *Third European survey on working conditions 2000* (ESWC), European Foundation for the Improvement of Living and Working Conditions (2000).

([7]) The 25 Member States had a working population of 197 239 000 (out of 298 913 000) in 2000. The latest available figures for 2003 are 199 636 000 (out of a total potential working population of (302 532 000). Assuming this statistic across the EU-25 is consistent with the EU-15, then 20 % of 197 239 000 means 39 447 800 or 39.5 million in the EU-25 stated, in 2000, that they suffered noise so loud that they had to raise their voices to talk to other people at least half the time or more. This is the same number as the entire population of Spain (39.5 million in 2000), or Poland (38.6 million in 2000). Seven per cent of 197 239 000 is 13 806 730.

([8]) Ad hoc module of the labour force survey on accidents at work and work-related health problems, 1999.

([9]) Total employment in 1999 in the EU-25 is 297 700 000, 0.1 % of which is 297 700 workers.

risks arising from physical agents (noise) (the 2003 noise directive), but also of Directive 98/37/EC of the European Parliament and of the Council of 22 June 1998 on the approximation of the laws of the Member States relating to machinery (the machinery directive).

Noise prevention measures designed into machines, workstations and places of work, and the selection of work equipment, procedures and methods so as to give priority to reducing the noise at source is the more effective method for reducing exposure to noise. Noise reducing provisions for work equipment and work methods thus contribute to the protection of the workers involved in line with the general principles of Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (the framework directive). The approach of collection preventive measures over personal protection measures should be strongly promoted, particularly as recent research results have shown that the overall application of personal hearing protection is generally not very successful in avoiding hearing losses.

Employers should make adjustments in the light of technical progress and scientific knowledge of risks related to exposure to noise, with a view to improving the health and safety protection of workers. An effective noise reduction programme includes:

- noise control by engineering and design;
- organisational and administrative noise control measures;
- adequate information and training to instruct workers to use work equipment correctly in order to reduce their exposure to noise to a minimum, and only as a last resort;
- individual protection measures.

The majority of known and available measures are aimed at reducing the exposure of employees to noise without exclusively observing exposure limits. This is because noise causes varying amounts of damage to different people's health. Some people are more sensitive than others so there is no exact level at which noise becomes a problem. Even for the risk of hearing damage it is only known that at exposure levels from 75 dB(A) there seems to be an increasing proportion of people who suffer significant hearing loss.

The scope of the noise problem

Noise at work is a global problem, covering a wide range of industry sectors, occupations, and workplaces. For example:

- farmers in Poland were found to be exposed to a mean annual level of noise exposure of $L_{EX, 8h}$ = 89.1 dB ([10]);
- measurements during the manufacture of textiles in Nigeria recorded noise levels higher than 130 dB(A) ([11]);
- the overall sound level average to which workers in urban music clubs in the USA were exposed to was measured as ranging from 91.9 to 99.8 dB(A) ([12]);
- the results of audiograms in a study of airport employees in China revealed a 41 % prevalence rate of high-frequency loss in all employees ([13]);
- a study from Canada into the exposure of truck drivers' noise exposure found that the drivers' L_{eq} ranged from 78 to 89 dB(A), with a mean of 82.7 dB(A), operating the radio increased the mean by 2.8 dB, driving with the

([10]) 'Preliminary evaluation of occupational hearing loss risk among private farmers', Keszek Solecki, *Ann Agric Environ Med 2003*, 10, pp. 211–215.

([11]) Reported in 'Prevention of noise hazards at Nigerian workplaces', *African Newsletter*, 3/1996, Finnish Institute of Occupational Health.

([12]) 'Risks of developing noise-induced hearing loss in employees of urban music clubs', Gunderson, E., Moline, J., Catalano, P., *Am J Ind Med.*, 1997 Jan, 31(1): 75-9.

([13]) 'Effects of aircraft noise on hearing and auditory pathway function of airport employees', Chen, T. J., Chiang, H. C., Chen, S. S., *J Occup Med.*, 1992 Jun, 34(6): 613-9.

driver's side window open increased the mean exposure by 1.3 dB, and driving with the window open and operating the radio resulted in an increase of 3.9 dB ([14]).

The World Health Organisation identify some of the sources of occupational noise as 'rotors, gears, turbulent fluid flow, impact processes, electrical machines, internal combustion engines, pneumatic equipment, drilling, crushing, blasting, pumps and compressors. Furthermore, the emitted sounds are reflected from floors, ceilings and equipment. The major sources of noise that damages hearing are impact processes, material handling and industrial jets' ([15]).

According to the European Commission, an estimated 22.5 million individuals suffer from hearing impairment with two million profoundly deaf ([16]). These figures are for all forms of hearing impairment, and not only for those suffering from hearing impairment caused by work. Data from the US National Centre for Health Statistics suggests that noise is the main reason for people becoming deaf or hard-of-hearing. Noise was seen as the cause in 33.7 % of the cases in a 1994 survey.

Twenty per cent of European workers are exposed to noise so loud that they would have to raise their voice to talk to other people at least for half their working time ([17]). Despite sometimes being viewed as being a problem for the declining heavy industries, 29 % of workers are exposed to high-level noise for more than a quarter of their working time ([18]), and this trend is not decreasing.

Some sectors identified as having noise problems

- Manufacture of textiles
- Manufacture of paper and paper products
- Manufacture of basic metals
- Manufacture of wood, wood products and cork
- Manufacture of fabricated metal products
- The hotel and restaurant sector
- Mining
- Construction
- Agriculture
- Fishing
- Electricity, gas and water supply
- Transport and communications ([19])

([14]) 'Occupational noise exposure of operators of heavy trucks', Seshagiri, B., *Am Ind Hyg Assoc J.* 1998 Mar, 59(3), pp. 205–213.

([15]) *Factsheet*, 258, 'Occupational and community noise', World Health Organisation, revised 2001.

([16]) The exact extent of hearing impairment in Europe is not known, extrapolation made from a survey carried out in the United Kingdom would indicate: 6 % (22.5 million individuals) of the European population suffer from a hearing impairment, approximately 10 million Europeans hear so poorly that a hearing aid would be necessary, about 600 000 individuals are profoundly deaf from birth, about three million individuals are profoundly deaf (cannot hear a sound below 80–100 dB, request hearing aid), 6.7 million individuals are severely deaf (cannot hear a sound below 60 dB, request hearing aid), and 12.2 million individuals are moderately (>40 dB) or slightly (>20 dB) deaf (hearing aid may help in several cases). These figures do not just relate to deafness caused by exposure to occupational noise. Reported at: http://europa.eu.int/comm/research/press/2003/pr2808en.html

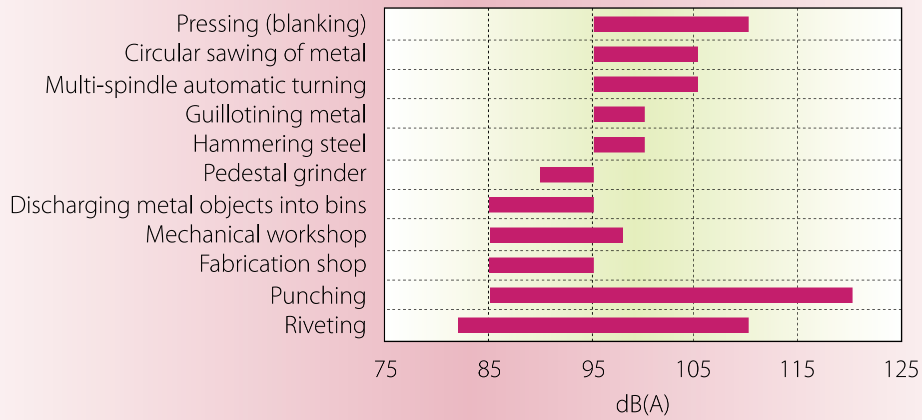
([17]) EU-15 data. *Source*: *Third European survey on working conditions 2000*, European Foundation for the Improvement of Living and Working Conditions.

([18]) According to the *Third European survey on working conditions 2000*.

([19]) Sources include *The state of occupational safety and health in the European Union — A pilot study*, European Agency for Safety and Health at Work (2000), ISBN 92-95007-00-X, and *EU hotel and restaurant sector: work and employment conditions*, European Foundation for the Improvement of Living and Working Conditions (2004) and *Work and health in the EU — A statistical portrait. Data 1994–2002*, Eurostat, 2004.

It should be noted that in the communication from the Commission, 'Adapting for change in work and society: a new Community strategy on health and safety at work 2002–06' (the 'new Community strategy'), eight sectors are identified as having significantly raised accident rates. All but one of these eight (the exception being health and social services) are included in the list above.

Noise levels in metalworking



Occupation of workers exposed to noise

So called 'blue-collar workers' are significantly more exposed to noise, along with craft workers and plant operators. The *Third European survey on working conditions 2000* by the European Foundation for the Improvement of Living and Working Conditions identified workers exposed to noise in the workplace. It found that 29 % of all workers were exposed to noise in the workplace at least one quarter of the time and 11 % all the time. Craft workers and machine operators were identified as having the greatest exposure, followed by agricultural workers, members of the armed forces such as military and police personnel, trainers, and conscripts, and persons in elementary occupations ([20]).

Noise and gender

In 2002, 43 % of the workforce of the EU was female, with the percentage of women in the workforce increasing. Men are exposed to noise more than twice as often as women, and men report that their health is at risk from their work in the form of hearing disorders more than three times as often as women ([21]).

About 97 % of cases of noise-induced hearing loss reported were male. This is no surprise as the sectors with exposure to the highest noise levels have a predominantly male workforce. In studies, once noise exposure is controlled for, no gender difference is found in the incidence of hearing disorders between men and women ([22]). There is some evidence that there may be gender differences in the experience of tinnitus ([23]).

([20]) *Third European survey on working conditions 2000*, European Foundation for the Improvement of Living and Working Conditions.

([21]) Main data source for statistics on gender: *Work and health in the EU — A statistical portrait. Data 1994–2002*, Eurostat.

([22]) Davis, A., Smith, P., Wade, A. (1998) 'A longitudinal study of hearing — Effects of age, sex, and noise', Proceedings of 'Nordic noise' 1998, Stockholm.

([23]) Estola-Partanen, M., *Muscular tension and tinnitus. An experimental trial of trigger point injections on tinnitus*, academic dissertation, 2000, University of Tampere, Medical School, Tampere University Hospital, Department of Otorhinolaryngology, Vammala, Vammalan Kirjapaino Oy.

The new Community strategy states 'preventive measures, and the assessment arrangements and the rules for awarding compensation, must take specific account of the growing proportion of women in the workplace and of the risks to which women are particularly liable. These measures must be based on research covering the ergonomic aspects, workplace design, and the effects of exposure to physical, chemical, and biological agents, and pay heed to the physiological and psychological differences in the way work is organised'.

Female-dominant jobs with exposure to high noise levels

- Food production
- Bottling
- Manufacture of textiles
- Work in the entertainment sector (24)

The costs of noise

The Better Hearing Institute in the USA has published an estimate of the annual costs due to lost productivity, special education and medical care as a result of untreated hearing loss which sets the amount at USD 56 billion per year, or USD 216 per capita. The figure is not scientifically documented, but is one of the estimates available.

If this estimate is applied to Europe, the annual cost for EU-15 countries would amount to EUR 92 billion— an annual per capita cost of EURO 228— based upon September 2000 exchange rates. While the costs of an effective occupational noise control programme may be significant, these costs will be more than offset by the continuing enormous social costs of current programmes.

While direct costs for workers' compensation can often be identified, for example, it amounts to 190 million euros per year in Germany, there is a high hidden cost of the effects of occupational noise. The frequently used metaphor, particularly relating to the costs of accidents (25), is that of an iceberg, with the observable direct costs (to both society and enterprises) and the hidden indirect costs. The direct costs to enterprises can include costs for sick leave from work-related stress, or from occupational voice disorders, and the indirect costs can include reduced performance by workers through restricted communication (due to difficulties in hearing and understanding) or reduced concentration. In some scenarios such reduced performance can lead to an increased risk of accidents at work.

(24) See *Gender issues in safety and health at work: A review*, European Agency for Safety and Health at Work.

(25) For example, in *The costs of accidents at work*, HSE (1993), revised 1997, ISBN 0 7176 1343 7.

2.

EFFECTS OF NOISE

Key points

- A large number of European workers are still exposed to potentially harmful noise at work
- The effects of noise are not limited to hearing loss
- Noise is not just an occupational health issue, it can also be a causal factor in workplace accidents and impede the effective performance of work tasks

Hearing impairment and hearing disorders

Hearing impairment is the most important effect of occupational noise. Permanent hearing loss is caused by long-term exposure to excessive noise. The scientific evidence that excessive noise causes physiological damage to the human hearing mechanism is incontrovertible. Such hearing impairment is known as noise-induced hearing loss (NIHL) that often progresses slowly over many years and may go unnoticed until permanent damage has occurred.

Excessive exposures to noise are probably the most common cause of hearing loss due to damage of the inner ear. In general terms, prolonged exposure to sound levels of more than 85 dB(A) is potentially hazardous although the important factor is the total amount of exposure given by the level and length of exposure time. The risk of instant, irreversible damage begins at around 130–140 dB(C) peak level. Exposures at this level can occur through exposure to noise sources such as bolt guns, explosions, firearm reports, or electric arcs.

The European picture of the number of workers suffering from hearing disorders is not complete. About 7 % of workers consider that their work affects their health in the form of hearing disorders ([26]). Men report that their work affects their health in the form of hearing disorders more than three times as often as women. In another survey, about 0.1 % of respondents suffered from a hearing problem caused or made worse by work ([27]).

According to the 1995 pilot data, there were 57 444 cases of occupational diseases that year in the EU. The number of cases varied from 17 in Luxembourg to 20 216 in Germany. The three most frequent occupational diseases were noise-induced hearing loss (18 419 cases), allergic or irritative skin disease (8 767) and respiratory allergy (4 543).

Information from Member States

Denmark

A report by the Danish Institute of Social Research (Socialforskningsinstituttet) in 1992 ([28]) entitled 'How many and who suffer from hearing impairment?' found that 16.4 % of unskilled and 24.2 % of skilled workers between the ages of 30 and 79 reported hearing problems. The report found that farmers and other agricultural workers are more likely than other groups to suffer from hearing impairment. These findings correspond to other findings mentioned in the report that show 17 % of those constantly working in noisy environments suffer from hearing problems. About 12 % of respondents, who worked in noisy environments 50–75 % of the time, said that they suffered from hearing problems. Twelve per cent of the people who worked at assembly lines in the manufacture of textiles said that they suffered from hearing problems. Of those people who had never been exposed to noise at their workplace, only 6 % said that they suffered from hearing problems.

([26]) *Third European survey on working conditions 2000,* European Foundation for the Improvement of Living and Working Conditions.

([27]) The *Ad hoc module on accidents at work and work-related health problems in the 1999 labour force survey.*

([28]) Reported at: http://www.medical.hear-it.org/page.dsp?page=969

United Kingdom

In 1999, the Royal National Institute for the Deaf (RNID), and the Trades Union Congress (TUC), published a joint report on noise at workplaces ([29]). The report, based on 525 questionnaires received from workers, shows that:

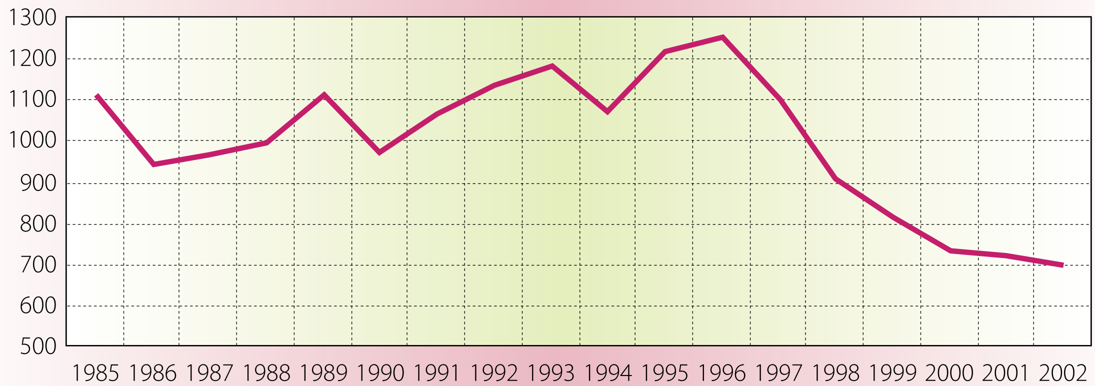
- nearly a quarter of the respondents were exposed to uncomfortably loud noise for more than four hours a day;
- one third of the respondents said that work tasks left them with dullness of hearing and in 16 % of the cases the dullness was continuous;
- 20 % of the respondents reported that work tasks left them with ringing or rushing in their ears or head lasting more than five minutes;
- nearly two thirds of the respondents said they had to raise their voice at work when speaking with people from a normal talking distance of around two meters.

In the United Kingdom, a Medical Research Council survey in 1997–98 estimated over half a million people in the United Kingdom suffering from hearing difficulties as a result of exposure to noise at work.

Germany

More than five million Germans are exposed to dangerous noise levels at work, and each year 6 000 new cases of work-related hearing loss are diagnosed, from which only a few reach levels leading to financial compensation. Noise in the workplace is the most common work-related health hazard in Germany.

New noise-related occupational pensions, Germany



The graph above charts the development of the occupational disease 'hearing loss' in Germany based on the number of new compensated cases.

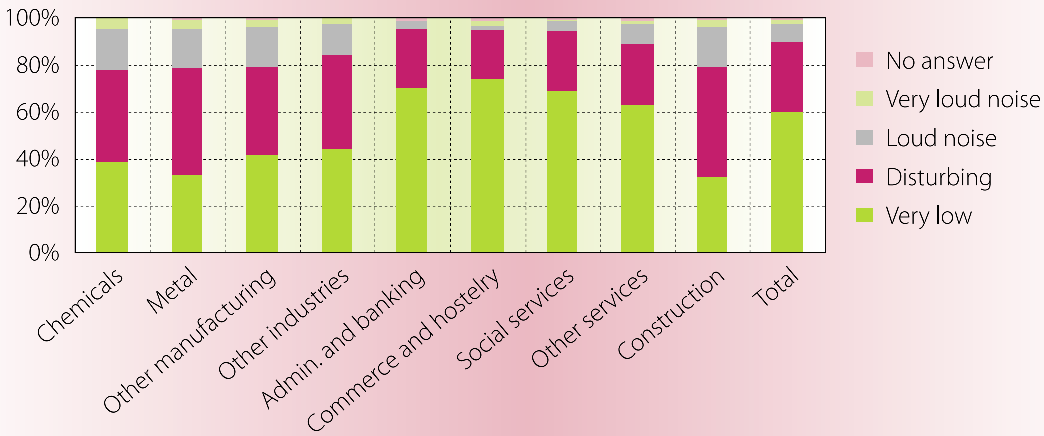
Spain

In the fifth national working conditions survey by the Instituto Nacional de Seguridad e Higiene en el Trabajo ([30]), the workers were asked their perception of the level of noise in the workplace. Almost 30 % (29.6 %) said that the noise level was disturbing (molesto), and nearly 10 % (9.3 %) said that the noise level was high or very high (ruido elevado/muy elevado). In the chemical, metals, manufacturing, and construction sectors, over 20 % of workers said that the noise levels were high or very high.

([29]) *Indecent exposure*: A joint report on noise at work by the RNID and the TUC, March 1999.

([30]) *V Encuesta Nacional de Condiciones de Trabajo*, Ministerio de Trabajo y Asuntos Sociales, Instituto Nacional de Seguridad e Higiene en El Trabajo, 2004.

Workers' perception of noise levels in their place of work by sector



France

More than two million people in France are exposed to prolonged noise exposure above 85 dB(A) in their workplace.

Temporary threshold shift

After exposure to typical hazardous industrial sound the ear fatigues and develops a temporary threshold shift (TTS) as the hair cells of the inner ear become exhausted from excessive metabolic stress. This is usually transient and after a 'rest' period, recovery ensues. If TTS occurs day after day, the recovery becomes less complete and a permanent threshold shift emerges. Initially this results in an audiometric notch between 3 and 6 kHz (i.e. where there is a dip in hearing sensitivity to these frequencies). The threshold for TTS is somewhere between 78 and 85 dB(A).

Tinnitus and hypersensitivity

Noise can also cause tinnitus. When permanent, this can lead to sleep problems. Tinnitus is often reported as being more tormenting than a hearing loss. A further problem with noise-induced hearing loss is hypersensitivity. Noises seem to get louder and suddenly distorted.

In the end, even a small reduction in hearing ability will isolate the victim, make usual work and social interaction a strain and cause problems not only in work but also in family life.

Noise and pregnant workers

A number of studies suggest that exposure of the foetus to excessive noise during pregnancy may result in high-frequency hearing loss in newborns, and may be associated with prematurity and intrauterine growth retardation.

It has been shown that sound is easily transmitted to the foetus through the abdominal wall which has an attenuation of 10 dB (4000 Hz) or less in the low frequency range.

In the formation of hearing the human cochlea and ears develop by 24 weeks of gestation. By 28 weeks of gestation, the auditory pathways are consistently functioning. The hearing threshold at 27 to 29 weeks of gestation is around 40 dB and decreases to a nearly adult level of 13.5 dB by 42 weeks of gestation.

In one study, children with high-frequency hearing loss tested at 4 to 10 years of age were more likely to have been born to women who were exposed consistently to occupational noise in the range of 85 to 95 dB during pregnancy.

The literature on the adverse effect of noise on pregnant women is more extensive for outcomes of birth defects, shortened gestation and decreased birth weight. These studies were done both on pregnant women exposed to noise at work and in relationship to environmental noise from living near airports. The results of the studies have been mixed, with some finding associations and others showing no effect. It is possible that noise could be a marker for other risk factors.

In summary, there have been few well-controlled randomised studies investigating the relationship between noise and foetal hearing loss, prematurity and decreased birth weight. However, several of these studies suggest that noise may be associated with these outcomes.

Requirements and information exist in Member States to protect pregnant workers ([31]). For example:

- in Germany, there is a rule to avoid an exposure of pregnant women to noise exceeding 80 dB (A);
- in Italy, guidelines have been produced on assessing risks related to pregnancy from noise, as well as vibrations and antineoplastic drugs; and
- in the United Kingdom, the Health and Safety Executive's guides for new and expectant mothers at work identifies noise as a hazard that should be addressed in the risk assessment ([32]).

Work-related stress

The European Agency for Safety and Health at Work states that 'work-related stress is experienced when the demands of the work environment exceed the employee's ability to cope with (or control) them.' Work-related stress is an organisational issue, not an individual weakness.

Work-related stress is often caused by a combination of risk factors, including the following.

- Culture — The 'atmosphere' of an organisation, and its implicit or explicit rules and norms.
- Demands — For example, workload or exposure to occupational hazards, such as noise.
- Control — The amount of influence that workers have on how and when to do their tasks.
- Relationships — Interactions among colleagues and with management, including issues such as bullying (mobbing) and harassment.
- Change — The rate in which organisational change is managed and the way it is communicated.
- Role — The role of the worker in the organisation, whether the worker understands the role, and whether there is conflict in this role.
- Support — The amount of support from colleagues and managers, both formal and informal.
- Training — The level of training received by workers to give them the skills to perform their task.
- Individual factors — Workers have individual differences and these should be borne in mind ([33]).

Noise can act as a physical and a psychological stimulus ([34]). While at high levels noise can impair hearing through damage to the middle and inner ears, less severe noise may interfere with speech perception

([31]) There is more information on pregnant workers under the section 'Risk groups'.

([32]) *A guide for new and expectant mothers on work* at http://www.hse.gov.uk/pubns/indg373.pdf and *New and expectant mothers at work — A guide for health professionals* at http://www.hse-databases.co.uk/pubns/indg373hp.pdf

([33]) *Research on work-related stress*, European Agency for Safety and Health at Work.

([34]) Akerstedt, T., Landstrom, U. (1998), 'Workplace countermeasures of nightshift fatigue', *International Journal of Industrial Ergonomics*, Vol. 21, No 3–4, pp. 167–178; Kryter, K. D. (1972), 'Non-auditory effects of environmental noise', *American Journal of Public Health*, 62, pp. 389–398; and Kasl, S. V. (1992), 'Surveillance of psychological disorders in the workplace' in: Keita, G. P., Sauter, S. L. (eds), *Work and well-being: An agenda for the 1990s*, American Psychological Association, Washington DC.

communication ([35]) and concentration. If prolonged, this may give rise to stress. However, one of the challenges in examining the effects of noise as a causal factor for work-related stress is that it is not always easy to isolate the effects of noise as a stressor separately from other workplace hazards present.

In general, stress effects have both psychological (annoyance, irritation, anger, strain) and physiological (endocrine, vegetative) components that can affect the cardiovascular systems and the metabolism. All these reactions can occur at noise levels much lower than 85 dB. Noise disturbances also cause impairment of work, and communication, lower performance of mental processes, and can provoke stress reactions at low noise levels.

Noise affects the central nervous system and causes physiological reactions that can become stress reactions due to their intensity, rate of repetition and the state of mind. Naturally, noise acts as a wake-up call. Sudden or unwanted noise alerts the human body and activates the stress response. This biological alarm serves to increase the release of stress hormones (cortisol), blood pressure, and heart rate (all signs of elevated physiological stress), and to prepare the body to react to noise threats. If the stress hormones are released constantly and these changes in the body are prolonged with no real outlet, harm to the organism will be caused in the long term. Inability to control the source or intensity of the noise will add to its stressful impact.

When a person is exposed to stress for a long period of time and they believe they have no control over it, they can develop what is called 'learned helplessness' syndrome. This is a condition where the sufferer learns that there is nothing he or she can do about a situation. It can range from passivity to serious forms of helplessness. It is linked to depression and reduced motivation, and can be caused by any source of prolonged stress, such as noise.

Another way in which noise affects behaviour is through the demands that it makes on attention. When a person is under stress, their primary goal is to deal with the main tasks. If extra demands are present, such as uncontrollable noise, their attention resources will be depleted. Under high environmental distractions, attention will become selective in an attempt to focus on the main task, and performance on secondary tasks is decreased. Although this effect has adaptive value, it leaves the person vulnerable to disruptions from further demands. It also causes information to be processed less efficiently, reduces the ratio of speed to accuracy in information processing, and increases risk-taking. These demands on attention affect the execution of work tasks and are the main reason that noise is a cause of accidents, especially when performing complex tasks.

Noise-related stress reactions

Physiological effects	Psycological effects
Production of hormones that affect the cardiovascular system and increase (or decrease) the heartbeat volume and blood pressure due to predisposition or as a result of over-compensation.	Anger – Noise above 80 dB may increase aggressive behaviour (*)
Decrease of blood circulation of the skin together with lower skin temperature	Strain
Decrease of electrical resistance of the skin	Resignation
Lower stomach and intestines movement, and lower production of gastric juice and saliva	Anxiety
Increase of general metabolism	Nervousness
Short time increase of blood sugar level	Tiredness
Change of breathing frequency	Inability to concentrate
Acute increase of muscular tone	Disturbed sleep

(*) World Health Organisation (WHO), *Factsheet*, 258, 'Occupational and community noise', revised 2001.

([35]) Jones, D. M. (1999), 'The cognitive psychology of auditory distraction: The 1997 BPS Broadbent lecture', *British Journal of Psychology*, 90(2), pp. 167–187.

Psychological and physiological aspects of stress reactions are inter-related and should be dealt with in a holistic manner. They can interact and strengthen each other to become psycho-physiological reactions.

At lower noise levels those psycho-physiological reactions are more correlated with perceived intensity than with the noise level. For that reason, in addition to noise-related parameters such as noise level, the amount of impulse noise, tonal narrow band noise, spectrum, bandwidth and time history, we should add factors such as conspicuousness, amount of information content and whether the noise could be easily avoided.

When calculating the dose–response relationship, the frequency of noise disturbance should be taken into account. Although there is some degree of individual adaptation to an ongoing stressor, which reduces the perceived pressure for a while, chronic stress can overwhelm the organism with serious consequences for physical and psychological health.

When considering noise in a workplace as a stress factor, it should not be seen only in isolation but together with other stress factors. Noise is a frequently mentioned stress factor, and often occurs together with other physiological (shift work, unusual posture, heat or cold) or mental stressors (work under pressure of time, complexity of work task). The development in information technologies and their intensive use in offices and other workplaces over the last years has led to a remarkable increase of mental load which makes noise disturbances at lower levels more important and more urgent to control.

Steps to prevent stress

Simple organisational changes can reduce work-related stress, for example by:

- eliminating harmful physical exposures;
- allowing adequate time for the worker to carry out tasks satisfactorily;
- providing the worker with a clear job description;
- rewarding the worker for good job performance;
- providing ways for the worker to voice complaints and have them considered seriously and swiftly;
- harmonising the worker's responsibility and authority;
- clarifying the work organisation's goals and values and adapting them to the worker's own goals and values, whenever possible;
- promoting the worker's control, and pride, over the end product of his or her work;
- promoting tolerance, security and justice in the workplace;
- identifying failures, successes, and their causes and consequences in earlier and future health actions in the workplace;
- learning how to avoid the failures and how to promote the successes, for a step-by-step improvement of occupational environment and health ([36]).

Influence on work tasks

The nature of the task is also a decisive factor in determining the impairing effects of noise at workplaces. An important reason why noise of medium intensity has become a more prevalent stressor is the generally increasing complexity of work tasks and working conditions. The more complex a task is the more likely it is that a stress reaction will occur at lower noise levels.

Some tasks require a higher level of concentration and attention because of their complexity and are likely to be worst affected by noise. For example:

([36]) 'Spice of life or kiss of death', Lennart Levi, article in Magazine 5, *Working on stress* (2002), European Agency for Safety and Health at Work.

- taking part in conferences, negotiations, examinations and teaching;
- scientific work (evaluating or analysing text), work in reading rooms of libraries, development of software or work on system analysis;
- medical examinations, treatment or surgical work;
- scientific or technical calculations;
- dialogue work at screens of data interfaces using complex software interfaces;
- design, translation, dictation, taking down or correction of difficult text;
- work in emergency call centres.

However, noise levels below 85 dB affect even routine tasks with effects especially on work efficiency and quality. For example, a four times higher rate of mistakes has been found at assembly work if the noise level increased from 60 dB(A) to 70 dB(A). Work tasks with higher demands on sensomotoric coordination usually take more time to obtain the same result. On the other hand, efficiency indicators improve with lower noise levels.

Disturbance of speech communication

Good speech communication (90 % syllables and 97 % sentences understood by the listener) requires a speech level at the ear of the listener that is at least 10 dB(A) higher than the surrounding noise level.

Up to 45 dB(A) noise level the speaker's voice usually remains unchanged. At a noise level of 55 dB(A) the speaker instinctively increases his voice level by about 5 dB(A) while the listener has a lack of 10–20 % of single syllables intelligibility. The missing information has to be completed by sense finding combinations of the contents, which requires more concentration effort.

Recommended maximum sound pressure levels for different working situations

Quality of speech communication	Workplace situation	Distance (metres)	Sound pressure level dB(A)
Excellent	Communication in an office	1 to 2	35 to 45
Good	Communication in a conference or teaching room	10	30 to 35
Satisfactory	Instruction in an apprentices' workshop	0.5 to 1	65 to 70
Satisfactory	Teamworking in a production environment	1 to 2	60 to 65
Fair	Short advice in an assembly room	0.5 to 2	70 to 80

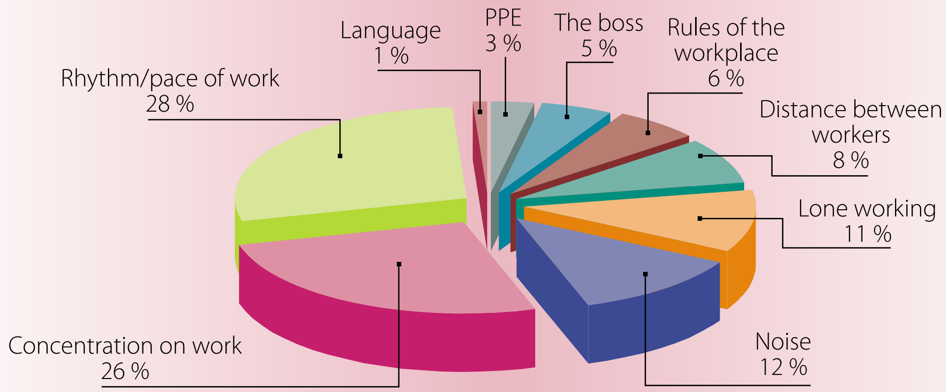
Surrounding noise is often felt as a distinct disturbance of speech communication, and in these situations, stress reactions are likely to occur. Noise is likely to disturb speech communication if:

- it is a daily occurrence;
- the listener has already a slight hearing loss;
- the listener's physical or mental constitution is already adversely affected (e.g. by infections, insomnia or increased workload under time pressure);
- the speaker is not a native speaker of the relevant language;
- the communication is held in a foreign language.

The extent to which noise impedes communication is not always clear, but the 2004 national Spanish survey of working conditions found that 32 % of workers reported impediments to conversation with colleagues during work ([37]).

([37]) *V Encuesta Nacional de Condiciones de Trabajo*, Ministerio de Trabajo y Asuntos Sociales, Instituto Nacional de Seguridad e Higiene en El Trabajo, 2004.

Impediments to communication with colleagues during work



Noise and human factors

'Human factors refer to environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety (38).'

Human factors are liable to cause errors that lead to workplace accidents. It has been estimated that up to 90 % of all workplace accidents have human error as a cause (39). All workers have limitations, and in the scope of human factors the key issues are the following.

- Attention — The modern workplace provides an 'overload' to human attention.
- Perception — Workers have correctly to perceive the work environment and the dangers that it holds.
- Memory — How and how much we remember and how we process the information.
- Logical reasoning — faulty reasoning can lead to critical errors.

While human error is to some extent inevitable, it is possible to design workplaces and systems to reduce the chances of such errors causing incidents. High profile events in the past (e.g. Three mile island in the USA) have highlighted the importance of human factors, particularly in relation to safety critical issues (40).

Noise is an issue when considering human factors. The University of California, Berkeley notes that noise:

- increases fatigue;
- masks warning sounds;
- makes it harder to mentally process complex information;
- distracts workers so they do not pay attention to other things that are happening; and
- makes it harder to monitor and interpret events (41).

Noise distracts, affects communication, and causes signals to be missed. The Health and Safety Executive's Hazardous Installations Directorate guidance states (42) 'Noise levels in the control room [of major hazards sites] should not interfere with communications, warning signals, or mental performance (43).'

(38) Health and Safety Executive (1999), *Reducing error and influencing behaviour* (second ed.), HMSO.

(39) Feyer, A. M. and Williamson, A. M. (1998), 'Human factors in accident modelling', quoted in *Postnote: Managing human error*, June 2001, No 156, Parliamentary Office of Science and Technology (United Kingdom).

(40) See also *NTP 619: Fiabilidad humana: evaluación simplificada del error humano (I)*, Josep Faig Sureda, Instituto Nacional de Seguridad E Higiene En El Trabajo at: http://www.mtas/insht/ntp/ntp_619.htm

(41) California — Arizona Consortium Labour Occupational Health Programme — Hazardous waste project, University of California, Berkeley.

(42) In control room design at: http://www.hse.gov.uk/comah/sragtech/techmeascontrol.htm

(43) This is also an issue for the healthcare sector when considering medical errors. See 'Communication in the emergency department: separating the signal from the noise', *MJA*, Vol. 176, 6 May 2002 at: http://www.mja.com.au/public/issues/176_09_060502/vin10141_fm.html

Noise as a cause of accidents

'Noise can adversely affect performance, for example in reading, attentiveness, problem solving, and memory. Deficits in performance can lead to accidents (44).' Apart from impeding the attention and concentration of workers, noise may also increase the risk of an accident at work by:

- reduced signal recognition;
- limited auditory localisation and speech communication;
- misunderstanding of oral instructions;
- masking sounds of approaching danger or warnings.

If there are risks due to unpredictable events (e.g. fire) or the unexpected approach of a moving transportation system (e.g. cranes or trains), the installation of devices generating an easily intelligible auditory danger signal is required. However, the installation of a warning system alone is not enough unless a check of recognition at the different working positions shows its efficiency. Such a test of course must take into account the worst case of ambient noise, the insertion loss of individual hearing protectors and headsets and the different hearing of workers. ISO 7731 and 8201 give detailed guidance on auditory danger signals. As a rule the signal to noise ratio at the listener's position should be 10 dB or more. In cases where this may clearly increase the risk of hearing damage, the signal to noise ratio should at least reach 6 dB but when possible in these situations, headphones with active noise cancelling (ANC) should be used to increase the signal to noise ratio without increasing the sound pressure level of the signal.

In addition to studies showing that noise can contribute in the occurrence of injuries and deaths at work (45), studies also indicate that hearing loss (either alone or in combination with noise) can be a causal factor (46).

Case studies: Noise and accidents (47)

Vehicle noise was hidden by the noisy environment
The victim was walking from the garage towards the car park. A few moments later, the driver of a coach reversed out of his parking space. The victim was hit in the back, fell, and was crushed under the left rear wheel and died soon after.

Motor noise as covered by the noise of the music system
The victim was a bar worker. She had just crushed some ice using a machine that made ice and juice. Not hearing the noise of the machine's motor, she thought that the machine had stopped and put the middle finger of her right hand into the outlet to get the ice. The machine caught the tip of her finger and badly cut it (48).

Process noise forced repair worker to climb closer to hear his workmate
Two men were on scaffolding changing a big tube of a process oven. One worker was on the upper level, the other on the lower. The worker on the lower stage had to climb a metre upwards to hear instructions from his colleague, but fell in doing so, suffering several fractures.

(44) World Health Organisation, *Factsheet*, 258, 'Occupational and community noise', revised 2001.

(45) Cohen, A. (1974), 'Industrial noise and medical, absence and accident record data on exposed workers', in: W. D. Ward (ed), Proceedings of the International Congress on Noise as a Public Health Problem. US Environmental Protection Agency, Washington DC; and Cohen, A. (1976), 'The influence of a company hearing conservative programme on extra-auditory problems in workers', *Journal of Safety Research*, 8, pp. 146–162.

(46) Baretto, S. M., Swerdlow, A. J., Smith, P. G. and Higgins, C. D., 'A nested case-control study of fatal work-related injuries among Brazilian steel workers', *Occupational and Environmental Medicine*, 1997, 54, pp. 599–604, Melamed, S., Luz, J. and Green, M. S., 'Noise exposure, noise annoyance and their relation to psychological distress, accident and sickness absence among blue-collar workers, The Cordis study'. *Israel Journal of Medical Sciences*, 1992; 28:629–635; Moll Van Charante A. W. and Mulder P. G. H., 'Perceptual acuity and the risk of industrial accidents', *American Journal of Epidemiology*, 1990; 131, pp. 652–663; Zwerling, C., Whitten, P. S., Davis, C. S. and Sprince, N. L., 'Occupational injuries among workers with disabilities', *Journal of the American Medical Association*, 1997, 278, pp. 2163–2166.

(47) Noise may not be the sole causal factor for accidents at work, so there may be other causal factors apparent in the cases given here.

(48) *Réduire le bruit dans l'entreprise*, INRS, available for download at: http://www.inrs.fr

Impulse noise masks instructions
A skilled worker and his less-skilled colleague were repairing a machine in a large workshop. The skilled worker put his hands between the gears and said 'don't start'. The word 'don't' was masked by hammer noise and the less-skilled worker started the machine, causing serious wounds ([49]).

Noise as a causal factor for occupational voice loss

Many workers, for example teachers, salespersons, lawyers, or entertainers, rely on their voice for their living. A number of risk factors can lead to occupational voice loss. These include:

- overuse — prolonged heavy use without breaks;
- noise — having to raise the voice to speak over background noise which may be either from within the workplace or from external sources ('community' noise such as from traffic);
- humidity and temperature — in particular low humidity;
- stress;
- fatigue;
- infections of the larynx;
- poor air quality, particularly where there are a lot of airborne particulates;
- exposure to dangerous substances — some substances such as bitumen fumes, can affect the voice;
- poor work organisation — systems of work where the worker is required to speak for a long time without breaks (e.g. reading out a long call centre script);
- use of speech recognition systems — by using these systems to avoid work-related upper limb disorders, the strain can transfer from the arms to the voice ([50]).

Case studies: Voice loss

Instructor loses voice speaking over background noise and in diesel fume
An instructor often had to lecture inside railway depots, where he had to compete with noise and diesel fume from the railway engines. He found himself becoming increasingly hoarse, and was often unable to work because of the state of his throat.

In a civil case brought by his union, it was revealed that the worker had laryngitis caused by the fumes in the depot and the volume at which he had to speak over the background noise. The condition was permanent and the worker was awarded significant compensation ([51]).

Teacher suffers voice loss
The ERGA-FP publication ([52]) of the Ministerio de Trabajo y Asuntos Sociales in Spain reports a case of a teacher in Bizkaia whose suffered voice loss.

The article identifies the following as risk factors commonly linked to 'voice loss' in schools:

- location of schools in noisy environments;
- poor acoustics in classrooms;
- lack of breaks;
- activities in the open air;
- the need for a wide range of voice intonation;
- the use of chalk not of an 'anti-dust' type.

([49]) Finnish register of serious and fatal occupational accidents (TAPS).
([50]) *Hazards Magazine*, October 2004, at: http://www.hazards.org/voiceloss/workhoarse.htm
([51]) *Hazards Magazine*, October 2004, at: http://www.hazards.org/voiceloss/workhoarse.htm
([52]) Instituto Nacional de Seguridad y Salud en el Trabajo, ERGA FP, No 20, 2000 at: http://www.mtas.es/insht/erga_fp/ErFP20_00.pdf and *Los niveles acústicos durante el horario laboral y las disfonías en los docentes* at: http://www.mtas.es/Insht/research/PRuizMJ2.htm

Some universities in Spain, for example in Lérida, Madrid, and the Basque Country, already have programmes for teaching personnel on voice care, and concern for voice loss in teachers in Scotland has led one part of the United Kingdom's National Health Service to promote appropriate voice care in the classroom for teachers as part of the health promoting health service framework. The 'Speaking up for teachers' voice care' project aims to promote vocal health in teaching and teaching-related staff and reduce the number of referrals of voice disordered patients to the hospital's 'voice clinic' ([53]).

Acoustic shock

'Acoustic incidents are loud, unexpected, randomly occurring high-pitched and startling stimuli, typically tones of 2.3–3.4 kHz, at intensities from 82 to 120 dB SPL at the tympanic membrane, with rise times of 0–20 milliseconds and varying durations ([54]).' The injuries caused by such incidents have been termed 'acoustic shock', and have been defined as 'any temporary or permanent disturbance of the functioning of the ear, or of the nervous system, which may be caused to the user of a telephone earphone by a sudden sharp rise in the acoustic pressure produced by it'. Symptoms reported include pain, tinnitus, loss of balance, and hypersensitivity to sound ([55]). Sources of acoustic shock experienced when using telephones include:

- electronic sounds from fax machines;
- random electronic impulses;
- customers tapping the handsets;
- malicious acts by the person at the other end of the telephone (e.g. customer blowing a whistle down the phone) ([56]).

Other health effects

'Prolonged or excessive exposure to noise, whether in the community or at work, can cause medical conditions such as hypertension and ischaemic heart disease ([57])'. However, as the Danish National Institute of Occupational Research (AMI) notes, it is difficult to document the association between noise and health effects. On the basis of scientific studies much literature concludes that the limit for developing cardiovascular diseases lies around 85 dB(A) if the average exposure is eight hours per working day ([58]).

The Danish report on health effects of noise in the work environment also identifies acoustic-related vibroacoustic disease, caused by long-lasting exposure to low-frequency noise that can cause a range of symptoms from gastro-intestinal diseases to muscular pain.

In a 20-year longitudinal study of hearing sensitivity in 319 employees from different sectors of industry, a remarkably large proportion of the workers in the chemicals sector showed pronounced hearing loss (23 %) as compared with groups from non-chemical environments (5–8 %) ([59]). This effect was found despite the lower noise levels in the chemical sector (80–90 dB(A)) when compared with other divisions (95–100 dB(A)). Thus, the exposure to industrial solvents (not identified in the article) was implicated as an additional causative factor for those hearing losses.

([53]) 'Speaking up for teachers' voice care', project by NHS Argyll and Clyde — National Health Service. Project presented at the 13th International Conference on Health-Promoting Hospitals, May 2005, Ireland. See: http://www.univie.ac.at/hph/dublin2005/

([54]) 'Acoustic shock injury: real or imaginary?', Milhinch, J. at Audiologyonline.com

([55]) More information is available at: http://www.nal.gov.au/

([56]) TUC website at: http://www.worksmart.org

([57]) World Health Organisation, *Factsheet*, 258, 'Occupational and community noise', revised 2001.

([58]) Karin Sørig Hougaard og Søren Peter Lund, *Helbredseffekter Af Støj I Arbejdsmiljøet* downloadable in Danish at: http://www.ami.dk/upload/dok13.pdf

([59]) 'Development of hearing loss during long-term exposure to occupational noise. A 20-year follow-up study', Bergstrom, B., Nystrom, B., *Scand Audiol.*, 1986, 15(4), pp. 227–234.

European Agency for Safety and Health at Work

EUROPEAN WEEK FOR SAFETY AND HEALTH AT WORK

3.

EUROPEAN OCCUPATIONAL NOISE POLICY

Key points

- Noise is identified as a priority in the new Community strategy
- A directive structure exists to eliminate and reduce workplace risks
- Requirements are placed on manufacturers of machinery to produce 'quiet' machinery, provide information and to limit noise emissions

The objectives of European occupational safety and health policy are clearly stated in the new Community strategy. These goals include:

- 'A continuing reduction in occupational accidents and illnesses';
- 'Mainstreaming the gender dimension into risk evaluation, preventive measures, and compensation arrangements';
- 'Prevention of social risks' (e.g. stress);
- 'Enhanced prevention of occupational illnesses' as an objective of Community policy on health and safety at work, going on to state that 'Priority should go to illnesses due to asbestos, hearing loss, and musculoskeletal problems';
- 'Taking account of demographic change in terms of risks, accidents, and illnesses';
- 'Taking account of changes in forms of employment, work organisation, arrangements, and working time.'

European noise control policy on occupational health and safety is largely based on the application of directives. These directives govern the protection of workers from risks arising from noise at work, noise emission from work equipment and machinery, and requirements for personal protective equipment. The effectiveness of their application will dictate the success of the above objectives with regard to noise.

Prevention of exposure to noise in the workplace

Minimum requirements to protect workers against risks to their hearing and to their health and safety are stated in Council Directive 86/188/EEC of 12 May 1986 on the protection of workers from the risks related to exposure to noise at work (the 1986 noise directive) which will shortly be replaced at national level by the 2003 noise directive.

The employer is obliged to assess and, if necessary, measure the levels of noise to which workers are exposed. In the light of this assessment, employers must put in place measures to be taken when the exposure limit values and exposure action values are exceeded. The exposure limit values are not supposed to be exceeded at all, but if they are, immediate measures are required.

The 2003 noise directive should be seen in the context of other directives:

- the framework directive places obligations on employers to guarantee a safe working environment;
- the 2003 noise directive to protect workers against risks to their hearing and health; and
- Council Directive 89/656/EEC of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment (the PPE directive) provides requirements about personal protective equipment.

Employers are required to ensure the health and safety of workers in every aspect related to their work. This is to be achieved by the prevention of occupational risks, provision of information and training, and the provision of necessary organisation and means, according to the general principles of prevention laid out in the framework directive.

The employer is required to evaluate the risks to workers' safety and health and, after this evaluation, take action to improve the level of protection from noise to workers. These measures should be integrated into the work activities of the enterprise, take account of the workers' capabilities, and ensure that the planning and introduction of new technologies are the subject of consultation with workers. These measures should not involve a financial cost to the workers, and where workplaces are shared, the employers should cooperate in putting in place safety and health prevention measures.

The directives identify actions that are required to prevent risks to workers from noise. These are:

- assessment of the risks;
- prevention of exposure, including the use of personal hearing protection;
- limitation of exposure in accordance with exposure and action levels;
- health surveillance;
- information, consultation, and training to, with, and of workers.

Assessing the risks

Assessment of the risks to workers is at the core of the European approach to prevention. There should be an up-to-date assessment of the risks to safety and health at work and based on this the employer should decide on the protective measures to be taken and, if necessary, the protective equipment to be used.

The assessment of risks arising from exposure to noise should consider:

- the level, type, and duration of exposure, including any exposure to impulse noise;
- the exposure limit values and action values;
- the effects of noise on the health and safety of workers in 'risk groups';
- as far as technically achievable, any effects on workers' health and safety resulting from interactions between noise and work-related ototoxic substances, and between noise and vibrations;
- any indirect effects on workers' health and safety resulting from interactions between noise and warning signals or other sounds that need to be observed in order to reduce the risk of accidents;
- information on noise emission provided by manufacturers of work equipment in line with the relevant Community directives;
- the existence of alternative work equipment designed to reduce the noise emission;
- the extension of exposure to noise beyond normal working hours under the employer's responsibility;
- information obtained from health surveillance, including published information, as far as possible;
- the availability of hearing protectors with adequate attenuation characteristics (60).

Workers' exposure to noise should be measured if necessary, using appropriate methods and apparatus that make it possible to determine the physical parameters used as risk predictors. These are the peak sound pressure (p_{peak}), the daily noise exposure level, and the weekly noise exposure level (61).

Elimination and reduction of risks

The 2003 noise directive similarly provides that employers must, taking account of technical progress and of the availability of measures, control the risk at source and eliminate it or reduce it to a minimum. The reduction of risks arising from noise exposure must be based on the general principles of prevention set out in the framework directive and the more specific provisions in the 2003 noise directive.

(60) Articles 2 and 4, 2003 noise directive, Articles 5, 6, and 9, framework directive.

(61) As defined by ISO 1999:1990, it covers all noises present at work, including impulsive noise.

The general principles of prevention

- Avoiding risks
- Evaluating the risks which cannot be avoided
- Combating the risks at source
- Adapting the work to the individual
- Adapting to technical progress
- Replacing the dangerous by the non-dangerous or the less dangerous
- Developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors related to the working environment
- Giving collective protective measures priority over individual protective measures
- Giving appropriate instructions to the workers

More specifically, the reduction in risks from exposure to noise should take into account:

- other working methods that need less exposure to noise;
- the choice of suitable work equipment, taking account of the work to be done, emitting the least possible noise;
- the design and layout of workplaces and work stations;
- adequate information and training to instruct workers to use work equipment correctly in order to reduce their exposure to noise to a minimum;
- noise reduction by technical means:
  - reducing airborne noise by means such as shields, enclosures, and sound-absorbent coverings;
  - reducing structure-borne noise by means such as damping or isolation;
- appropriate maintenance programmes for work equipment, the workplace and workplace systems;
- organisation of work to reduce noise, by:
  - limitation of the duration and intensity of the exposure;
  - appropriate work schedules with adequate rest periods ([62]). Where, owing to the nature of the activity, a worker benefits from the use of rest facilities under the responsibility of the employer, noise in these facilities shall be reduced to a level compatible with their purpose and the conditions of use.

Exposure values

The 2003 noise directive introduces exposure values with requirements for action at these levels. These are summarised as follows.

Lower exposure action value

- Set at $L_{EX,8h}$ = 80 dB(A) and $\boldsymbol{p}_{peak}$ = 112 Pa ([63]) respectively.
- The employer shall ensure that workers who are exposed to noise at work at or above the lower exposure action values, and/or their representatives, receive information and training on the risks resulting from exposure to noise.
- Preventive audiometric testing shall also be available for workers where the assessment and measurement provided for indicate a risk to health.
- If the risks arising from exposure to noise cannot be prevented by other means, suitable, properly fitting individual hearing protectors shall be made available to workers.

([62]) Framework directive, Article 6, 2003 noise directive, Article 5.

([63]) 135 dB(C) in relation to 20 µPa.

Upper exposure action value

- Set at $L_{EX, 8h}$ = 85 dB(A) and p_{peak} = 140 Pa (64) respectively.
- If the assessment of risks from noise exposure indicates that an upper exposure action value is exceeded, the employer is required to establish and implement a programme of technical and/or organisational measures intended to reduce the exposure to noise.
- On the basis of the risk assessment, workplaces shall be marked with appropriate signs. The areas in question shall also be delimited and access to them restricted where this is technically feasible and the risk of exposure so justifies.
- A worker shall have the right to have his/her hearing checked by a doctor.
- If the risks arising from exposure to noise cannot be prevented by other means, appropriate, properly fitting individual hearing protectors shall be made available to workers and used by them.

Exposure limit value

- Set at $L_{EX, 8h}$ = 87 dB(A) (65) and p_{peak} = 200 pa respectively (66).
- Under no circumstances shall the exposure of the worker exceed the exposure limit value. If, despite the measures taken, exposures above the exposure limit values are detected, the employer shall take immediate action to reduce the exposure to below the exposure limit values, identify the reasons why over-exposure has occurred, and amend the protection and prevention measures in order to avoid any recurrence.

Case study — Reduced noise, reduced dust

In an enterprise in Austria, intensive grinding was carried on in a metal fabrication process, creating much dust and noise. The company decided to make improvements and set up a special project to reduce these emissions.

Sufficient finance and staff resources were made available and the project team included the affected workers, managers, occupational physicians, works council representatives and prevention specialists. They looked into possible solutions, holding discussions with potential suppliers and talks with the health and safety authorities. Around a dozen design ideas were prepared and assessed. The changes introduced included:

- grinding cabins with extractor systems;
- spot extractor systems;
- cartridge filtration systems; and
- optimising dust capture by redesigning the tool grinding shop.

Cooperation with experts from the public authorities (labour inspectorate including medical, mechanical engineering and emission specialists) formed an important part of the project.

The result was:

- a reduction in atmospheric dust loads (up to 90 % in some places);
- improved lighting to reduce glare and shadows;
- draught reduction; and
- noise reduction by 10 dB(A) for the machine operators and the surrounding hall area after the introduction of the cabins.

The total investment was around EUR 400 000. Apart from improved worker health and safety, the benefits of less airborne dust include, the calculated total savings were around EUR 70 000 a year (67).

(64) 137 dB(C) in relation to 20 µPa.

(65) When applying the exposure limit values, the determination of the workers' effective exposure shall take account of the attenuation provided by the individual hearing protection worn by the worker. The exposure action values shall not take account of the effect of any such protection.

(66) 140 dB(C) in relation to 20 µPa.

(67) European Agency for Safety and Health at Work, *Report 106 — The practical prevention of risks from dangerous substances at work.*

Personal protective equipment

The use of personal protective equipment (PPE) is required when risks cannot be avoided or sufficiently limited by other means. For noise, PPE means properly fitting personal hearing protection. The employer has to make every effort to ensure the wearing of such PPE and is responsible for checking the effectiveness of the measures taken. The worker has a duty to use the personal protective equipment. Personal hearing protection should be used:

- where noise exposure exceeds the lower exposures, the employer shall make individual hearing protectors available to workers;
- where noise exposure matches or exceeds the upper exposure action values, individual hearing protectors shall be used;
- the individual hearing protectors shall be so selected as to eliminate the risk to hearing or to reduce the risk to a minimum.

Before choosing personal protective equipment, the employer is required to assess whether the PPE he intends to use meets the national legislation put in place to implement the PPE directive. This assessment, which has to be reviewed if any changes are made to any of its elements, involves:

- an analysis and assessment of risks which cannot be avoided by other means (such as collective control measures);
- the definition of the characteristics required by the personal protective equipment in order to be effective against the relevant risks (e.g. noise) taking into account any risks which this equipment itself may create; and,
- a comparison of the characteristics of the personal protective equipment available.

Requirements for personal protective equipment

The supply of personal protective equipment is covered by Council Directive 89/686/EEC of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment (the supply of PPE directive).

The conditions of use of personal protective equipment, in particular the period for which it is worn, shall be determined on the basis of the seriousness of the risk, the frequency of exposure to the risk, the characteristics of the workstation of each worker and the performance of the personal protective equipment.

Personal protective equipment must meet the relevant Community provisions on design and manufacture with respect to safety and health, and be appropriate for the risks involved, without itself leading to any increased risk, correspond to existing conditions at the workplace, take account of ergonomic requirements and the worker's state of health, and fit the wearer correctly after any necessary adjustments.

Where the presence of more than one risk makes it necessary for a worker to wear simultaneously more than one item of personal protective equipment, such equipment must be compatible and continue to be effective

Personal hearing protection, and where it may be used

Non-exhaustive list of personal hearing protection devices (*)	**Non-exhaustive guide list of activities and sectors of activities which may require the provision of PPE** (**)
Earplugs and similar devices	Work with metal presses
Full acoustic helmets	Work with pneumatic drills
Earmuffs which can be fitted to industrial helmets	The work of ground staff at airports
Ear defenders with receiver for LF induction loop	Pile-driving work
Ear protection with intercom equipment	Wood and textile working

(*) Annex II, PPE directive.
(**) Annex III, PPE directive.

against the risk or risks in question. Workers should receive instruction and training in the use of their personal protective equipment (68).

Limitation of exposure

Exposure limit values may under no circumstances be exceeded. If, despite the measures taken to implement this directive, exposures above the exposure limit values are detected, the employer shall take immediate action to reduce the exposure to below the exposure limit values, identify the reasons why over-exposure has occurred, and amend the protection and prevention measures in order to avoid any recurrence.

The exposure limit values set in the 2003 noise directive are, for daily noise exposure levels and peak sound pressure, $L_{EX,8h}$ = 87 dB(A) and $\boldsymbol{p}_{peak}$ = 200 Pa (69) respectively. Member States have the option of putting in place weekly noise exposure level in place of the daily noise exposure level to assess the levels of noise to which workers are exposed (70).

When applying the exposure limit values, the determination of the worker's effective exposure shall take account of the attenuation provided by the individual hearing protectors worn by the worker. However, it is difficult to comply with this requirement because the effective attenuation of the hearing protector under practical individual usage is unknown. Thus it is necessary to assume an attenuation of the respective hearing protector less than the values given in the official test certificate.

Health surveillance

Where the assessment and measurement indicate a risk to health from noise, then health surveillance should be put in place in order to provide early diagnosis of any loss of hearing due to noise, and to protect the hearing function.

A worker whose exposure exceeds the upper exposure action values has the right to have his/her hearing checked by a doctor or by another suitably qualified person under the responsibility of a doctor. Preventive audiometric testing shall also be available for workers whose exposure exceeds the lower exposure action values, where the assessment and measurement indicate a risk to health.

Where, as a result of surveillance of the hearing function, a worker is found to have identifiable hearing damage, a doctor, or a specialist if the doctor considers it necessary, shall assess whether the damage is likely to be the result of exposure to noise at work. If this is the case:

- the worker shall be informed by the doctor or other suitably qualified person of the result which relates to him or her personally; and
- the employer shall review the risk assessment and the measures provided to eliminate or reduce risks, including the possibility of assigning the worker to other work where there is no risk of further exposure, and arrange systematic health surveillance and provide for a review of the health status of any other worker who has been similarly exposed (71).

Information, instruction, training, and consultation of workers

Employers are required to take appropriate measures to provide the necessary information to workers (including workers from outside undertakings) on the safety and health risks faced and the protective and

(68) PPE directive, Articles 3, 4 and 5, 2003 noise directive, Article 6, framework directive, Article 13.

(69) 140 dB(C) in relation to 20 µPa.

(70) 2003 noise directive, Articles 3 and 7.

(71) 2003 noise directive, Article 10, framework directive, Article 14.

preventive measures (including personal protective equipment) and activities in respect of both the undertaking and/or establishment in general and each type of workstation and/or job and emergency procedures.

Consultation with workers and their representatives is also required, and should cover the assessment of risks and identification of measures to be taken, the actions aimed at eliminating or reducing risks arising from exposure to noise, and, where necessary, the choice of individual hearing protectors.

Adequate health and safety training is a requirement under both the framework and 2003 noise directives, particularly:

- on recruitment;
- in the event of a transfer or a change of job;
- in the event of the introduction of new work equipment or a change in equipment;
- in the event of the introduction of any new technology.

Where workers are exposed to noise at work above the lower exposure action values, they should receive information and training on the risks resulting from exposure to noise, including the nature of such risks, the measures taken to eliminate or reduce the risks, safe working practices to minimise exposure to noise, the exposure limit and action values, the results of the assessment and measurement of the noise carried out together with an explanation of their significance and potential risks, why and how to detect and report signs of hearing damage, the circumstances in which workers are entitled to health surveillance, and the correct use of hearing protectors where required ([72]).

Risk groups

Particularly sensitive risk groups must be protected against the dangers that specifically affect them, and the employer shall adapt preventive measures to the needs of workers belonging to particularly sensitive risk groups ([73]). There may be other directives that cover aspects of prevention of exposure to risks from noise for these groups.

Pregnant workers

Council Directive 92/85/EEC of 19 October 1992 on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding (the pregnant workers' directive) requires the assessment of risks to the safety or health and any possible effect on the pregnancy of a worker and measures to be taken to ensure that, by temporarily adjusting the working conditions and/or the working hours of the worker concerned, the exposure of that worker to such risks is avoided. If changes to the working conditions and/or working hours is not technically and/or objectively feasible, or cannot reasonably be required on duly substantiated grounds, the employer shall take the necessary measures to move the worker concerned to another job.

Annex I of the pregnant workers' directive lists noise as a physical agent regarded as agents causing foetal lesions and/or likely to disrupt placental attachment. The European Commission's *Guidelines on assessing the risks to pregnant workers and new mothers* contains information on the evaluation of chemical, physical, and biological agents, as well as industrial processes deemed harmful to pregnant workers' health. It says 'loud noises can cause an increase in blood pressure and a feeling of fatigue; experimental evidence suggests that prolonged exposure of the unborn child to loud noise during pregnancy can also effect his/her hearing abilities after birth and that lower frequencies are more likely to cause damage ([74]).'

([72]) Framework directive, Articles 10 and 11, PPE directive, Articles 7 and 8, 2003 noise directive, Articles 8 and 9.

([73]) Framework directive, Article 15, 2003 noise directive, Article 5.

([74]) European Commission, *Guidelines on assessing the risks to pregnant workers and new mothers.*

Workers with disabilities

People with disabilities should receive equal treatment at work, and this includes regarding health and safety at work. People with disabilities are covered by both European anti-discrimination legislation and occupational health and safety legislation. This legislation, implemented by Member States in national legislation and arrangements, should be applied to facilitate the employment of people with disabilities, not to exclude them. Equal treatment legislation and health and safety legislation take similar approaches and are not in conflict.

The most relevant directive is Council Directive 2000/78/EC of 27 November 2000 establishing a general framework for equal treatment in employment and occupation. Employers are required to carry out risk assessments and protect particularly sensitive groups, such as workers with disabilities, against the dangers that specifically affect them. In taking protective action, the priorities are to eliminate risks at source and adapt work to workers. The latter is of particular importance for workers with disabilities ([75]).

The term 'workers with disabilities' covers a wide range of conditions, including:

- workers with hearing impairment;
- workers with speech impairment;
- workers with visual impairment;
- workers with mobility impairment;
- workers with learning difficulties.

Young workers

Council Directive 94/33/EC of 22 June 1994 on the protection of young people at work (the young workers' directive) requires Member States to make sure that young people are protected from any specific risks to their safety, health and development which are a consequence of their lack of experience, of absence of awareness of existing or potential risks or of the fact that young people have not yet fully matured. Specifically, it requires Member States to prohibit the employment of young people for work in which there is a risk to health from noise or vibration ([76]).

Older workers

Hard work ages us, although the pace of ageing varies according to the individual. The International Labour Organisation notes that a combination of age-related hearing loss and noise-induced hearing loss make it harder for older workers to distinguish sounds, especially high pitched ones. In assessing the risks to older workers and identifying prevention strategies, employers should consider the ability of workers to hear warning signals and spoken instructions, especially when containing difficult technical or foreign language terms. Workers over 55 years tend to suffer the most serious accidents and are the group of workers with the greatest incidence of long development-time occupational illnesses ([77]).

Temporary, migrant, and other precarious workers

The harm caused by noise can be cumulative. This may mean that peripatetic workers may be exposed to harmful noise but unlike workers in more stable forms of employment may miss out on adequate health surveillance. Such mobile workers should be carefully considered within any risk assessment and receive appropriate protection.

([75]) European Agency for Safety and Health at Work, *Factsheet*, 53, 'Ensuring the health and safety of workers with disabilities'.

([76]) Young workers' directive, Article 7.2.e.

([77]) Communication from the Commission, 'Adapting for change in work and society: a new Community strategy on health and safety at work 2002–06'.

Noise and fishing vessels

Workers on fishing vessels work irregular hours and often have short-term contracts. They are potentially at risk from harm arising from exposure to noise, particularly given the unique nature of the workplace and the type of work carried out. *Seafish* have published noise readings from fishing vessels in the UK fleet.

Noise in fishing vessels (*)

Location	Range (dB(A))	Peak (dB(A))	Typical sources of noise
Bridge	70–80	85	Radio (for communication)
Mess	75–81	95	Radio (for entertainment)
Deck	75–90	100	Deck machinery and fishing gear
Cabin	75–83	90	Radio (for entertainment)
Engine room	100–110	115	Main engine, turbo charger, exhaust, gearbox

(*) Source: *Seafish*, 'Noise and fishing vessels', 1988/15/FG.

Hydraulic noise can be a particular problem when it is carried around the vessel structure and spaces by the pipework system. It is often at an annoying frequency and can be loud enough to be a risk to workers' hearing. It can also impede speech communication. Hydraulic noise can be caused by:

- undersized, poor positioning and poor design of hydraulic tank causing aeration;
- system pipework being too small causing high velocity of oil;
- suction pipework being too small or too long causing cavitation and aeration;
- undersized valves or valve instability;
- pipework elbows and undersized adaptors causing flow restrictions;
- poor positioning and rigid clipping of pipework to relatively thin bulkheads which then act as loudspeaker devices;
- pipework routed through or near accommodation spaces;
- fluid-borne noise from pressure energy pulsations from pumps;
- fluid-borne noise from pressure energy pulsations from pumps such as piston pumps. Pumps with fewer pulsations, such as inner gear pumps, should be preferred.
- Properly specified and installed pipework and components should reduce the amount of hydraulic noise, and hydraulic attenuators can reduce the problem of fluid-borne noise ([78]).

Noise emissions from machinery in the workplace

The 2003 noise directive introduces action values and a limiting value for both A-weighted average and C-weighted peak sound pressure levels. The action values lead to concrete actions such as the requirement to tell workers about potential risks, the provision and wearing of hearing protectors, the checking of workers' hearing and the drawing up of a noise abatement programme including a requirement to use adequate information for choosing quiet machines.

To comply with the latter, the machinery directive, in general dealing with classical machinery safety requirements, states that machines shall be designed at source to reach lowest noise emission levels. Furthermore, a noise emission declaration must be given in the instruction manual and in the technical documents presenting the machine.

([78]) *Seafish*, 'Hydraulic noise on fishing vessels', 1988/16/FG.

For equipment used outdoors such as dozers and concrete breakers, Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors (the outdoor machinery directive), requires on the one hand, to mark these machines with the guaranteed sound power level, and on the other hand, requires that the emission of some machines complies with noise emission limits. In 2006, the permissible sound power levels in dB/1pW will be reduced.

Equipment subject to noise limits under Article 12 of the outdoor machinery directive

Builders' hoists for the transport of goods (combustion-engine driven)
Compaction machines (only vibrating and non-vibrating rollers, vibratory plates and vibratory rammers)
Compressors (< 350 kW)
Concrete-breakers and picks, hand-held
Construction winches (combustion-engine driven)
Dozers (< 500 kW)
Dumpers (< 500 kW)
Excavators, hydraulic or rope-operated (< 500 kW)
Excavator-loaders (< 500 kW)
Graders (< 500 kW)
Hydraulic power packs
Landfill compactors, loader-type with bucket (< 500 kW)
Lawnmowers (excluding agricultural and forestry equipment, and multi-purpose devices, the main motorised component of which has an installed power of more than 20 kW)
Lawn trimmers/lawn edge trimmers
Lift trucks, combustion-engine driven, counterbalanced (excluding 'other counterbalanced lift trucks' as defined in Annex I, item 36, second indent with a rated capacity of not more than 10 tonnes)
Loaders (< 500 kW)
Mobile cranes
Motor hoes (< 3 kW)
Paver-finishers (excluding paver-finishers equipped with a high-compaction screed)
Power generators (< 400 kW)
Tower cranes
Welding generators

Standards complementing directives

A major decision taken in 1985 by the European Economic Community (EEC, now the European Union (EU)) was the removal of technical barriers to trade. This was achieved by adopting a series of directives that would 'approximate the laws of Member States'.

These 'new approach' (79) directives define legislative harmonisation in specific sectors where barriers to trade existed due to divergent national regulations. One example of this was in the assessment of machinery hazards. The basic principle is that the directives are written as a series of simple legal requirements ('Essential health and safety requirements' — EHSR) and leave to standards how to reach the objectives.

(79) http://www.newapproach.org/

Although their use remains voluntary, the use of a harmonised standard is one way to get presumption of conformity to the related new approach directive.

Three types of standards are elaborated to support the machinery directive:

- Type A standards covering basic safety concepts;
- Type B standards covering horizontal issues (e.g. noise emission measurement in general) applicable to a lot of machinery; and
- Type C standards concerning safety aspects (including hazards due to noise emission) of single types of machinery.

The machinery directive addresses specifically the noise issue through two EHSRs, the first one in clause 1.5.8, is focusing on the development of low-noise machinery:

'Machinery must be so designed and constructed that risks resulting from the emission of airborne noise are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at source'.

The second EHSR in clause 1.7.4 f, is about the provision of noise emission values by manufacturers of machinery, the so-called 'noise emission declaration':

'…The technical documentation describing the machinery must give information regarding the airborne noise emissions… The instructions must give the following information concerning airborne noise emission by the machinery…

- Equivalent continuous A-weighted sound pressure level at workstations, where this exceeds 70 dB(A)…
- Peak C-weighted instantaneous sound pressure value at workstations when this exceeds 63 Pa (130 dB in relation to 20 μPa)…
- Sound power level emitted by the machinery where the equivalent continuous A-weighted sound pressure level at workstation exceeds 85 dB(A).'

It also specifies 'the manufacturers must indicate the operating conditions of the machinery during measurement and what methods have been used for the measurement.' The intention is to allow potential buyers to compare machinery on the market on the basis of their noise emissions and thus to choose comparatively quiet machines.

The European Committee for Standardisation (CEN) and Cenelec for the electrical counterpart are in charge, in close cooperation with the European Commission (EC) and the European Free Trade Association (EFTA), of producing European Standards (EN) that support the new approach directives. Under the machinery directive, the European Committee for Standardisation is handling a 'machinery programme'. This programme started around 1988 with the acceptance of mandates from the EC and EFTA that define the criteria for standards to achieve the status of being 'mandated'. By early November 2003, 472 standards were ratified, 179 were under approval and 53 under development.

The preparation of drafts is carried out in CEN technical committees (TCs), each of them composed of several working groups (WGs).

- Five technical committees elaborate type B standards:
  - TC 114 for machinery safety in general, including safety components
  - TC 122 for ergonomics
  - TC 211 for acoustics
  - TC 231 for vibrations
  - TC 169 for lighting.
- Forty-six technical committees elaborate type C standards for specific families of machinery (e.g. woodworking machinery, construction equipment, printing and paper machinery, tannery machinery, textile machinery, forestry machinery).

Since most machinery significantly emit noise, most standards prepared by these technical committees give (or should give) provisions on noise to back the EHSRs on noise of the machinery directive. Thus if noise has been considered to be a hazard caused by the specific machine the respective machinery safety standard must provide information about suitable noise reduction measures and about the noise emission declaration. The latter needs a noise test code, which is either a separate standard or a normative annex to the type C standard. Some are published (EN or ISO or EN ISO).

C-standards dealing with noise reduction, noise emission measurement and declaration

Subject	Number
Pumps (presently being exported to the ISO level)	EN 12639:2000
Printing, paper making and paper converting machinery (noise test code)	EN 13023:2003
Agricultural machinery (as frame noise test code for this wide family of machines)	EN 1553:1999
Forestry machinery (e.g. wood chippers)	prEN 13525[1]
Garden equipment (e.g. integrally powered shredders/chippers)	EN 13683:2003
Pedestrian controlled lawn aerators and scarifiers	prEN 13684
Hand-held integrally powered hedge trimmers	EN 774:1996/Amendment 3
Electrically powered walk-behind and hand-held lawn trimmers	EN 786:1996/Amendment 1:2001
Powered lawn-mowers	EN 836:1997/Amendment 2:2001
Mobile cranes	prEN 13000
Industrial trucks	EN 12053:2001
Some families of construction equipment (e.g. core drilling machines)	EN 12348:2000
Masonry and stone cutting-off machines	EN 12418:2000
Floor sawing machines	EN 13862:2001
Hydraulic hammers	prEN 13778
Some families of food processing machinery (e.g. food processors and blenders)	EN 12852:2001
Rotating bowl cutters	EN 12855:2003
Salad dryers	prEN 13621
Mincing machines	EN 12331:2003
Fixed deck oven loaders	prEN 13591
Circular saw machines	EN 12267:2003)
Some rubber and plastics machinery (e.g. blade granulators, strand palletisers, shredders)	EN 12012-1:2000, -2 and -3:2001
Footwear and leather goods manufacturing machines	EN 12545:2000
Industrial thermo-processing machinery	EN 1547:2001
Foundry machinery	EN 1265:1999
Fastening driving tools	EN 12549:1999
Textile machinery	EN ISO 9902:2001 in seven parts
Non-electrical hand-held tools	EN ISO 15744:2002
Compressors	EN ISO 2151:2004
Earth-moving machinery	Revision of ISO 6393 to 6396 in progress
Chainsaws and brush-cutters	prEN ISO 12868 to replace ISO 9207:1995 and ISO 10884:1995
Aircraft ground support equipment	prEN 1915-4

NB: The prefix 'pr' indicates that the standard is still in preparation (e.g. prEN 13000).

A comparable long list of machines particularly covering the large amount of handheld electrical tools is dealt with in Cenelec standards, for example EN 60745-1 and prEN 60745-2-xx.

Type B standards dealing with general acoustical matters are not related to a specific product but make keystones to which type C standards may make a normative reference. For example, a type C standard on the safety of meat mixers will make reference to one or several type B standards for the measurement of noise emission as well as for the declaration and verification on noise emission values (EN ISO 4871).

All work items of European interest have systematically been first submitted to ISO and so far ISO has accepted them. As a result, an intense activity developed, in particular through WG 28 of ISO TC 43/SC 1. The consequence is that all type B standards on noise emission from machinery (except EN 1746) are also EN ISO standards.

In order to back the machinery directive's EHSRs on noise:

- New type B standards were needed on the design of low-noise machinery, and EN ISO 11688-1:1998 and -2:2000 (published as technical reports in ISO) were elaborated.
- The determination of A-weighted emission sound pressure levels at the workstation(s). The EN ISO 11200 series (EN ISO 11201–11205) was prepared with EN ISO 11200:1995 as an introduction and aid to choose the most appropriate standard(s) in a given practical situation.
- The determination of the sound power level of machinery. The European incentive triggered the revision of the whole ISO 3740 series. Two new methods were added: EN ISO 3743-1:1995 (comparison method in hard-walled rooms) and EN ISO 3747:2000 (comparison method *in situ*). The reverberation room standards were combined into one single EN ISO 3741:2000. The frame standard EN ISO 3740 introduces both EN ISO 3740 and EN ISO 9614 series and helps to choose the most appropriate standard(s) in a given practical situation.
- The declaration (and, consequently, the verification) of noise emission values. ISO 4871 did exist and was revised and finally published as EN ISO 4871.
- The evaluation of noise emission data in view of the comparison of noise emissions from similar machinery put on the market by different manufacturers. EN ISO 11689, with the concept of noise control performance, was published. A concept that has now also been introduced as comparative emission data in the basic machinery safety standard the EN ISO 12100-1,-2.

According to the Vienna Agreement between CEN and ISO, the policy has been to develop basic standards in acoustics at the international level (ISO) following the Vienna Agreement between CEN and ISO. This policy proved itself effective; all type B standards on noise emission are ISO and European (EN) standards. The situation is quite different regarding noise from products. Indeed, product standards are prepared in specific technical committees. Under the pressure of economics and competition between industrial partners standardisation is presently carried out mostly at the European level, but with a clear tendency to move to ISO.

A type C standard deals in principle with all hazards that are identified through a risk assessment as being significant for the specific family of machinery that it covers. Whenever noise is a significant hazard, and it is in most cases, the relevant type C standard must deal with noise. Recommendations for the drafting of noise clauses of type C standards are given in EN 1746 which in fact can be regarded as a policy document. It describes what aspects of noise emission should be covered in a type C standard so that the use of the type C standard can give presumption of conformity to the machinery directive. Finally, noise test codes shall be prepared on the basis of ISO 12001.

The machinery directive is not unique in dealing with machinery noise. Employers, particularly those in the construction industry, should take into account the outdoor machinery directive on the 'noise emission in the environment by equipment for use outdoors', particularly those in the construction industry. This directive aims at the protection of the environment from excessive noise being emitted by 57 families of equipment used outdoors. These equipment families include:

- earth-moving machinery
- road-breakers
- paver-finishers
- compaction machines

- chainsaws
- lawn-mowers
- mobile and power cranes
- mobile waste containers, compressors
- truck mixers.

Unlike the machinery directive, the outdoor machinery directive considers only the A-weighted sound power level, fixes noise emission limit values for 23 machinery families (80) and specifies the measurement method to be used by applying only a few B-standards dealing with noise emission measurement methods. The outdoor machinery directive does not require explicitly that noise be reduced at the design stage but it requires manufacturers to put on the machine the guaranteed value of the A-weighted sound power level.

Even more than the machinery directive, the outdoor machinery directive relies on market forces to make sure that less noisy machines are progressively put on the market. However, a recent market survey showed that most machines falling under limit values are labelled with exactly these limit values. This makes it difficult for purchasers to really choose the quieter machine.

Quality control of standards

The 'new approach' has given standardisation a power that it did not have before. The basis for standardisation is the consensus between the experts and stakeholders. But how is then the quality of standards regarding the EHSRs ensured? Until 1994 when a quality control system was introduced at the European level, the technical quality of standards was never assessed. In November 1998, three independent experts, the 'CEN/Cenelec consultants for noise', in charge of checking the quality of the noise content of European standards prepared under the machinery directive, started to work for CEN and Cenelec under a sponsorship of the European Commission. The reason is that the expertise of WG members elaborating type C standards is mostly in the field of mechanical and electrical safety. The challenge noise consultants face is to introduce in product safety standards high quality technical requirements on noise while keeping within what is judged as economically acceptable by manufacturers.

The main tasks of these consultants for noise are:

- to assess drafts formally at the CEN/Cenelec Enquiry stage (DIS stage in ISO) and at the CEN/Cenelec formal vote stage (e.g. FDIS stage in ISO). A CEN draft cannot proceed to formal vote until an agreement has been reached between the working group and the consultants concerned.
- to assist working groups at the earliest possible drafting stage (in order to avoid negative assessments of drafts and delays at later stages).

A good job done by the CEN/Cenelec consultants not only avoids a safeguard clause procedure or a formal objection by EU Member States, which can enforce an amendment, but also ensures a good applicability of the standard with finally a positive economic effect.

Standards supporting noise control measures in the workplace

Considering machines as the major sound source in workplaces it is essential to foster the purchasing of quiet machines on the basis of noise emission values. To allow a comparison of the noise emission of machines detailed rules for the noise measurement were needed. It was quickly admitted that the requirements of

(80) The limit values for those 23 machinery families will be lowered by 2 or 3 dB in 2006.

existing noise test codes were not precise enough and that, for a given family of machinery, one single noise test code should be in force over the entire EU. EN ISO 12001 was then prepared. It gives the rules for the drafting of a noise test code, leaving to CEN or ISO/TCs in charge of type C standards the responsibility to prepare noise test codes. It is now accepted that each working group of each CEN/TC elaborating type C standards should prepare a noise test code for its family of machinery as long as noise is a significant hazard for the machinery concerned.

The use of a unique method (the noise test code relevant to the family concerned) for determining the noise emission values of a machine by all manufacturers ensures that these values are comparable. By collecting comparable noise emission values and printing them in a single graph a cloud of data is formed ([81]). This cloud then allows the identification of the state of the art of the noise emission of the respective family of machines. Knowing the state of the art is the key to assess what is meant with the 'lowest possible' noise emission for a given family. Unfortunately, manufacturers of industrial machines seem to not yet have made use of this concept. Health and safety organisations are carrying out pilot actions to show that this is feasible and encourage manufacturers to join in.

In parallel to the 'new approach' and in the wake of it useful European standards have been prepared that are not harmonised as they are not associated to any European regulation.

Main issues now covered by standards are the following.

- The design of low-noise workplaces (EN ISO 11690 parts 1 to 3). Part 3 deals with the key issue of prediction of noise levels in workshops.
- The design of means to reduce noise during its propagation and the measurement of their acoustical performance. These include:
  - enclosures (EN ISO 15667, EN ISO 11546)
  - cabins for personnel (EN ISO 15667, EN ISO 11957)
  - screens (EN ISO 11821)
  - silencers (EN ISO 14163, EN ISO 11691 and EN ISO 118201).
- The characterisation of workplace acoustics using spatial sound decay curves ([82]). Measurement of exposure to noise in the workplace is so far a subject for national standardisation only as it does not concern products but people. Other details of the implementation of the 2003 noise directive are national matters, such as the compensation system for noise-induced hearing loss. There is however an ISO standard ([83]) on the measurement of noise exposure that has been rejected some years ago as a European standard. When the present revision of ISO 9612 is carried through, it will be interesting to see, in the context of the 2003 noise directive, whether the European policy will change. Some national authorities seem today more in favour of a single measurement method being used throughout the EU on the ground that, although workshops do not move from one country to another, workers do. Therefore especially big enterprises with several plants in different European countries are interested to manage safety and health uniformly throughout the company.
- Personal hearing protectors have also been the subject of intensive standardisation ([84]). The standards regard the special requirements concerning quality control according to supply of PPE directive, which needs the type testing of hearing protectors by a notified body.

([81]) See EN ISO 11689:1996.

([82]) See EN ISO 14257.

([83]) ISO 9612.

([84]) See EN 352, EN 458 and EN 24869.

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EUROPEAN WEEK FOR SAFETY AND HEALTH AT WORK

4.

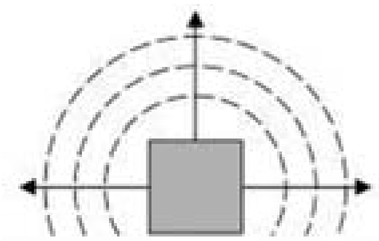
THE MANAGEMENT OF NOISE

Key points

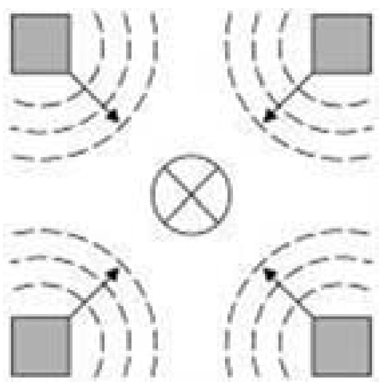
- Noise should be addressed first by the design of the noise source
- Reduction of noise on the transmission path is essential in reducing workplace noise
- Organisational measures can be introduced to reduce exposure to noise

THE CONCEPT OF NOISE REDUCTION

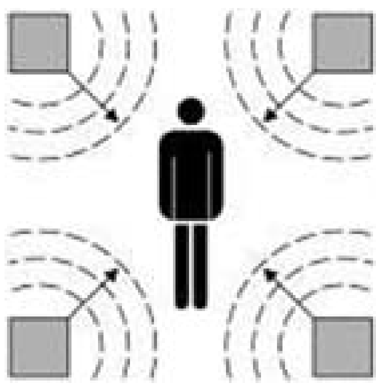
An effective noise reduction requires a systematic approach. EN ISO 11690-1 describes the systematic approach to noise reduction in working plants and offices and defines basic terms such as emission, immission and exposure.



Emission: The noise generated by the source



Immission: The effect of the noise at a distance (for example at the workplace)



Exposure: The load of the noise on a person

As a basic strategy for noise reduction EN ISO 11690-1 describes the following steps for new and existing workplaces.

- Determine objectives and set criteria.
- Carry out noise assessment by identifying:
  - the areas concerned;
  - the immission at work stations;
  - the contributions of the different noise sources to the immission at work stations;
  - the exposure of persons;
  - the emission of sources in order to rank them.
- Apply noise reduction measures ([85]):
  - at source ([86]);
  - on the transmission path;
  - at the workstation.
- Formulate a noise control programme.
- Put in place appropriate preventive measures.
- Verify the attained noise reduction.

Planning the acoustics should be part of the overall planning process for a new factory or for major changes of old ones, so that all building, production and soundproofing aspects of the project can be coordinated right from the start.

Any noise control is based on the source — transmission path — receiver model, whereby the source is generally interpreted as the operating machine that is generating noise. The transmission path is the path along which the sound energy from the source travels to the receiver, which is in fact the worker at the workstation. Although it is possible to change any of these elements, it is particularly effective to reduce the noise at its source.

Box Text: Case study: Reducing noise in paper manufacture

In a continuous process paper factory, the trunks during the various manufacturing stages are moved along from one area to another on long belt conveyor lines. Along these lines are switching metallic hoppers where the trunks change direction. These generated high noise levels (L_{Aeq} 86.6 dB(A) at 3 m).

By installing an acoustic cabin with silenced main doors and belt input, the noise level was reduced to 71dB(A) ([87]).

Noise control by design

Since machines can normally be considered the major sources of noise at the workplace, the design of low-noise machines as required by the machinery directive is an essential measure to effectively reduce noise at the workplace. To support machine manufacturers in designing quieter machines important standards have been prepared namely EN ISO 11688-1 and EN ISO 11688-2. Part 1 of this standard contains information on the recommended practice for planning the design of low-noise machinery and equipment, while part 2 provides an introduction into the physics of low-noise design.

([85]) See EN ISO 11690-2.

([86]) See EN ISO 11688-1.

([87]) *Source*: 'L'Istituto superiore per la prevenzione e la sicurezza del lavoro (Ispesl)', from unpublished good practice manual for noise control and the reduction in noise at workplaces.

Starting from the acoustic model:

generation — transmission — radiation

and its counterpart on the side of the machine:

source — path — surface

Part 1 explains the basic model of noise generation by machines. Thus airborne, liquid-borne and structure-borne sources are presented together with the different possibilities for influencing their source strength. If we consider airborne noise, physical characteristics such as turbulence, pulsation, shock will need to be addressed. In the case of structure-borne noise, physical characteristics such as tooth meshing, friction, inertia, magnetic field or rolling may be relevant.

As basic steps these design rules should be followed:

- division of the machine components into active and passive ones;
- identifying airborne, liquid-borne and structure-borne sound sources;
- locating airborne, liquid-borne and structure-borne sound paths;
- identifying the sound-radiating surfaces;
- assessing the strongest contributors (sources, transmission paths, radiating surfaces).

EN ISO 11688-1 then gives guidance on how to influence the different sources, transmission paths and radiating surfaces. As an example, structure-borne noise sources generating impact noise can be influenced by:

- Increasing impact time;
- Decreasing impact velocity;
- Minimising the mass of the free impacting body;
- Increasing the mass of the fixed body;
- Avoiding loose components with alternating loads.

For the reduction of structure-borne noise transmission it is recommended to install a sufficiently stiff and heavy foundation to improve vibration isolation, or to use more damping (e.g. for thin plates).

Finally, guidance is given on how to minimise the radiation of structure or airborne noise. Part 1 of EN ISO 11688 provides design rules without relying on formulas, while part 2 assists in quantifying the effect of specific noise reduction measures by presenting simple formulas for the physics of noise generation, transmission and radiation.

For further support for manufacturers in the design of new and quieter machines, or for reducing the noise of already existing machines, standards on the application and assessment of performance of enclosures ([88]) and silencers ([89]) are available.

Case study: Pneumatic impact press reduction

High peak noise emissions were being experienced from the release of compressed air at the actuator exhaust on a pneumatic impact press and from the impact of the metal actuator ram as it struck the metal tool ram. Fitting a silencer, passing airflow through a porous polythene cap, and using an 8 mm thick cushion of a proprietary urethane elastomer between the metal surfaces achieved an overall reduction in noise levels of 9 dB achieved without a significant effect on the overall working efficiency of the press ([90]). This results in a drastic risk reduction with about a 10th of sound pressure intensity and about half of the subjective perceived loudness.

([88]) See EN ISO 15667, EN ISO 11546.

([89]) See EN ISO 14163, EN ISO 11691 and EN ISO 11820.

([90]) Case study from Health and Safety Executive 'Sound solutions' at: http://www.hse.gov.uk/noise/soundsolutions/index.htm

Noise control by choosing quiet machines

Occupational health and safety professionals are usually not in a position to change the fundamental design of machines, but when buying new machinery they can use the noise emission declaration made by the manufacturer under the machinery directive in the procurement decision-making process. This obligation on the manufacturer to provide a noise emission declaration increases market transparency. It not only assists the buyers of machinery in choosing quieter ones, but should also give the producers of quieter machines an advantage on the market. Consequently, a low noise emission should become a quality parameter for machines such that the noise emission of the machine determines its sound quality. A machine with a high sound quality would emit less noise, thus lowering the exposure of the workers at their workplaces and in the neighbourhood. The noise emitted from the machine travels as sound in all directions and is partly reflected and absorbed, creating the sound pressure at the workstation, which can be measured with a sound level meter.

The important parameters to describe the sound emission of a machine are:

- the sound power level (L_{WA}) in dB;
- the emission sound pressure level at the workplace (L_{pA}) in dB and, as further information in the case of impulse noise;
- the peak sound pressure level ($L_{pC, peak}$) in dB.

The sound power level L_{WA} of a machine describes the sound energy emitted by a machine per time unit and therefore indicates how much noise is emitted in total. The sound power level is given in dB(A). As a single measure for the overall sound emission, the sound power level is best suited for comparing different machines and for calculating the sound pressure levels in a room at a workplace.

The second parameter for the evaluation of the sound emission of a machine is the emission sound pressure level L_{pA}. This tells us how loud it would be at the workplace associated with the machine if there were only the sound of the machine and neither the sound of other machines nor the reflections of the sound coming from the ceiling and walls. It is usually determined for the same operating conditions as the sound power level, as defined in the relevant standards.

The procedures for measurement, declaration and verification of the sound emission quantities are defined in the basic standards.

- The sound power level is based on EN ISO 3740 or EN ISO 9614.
- The emission sound pressure level is based on EN ISO 11200.
- The declaration and verification of sound emission values is described in EN ISO 4871.

The machinery directive requires not only technical noise reduction at the source ([91]), but also a declaration of noise emission ([92]), which has to be part of the instruction manual ([93]) and of the technical brochures used to sell the machine ([94]). In addition, for about 57 different families of machines commonly used outdoors (e.g. earth moving machinery, compressors, lawn mowers), the outdoor machinery directive defines procedures for the determination of the noise emission quantity sound power level. For 23 of these machine families upper limits for sound emission have been set.

On the basis of the declared noise emissions from several machines of different manufacturers the potential customer can choose the machine with the lowest noise emission as intended by the 2003 noise directive.

([91]) Annex 1. Essential health and safety requirements relating to the design and construction of machinery and safety components, Section 1.5.8.

([92]) Annex 1. Essential health and safety requirements relating to the design and construction of machinery and safety components, Section 1.7.4f.

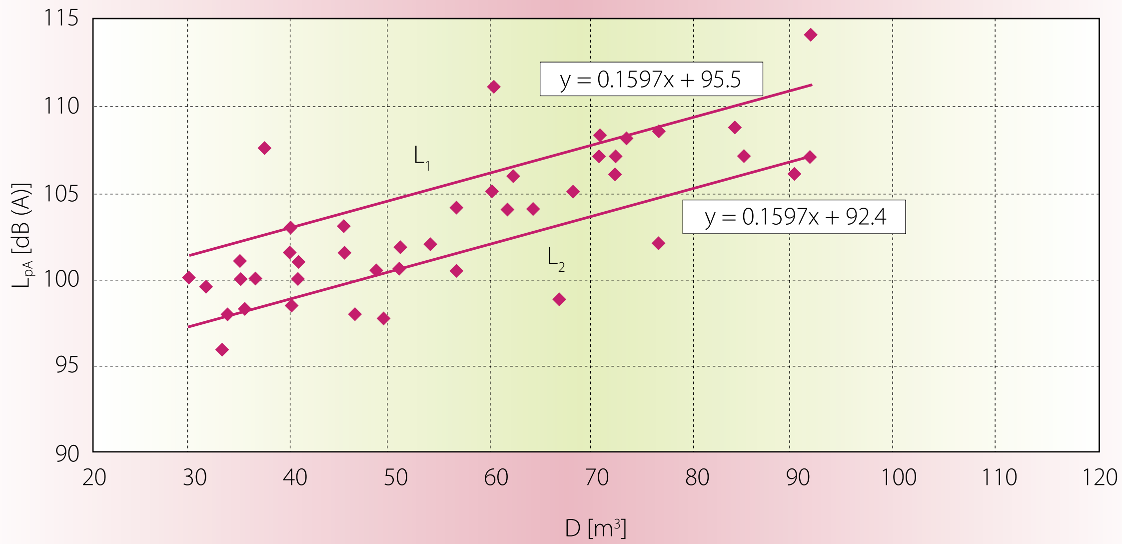
([93]) Annex 1. Essential health and safety requirements relating to the design and construction of machinery and safety components, Section 1.7.4f .

([94]) Annex 1. Essential health and safety requirements relating to the design and construction of machinery and safety components, Section .4f.

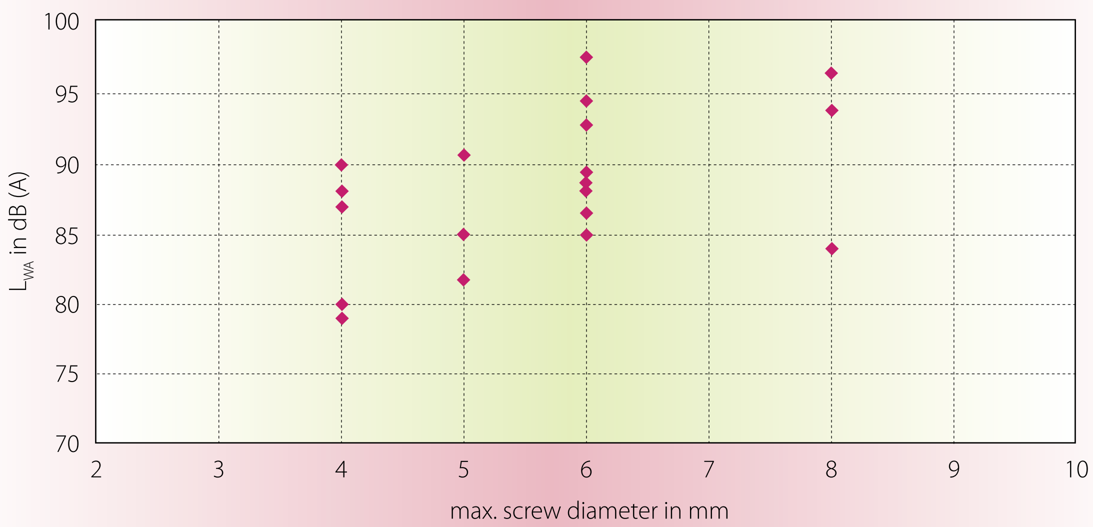
However, this does not necessarily mean that this machine is really one of the quietest on the market within a given group. This can only be proven if the state of the art of noise emission for the respective type of machines performing the same tasks is known.

The term 'current state of noise emission' (comparative emission data EN ISO 12100-1, level of noise reduction EN ISO 11689) was created for this purpose. This current state defines a range of comparable noise emission values measured in accordance with methods laid down in C-standards.

The state of the art of noise reduction can be derived from this range of noise emission values. Normally a machine is state of the art if the emission value is lower than 50 to 75 % of comparable machines, which means it belongs to the group of machines with lower noise emission values and therefore of a higher sound quality.



Emission sound pressure level (L_{pA}) of chainsaws according to a standard with defined operating conditions (ISO 22520)



Sound power level (L_{WA}) of pneumatically powered screwdrivers with air cut-off gear as function of the maximum screw diameter

The current state of noise emissions of about 20 machine groups is described in a few international standards and in some VDI-ETS guidelines that are valid only for Germany.

In the future, it would be useful if collections of sound emission data in the form of a European database were available, to help machine producers to fulfil the directive on minimising noise emissions and to help buyers to find quiet machines.

Case study — Marketing office equipment: The TCO Labelling scheme

In the beginning of the 1980s, the TCO (The Swedish Confederation of Professional Employees) realised that personal computers were going to be the primary tool for the 1.3 million members in the TCO association. At the same time, the first concerns began over potential risks to workers' health from working with visual display units (VDUs) and computers. On this basis, the TCO decided to draw up and set requirements together with user representatives and technical experts — and to address the requirements directly to the market.

The purpose of the TCO label is to:

- stimulate the manufactures to develop more occupational and environmental safe office equipment;
- assist purchasers to choose office equipment less problematic for the users and the external environment;
- provide the purchaser as well as the vendor with a clearly defined label, saving time, work and cost in the purchasing process.

Among the requirements relevant to the safety and health of the employees, the TCO '99 includes requirements on noise levels for printers (95).

Noise reduction on the transmission path and recommended acoustic properties for work rooms

In order to be really effective, the acoustic planning of new workplaces and the selection and implementation of noise control measures in existing workplaces should occur during the design of a whole new plant or changes to existing ones. In every case, noise control objectives should be set in order to meet existing regulations. Such objectives would be, for example, staying well below the maximum recommended background noise levels as stated in EN ISO 11690-1.

Maximum recommended background noise levels (EN ISO 11690-1)

Type of room	Sound pressure level (L_{pAeq}) in dB
Conference rooms	30 to 35
Classrooms	30 to 40
Individual offices	30 to 40
Multi-person offices	35 to 45
Industrial laboratories	35 to 50
Control rooms in industry	35 to 55
Industrial workplaces	65 to 70

(95) Further information can be found on the TCO's homepage and in Reports 304 (Occupational safety and health in marketing and procurement) and 308 (Recognition schemes in occupational safety and health) by the European Agency for Safety and Health at Work.

In the case of a workplace in industry, for example, background noise is defined as noise arising from indoor technical equipment such as air conditioning units or lifts, or noise coming from the outside such as traffic noise, when the production machines are turned off.

In recent years, new criteria and methods (96) have been introduced for the evaluation of workspaces in order to create new standards. This was necessary because the previously used reverberation time is insufficient for the description of working spaces. The sound field in a room can only be described adequately by reverberation time if it is diffuse. This is not the case for working spaces being flat and/or long industrial halls and offices. From the noise reduction point of view the sound pressure levels at an immission point in the room caused by a sound source are of specific interest. To achieve this, the method of determining an average sound diffusion curve for a workspace was developed. From this curve parameters for an acoustical assessment of the workspace can be deduced. These parameters are:

- the sound pressure level decay per distance doubling (DL2);
- the excess of sound pressure levels (DLF), that is, the average difference between the sound propagation curve in the room under consideration and a free sound field.

In some standards recommended reverberation times or parameters of sound propagation are given that would achieve a satisfactory to good sound quality in a workplace. According to these standards, the sound pressure level decay per distance doubling should be greater than 4 dB, and for large rooms (V>500 m^3) greater than 4 to 5 dB. The excess of sound pressure levels should be less than 8 dB. Reverberation times in offices should not exceed 0.6 s.

Case study: Reducing noise by absorbing reverberant sound energy

Noise levels from high-speed presses operating in the production area of a healthcare company manufacturing metered dose aerosols were generally over 85 dB(A). Most of the operators' exposure was due to direct radiation from the nearest presses, but reflected noise also built up as reverberant sound energy.

As part of their overall noise-control programme, the company decided to install a network of absorbers suspended from the roof of the building. The absorbers had to be as low as possible for maximum acoustic effect but could not interfere with the fire alarm, power and sprinkler systems already placed in the ceiling. About 1 400 absorbers were suspended from the eaves. Each unit was 900 mm long x 600 mm wide x 50 mm thick with a perforated steel case and plastic wrapping to prevent oil getting into the absorbent material. After installation, the reverberation time of the press shop fell and overall there was a noise reduction of 4 dB (97).

Organisational and administrative noise control

The reduction of noise risks by organisational noise-control measures should consider:

- having noise emissions as an evaluation factor in a work equipment procurement policy;
- working methods which generate less noise;
- organisation of work to reduce noise.

(96) EN ISO 11690-1, -2, -3.

(97) Case study from Health and Safety Executive 'Sound solutions' at: http://www.hse.gov.uk/noise/soundsolutions/ss10.htm

The organisation of work could limit the duration and intensity of exposure by:

- keeping the number of workers in noisy areas to a minimum;
- task rotation;
- scheduling noisy activities for when fewer workers are exposed;
- having appropriate work schedules with adequate rest periods.

Improving the acoustic safety and comfort in call centres

Call centres are a relatively new form of workplace. Noise exposure in this work environment does not follow the traditional forms as experienced in, for example, metal fabrication. This means that prevention measures have to be adapted, while following the European directive structure.

According to a study of operators, the main sources of background noise, within the call centres, were other call handlers speaking to customers, staff talking to each other, particularly at shift changes, meetings being held and telephones ringing in other parts of the open-plan office. At the caller's end, the television, radio, dogs barking and babies crying were cited. Call handlers' overall daily personal noise exposure is unlikely to exceed 85 dB(A).

However, there are still a variety of measures that can be taken to reduce their exposure to noise at work and improve the acoustic comfort of their work.

- Train call handlers to place the microphone in the optimal position in front of a call handler's mouth to avoid too much vocal feedback for both the caller and the call handler. Callers may become frustrated if they cannot hear call handlers clearly, and there is a risk that call handlers may start to strain their voices in order to be heard.
- Special noise absorbing material, often in ceilings, can help to reduce reverberation in the call centre. Carpet, chairs with soft seats and padded screens between call handlers can also be effective noise absorbers if designed and fitted appropriately.
- To limit call handlers' daily personal noise exposure, headsets, amplifiers and/or turrets should be fitted with volume controls, and call handlers should be trained in how to use the volume controls. There is a risk that call handlers will turn the volume up in order to hear a quiet caller but forget to turn it down for the next caller even if that caller speaks at a higher level. Call handlers may then get used to listening to callers at higher levels than are really necessary. Some systems return the call handler's listening level to a default setting after each call. An on-screen reminder at the start of a new call could also prompt call handlers to assess the level and adjust the volume if necessary. A designated key on the keyboard can be used to reduce headset noise immediately to a minimum when pressed. This is a quick method for call handlers to reduce sudden high headset noise levels. Prompt call handlers to adjust the listening level (both up and down) through their headsets at the beginning of each call.
- Call handlers should be encouraged to report to management exposure to all acoustic shock incidents or any other abnormally loud noises. Employers should make a record of these reported events.
- One practical way of limiting exposure to unexpected high noises from headsets is through headset design, such as the incorporation of an acoustic (shock) limiter. A limiter ensures that any type of noise (for example, conversation, short duration impulses) above a fixed volume is not transmitted through the headset.
- Call handlers wear a headset throughout their shift so it is important that it is fully adjustable to ensure a comfortable fit. Headsets should be checked regularly and repaired or replaced at once if necessary. There may be an increased risk of ear irritation and infection because headsets are worn so intensively. To reduce this risk, staff should be trained in headset hygiene and given the time and the materials to complete a hygiene programme. The issue of headsets to individuals is strongly recommended.
- Voice tubes can become blocked with food, make-up and dust, and this compromises the effectiveness of microphones. Call handlers must be trained in how to clean the voice tubes in order to optimise the volume of the transmitted signals and avoid the risk of frustrated callers and strained voices.

- Ensure there is a big enough stock of new or sterile headset pads and voice tubes.
- Employees should be encouraged to report at once exposure to any acoustic incident that results in physical damage. Employers should have a policy to record the details of these incidents, and employees are examined by an appropriate expert to investigate the extent of any physical damage (this may include a hearing check).
- Call handlers should be provided with information about the potential risks to hearing and the measures being taken by their employer to control these risks. Call handlers or their representatives should be consulted about working practices ([98]).

Reduction of noise exposure by personal protective means

There are many cases where noise control is ineffective, infeasible or prohibitively expensive, such as in the aircraft taxiing areas at airports. If the risks arising from exposure to noise cannot be prevented by other means, workers should use individual hearing protection. It should be noted that

- where noise exposure exceeds the lower exposure action values of the 2003 noise directive, the employer must make individual hearing protectors available to workers;
- where noise exposure matches or exceeds the upper exposure action values, individual hearing protectors shall be used;
- the individual hearing protectors should be selected to eliminate the risk to hearing, or to reduce the risk to a minimum, or at least to make sure the exposure limit values are not exceeded;
- the employer should make every effort to ensure the wearing of hearing protectors and is responsible for checking the effectiveness of the measures taken.

Some types of hearing protection devices

Earplugs	Vinyl, silicone, spun fibreglass, cotton/wax combinations, and closed-cell foam products that are inserted or semi-inserted in the ear canal to form a noise blocking seal. Comparatively, the attenuation is better below 500 Hz and above 2 000 Hz.
Earmuffs	Ear cups, usually of rigid plastic material with an absorptive liner, that completely enclose the outer ear and seal around it with foam- or fluid-filled cushions. Comparatively, the attenuation is better at intermediate frequencies.
Earmuffs	With incorporated active noise cancellation — a new technology that especially for the lower frequency range offers an active noise-level-dependent attenuation, as well as a passive protection.

The use of hearing protection devices is generally less effective than other measures of noise control because its effect significantly depends on the wearer's behaviour, which is influenced by some side effects of the devices (e.g. poorer perception of signals and spoken communications, discomfort, isolation). Apparently workers tend to underestimate noise as a hazard for their hearing. As hearing loss gradually develops over a period of years, noise is not taken as something serious. This is even worse for high impulses of sound that may exceed the physiological limit of the inner ear structures with the result of a sudden breakdown of hearing.

([98]) HELA (Health and Safety Executive/Local Authorities Enforcement Liaison Committee) 2001, 'Advice regarding call centre working practices', LAC 94/1 (rev).

Although the wearing of hearing protection is enforced by law and promoted and although the checking of workers' hearing is required by law for workers being exposed to levels over 85 dB(A) or 137 dB(C), workers often avoid wearing hearing protectors, in many cases simply for convenience, even when their use is required.

A study by the Institute of Occupational Medicine for the Health and Safety Executive found that workers did not wear hearing protection (even when required to do so) mainly because it impeded communication and because they are uncomfortable. Personal hearing protection is more likely to be worn:

- if workers understand the physiological effects of noise exposure;
- where noise levels are highest;
- where the noise levels are constant;
- where the process conditions are unchanging;
- where the task or job is routine;
- where the workers are actively involved in the noise task;
- where the workers are directly supervised;
- where there is positive support from peer groups ([99]).

Hearing protectors do not reach the laboratory insertion loss performance under practical conditions due to the variability of human ear canal dimensions, leaks around the protector and incorrect use by the wearer. Moreover, a report on the application of hearing protectors showed that even in workplaces where ear protection was compulsory, 29 % of the exposed employees admitted not to wearing ear protection in the designated zones.

Hearing protectors can improve the intelligibility of signals and words in continuous noise. For example, drivers of very noisy snow ploughs report hearing the signals of emergency vehicles earlier when wearing earplugs than when not wearing them. However, in intermittent or impulsive noise, the effect is the opposite, with intelligibility reduced ([100]).

Information and training

The employer should also ensure that if workers are exposed to noise at or above the lower exposure action values, they receive information and training on the risks resulting from exposure to noise, in particular:

- the nature of such risks;
- the measures taken in order to eliminate or minimise the risks from noise, including the circumstances in which the measures apply;
- the exposure limit and exposure action levels;
- the results of the assessment and measurement of the noise together with an explanation of their significance and potential risks;
- the characteristics and properties of different types of hearing protectors;
- the correct use of hearing protectors;
- why and how to detect and report signs of hearing damage;
- the circumstances in which workers are entitled to health surveillance and its purpose;
- safe working practices to minimise exposure to noise.

([99]) *Research report*, 28, 'Behavioural studies of people's attitudes to wearing hearing protection and how these might be changed', Institute of Occupational Medicine for the Health and Safety Executive, 2002.

([100]) Except in the case of level-dependent hearing protectors.

Success factors for prevention of noise-induced hearing loss

The World Health Organisation in 2004 published requirements for successful hazard prevention and control programmes. These were:

- political will and decision-making;
- commitment from top management, with a clear and well-circulated policy;
- commitment from workers;
- well-defined goals and objectives;
- adequate human and financial resources;
- technical knowledge and experience;
- adequate implementation of the programme and competent management;
- multidisciplinary teams;
- communication mechanisms;
- monitoring mechanisms (indicators);
- continuous programme improvement.

Furthermore, specific noise prevention and control strategies usually involve action with these elements:

- the work process (e.g. more accurate preparation and welding to avoid noisy straightening, chiselling and grinding, or installing quieter work equipment);
- the workplace (e.g. the use of noise enclosures);
- the workers (e.g. worker education programmes) ([101]).

([101]) *Assessing the burden of disease from work-related hearing impairment at national and local levels*, World Health Organisation, 2004, referring to Goelzer, *BIF hazard prevention and control programmes*, 2001.

5.

EXAMPLES OF WORKPLACE INTERVENTIONS

Noise assessment in the construction industry

In 2003 the Hellenic Institute for Occupational Health and Safety carried out a one-year study into occupational safety and health in road construction works ([102]). About 15 construction sites were visited in Athens and northern Greece where safety audits as well as industrial hygiene measurements and audiometries were conducted. In particular noise monitoring consisted of daily exposure measurements on basic phases of tunnel and bridge construction. Noise exposure was evaluated for operators of boring machines such as jumbo, vagodrill and forepolling, charging and blasting workers, workers near concrete pumps and reinforcement instalment workers and others. In parallel and whenever this was possible audiometries were performed to similar group of workers. In total 112 workers had hearing checks and a medical file being drafted.

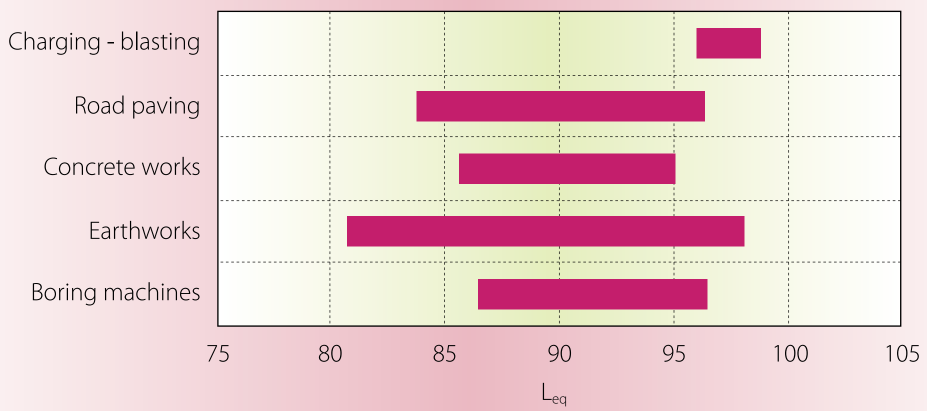
The main goal of the study was to create a noise map of road construction works and start a pilot epidemiological study with a significant number of audiometries for construction workers that are scarce nowadays in field studies.

The ambition of the study was to discover a statistical significance of noise exposure between different specialities in road construction works and correlate it with related audiometric findings. Given the limited number of some groups of workers such as the blasting workers no statistical significance was evident between specialities. However the differences on noise exposure and acoustic ability reduction for this group are so great that it allows the supposition that by enlarging the sample a statistical difference is likely to appear.

The results of the noise measurements for road construction workers showed that 91 % exceeds action value of 85 dB(A). In particular average equivalent noise levels varied from 86 dB(A) for vagodrill operators working outdoors to 97.2 dB(A) in blasting operations in tunnels. The data were further analysed using homogeneous groups of workers comprised of operators of boring machines, earthworks, concrete works, road paving and charging — blasting workers.

From the audiometries it was discovered that 26 % of the workers examined suffered occupation-related hearing loss. The blasting workers seem to have the highest reduction of acoustic ability in 4 000 Hz (– 30) followed by general workers (– 28.1), of which the majority worked close to boring machines, and the concrete workers (– 27). The blasting workers' group has the worker that has the highest score (3) on Merluzzi climax. An analysis of variances was made to check if the age, working age and speciality affect the appearance of hearing loss in road

Portable noise measurements per speciality group



([102]) The Hellenic Institute of Occupational Safety and Health have also carried out an interesting study into the effects of noise in the restoration of ancient monuments. This is reported in *Achieving better safety and health in construction* (2004), European Agency for Safety and Health at Work.

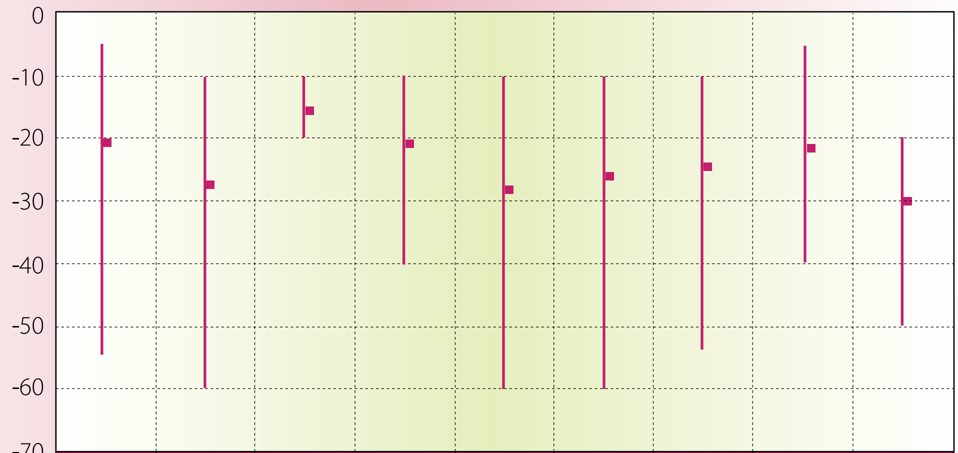
construction workers. It was realised that age and working age do affect the intensity of the occupational disease. For the average audiometry values between specialities no statistically significant difference was discovered. For the analysis purposes similar groups of workers such as in noise monitoring were formed.

A particular problem faced was over the audiometries conducted on site. It was hard to reach workers in the remote tunnel construction sites, so a van was specially fitted out to allow such measurements to be carried out.

Noise measurements per speciality (L_{eq})

Speciality	Min. value	Max. value	Average	N	Standard deviation	% > 85 dB
Jumbo operator	87.4	95.6	91.53	4	4.17	100
Forpoling operator	94.5	94.5	94.5	1	—	100
Vagodrill operator	86.2	86.2	86.2	1	—	100
Hammer operator	92.4	96.8	94.1	3	2.36	100
Spade operator	80.5	95.4	91.2	4	7.17	75
Loader operator	85.4	92.5	89.93	3	3.94	100
Excavator operator	96.2	96.2	96.2	1	—	100
Gunite pouring	90.5	94.8	92.65	2	3.04	100
Concrete pouring	89.8	93.4	91.87	6	1.34	100
Road paving	83.5	96.1	89.8	2	8.91	50
Rock breaker	91.3	97.9	94.67	3	3.3	100
Truck driver	81.2	95.3	88.65	4	5.95	75
Charging and blasting workers	95.8	98.6	97.2	2	1.98	100
Other earthworks	84.7	97.9	91.3	2	9.33	50
Concrete vibrator	85.4	94	88.28	4	3.88	100
Total	80.5	98.6	91.54	42	4.62	90.5

Audiometry results by group of speciality



	Operators	Pouring Concrete	Office workers	Engineers	Workers	Electrical	Reinforce-ment installers	Foremen	Charging and blasting
Min Audiometry value	-53	-60	-20	-40	-60	-60	-53	-40	-50
Max Audiometry value	-5	-10	-10	-10	-10	-10	-10	-5	-20
Average Audiometry value	-20,1	-27	-15,6	-20,6	-28,1	-25,2	-24,7	-21,4	-30

Audiometry frequencies based on the Merluzzi climax

Merluzzi climax	Frequency	Relative frequency (%)
0	90	73.8
1	19	15.6
2	12	9.8
3	1	0.8
Total	122	100

Audiometries by average age and working average age

Merluzzi climax	Average age	St dev	Average working age	St dev
0	36.4	10.72	11.3	10.25
1	45.1	9.71	14.9	11.6
2	51.8	8.2	20.3	13.19
3	61	—	10	—
Total	39.3	11.52	12.8	11.05

Noise in schools — causes and reduction

In educational facilities people teach and people learn. This gives rise to sounds that are a nuisance, that disturb and that are perceived as noise. This is claimed to be a major stress factor by about 80 % of those teaching in schools (103).

The project 'Noise in education facilities — Causes and reduction' funded by the Federal Institute for Occupational Safety and Health in Germany dealt with this problem. Alongside a review of the actual noise situation, possibilities were investigated as to how this stress factor can be countered. The education facilities here are represented by regular schools (four primary schools and one school of the German secondary level I in the public school system), their teaching staff, male and female, and by pupils in the age groups of about 6 to 16. The rooms in which educational or training processes take place, particularly their acoustic features, play a role in the noise development. In all these schools sample classrooms were taken (N = 30) and their room-acoustic features were examined (reverberation times, speech intelligibility index). In addition all the noise-related events in 565 teaching periods in the first to 10th years were registered by, in each case, two observers; at the same time the intensity of the noises arising in the teaching-learning process were continuously recorded using sound level measuring instruments.

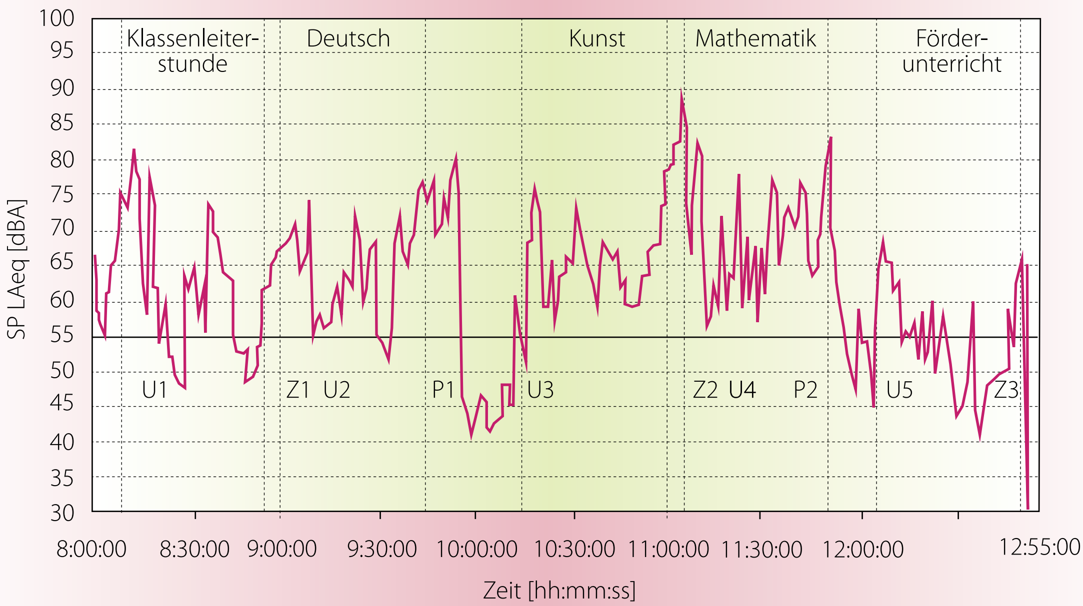
Noise arising in education institutions only rarely attains the high intensity that can result in hearing damage after many years of exposure. A rating level (the average noise level during working time) of 85 dB(A) and above was not found in this study, although findings obtained in woodwork and metalwork shops in occupational training facilities show that intensity levels can arise occasionally in education facilities; but they are not the rule. Rather it is 'noise of medium intensity' which teachers perceive as disturbing in work situations and which has to be classified as stress inducing. It contributes to the stress spectrum for people working in education institutions and hinders them in the optimum performance of their tasks (104).

(103) This information is based on an article, 'Noise situation in educational facilities', Schönwälder, H. G., Berndt, J., Ströver, F., Tiesler, G., BAuA.

(104) See also: *Los niveles acústicos durante el horario laboral y las disfonías en los docentes*, Ms Josefa Ruiz Figueroa, Francisco Bernier Herrera, Ester Carrasco Pavon, Francisco J. Gómez López, Centro Nacional de Medios de Protección, INSHT, Delgación de la Consejeria de Educación y Ciencia de la Junta de Andalucía en Sevilla, 2001 at: http://www.mtas.es/Insht/research/PruizNJ2.htm

In this study average sound levels of between 60 and 85 dB(A) were measured in schools during teaching. These are sound levels partly surpassing by a factor of several times the sound intensities recommended by scientists for informative activities such as office work (105). However, basic sound levels and reverberation times should be lower in rooms used for educational purposes than for other mental activities (for basic sound levels by 30–45 dB(A)) and for reverberation times (by 0.4 seconds). The crucial fact is that education processes are often mainly based on the medium of verbal-auditive communication, on speaking (informing and explaining) and on listening (understanding and processing). It is this medium that is impaired most or even partly rendered ineffective by interfering noises.

Portable noise measurements per speciality group



The graph above illustrates a day profile of sound level in a first year class. Key:

- *Klassenleiterstunde — Class teacher period,*
- *Deutsch — German,*
- *Kunst — Art,*
- *Mathematik — Mathematics,*
- *Förderunterricht — Special instruction.*

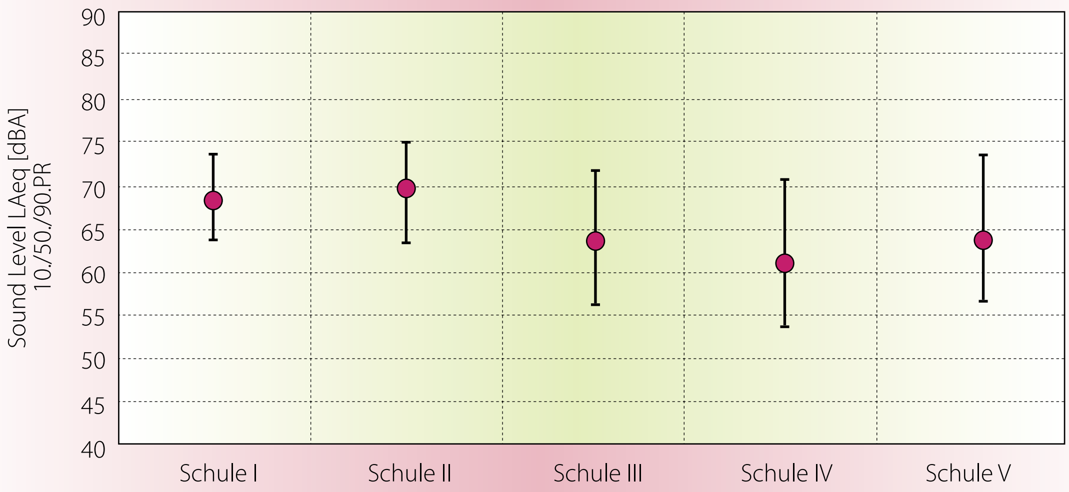
The faultless transfer of information assumes optimum room-acoustic conditions. These are assessed on the basis of the reverberation time of sound signals and the speech intelligibility of spoken texts, calculated as the speech intelligibility index (STI). Deficient room acoustics quickly lead to a rise in the noise level due to the insufficient absorption of interfering noises and to speakers trying to avoid errors of comprehension by raising their voices.

The consequences are defective communication, interference with cognitive processes, greater effort of speech, raised stress perception and hence, ultimately, exhaustion. The results of teaching and learning are impaired. Defective room acoustics were encountered in the majority of the 30 classrooms examined in five schools in Bremen and North Rhine-Westphalia.

(105) Sust, C., and Lazarus, H., Auswirkungen von Geräuschen mittlerer Intensität in Schule, Aus- und Weiterbildung (Hrsg.): Bundesanstalt für Arbeitsschutz und Arbeitsmedizin; Arbeitswissenschaftliche Erkenntnisse, 103. Dortmund: NW-Verlag 1997.

The observations made in the present study suggest a clear age dependence of the intensity of noises in lessons within the age range examined of 6 to 16: younger age groups are louder than the older ones. For the adolescent group it can be assumed that their attention is directed more towards the learning process than is the case with those who have just started school, a part of whose energy (including their vocal energy) is devoted to assertion in the learning group (pecking order). The effects of the social behaviour of pupils and of the noise level they help to cause on learning processes can be estimated ([106]).

Effects on the noise situation in a learning or working group were made clear by the finding obtained in the primary schools involved in this study; the staff here differ very much in the way they handle behavioural problems.



The graph above shows the average sound level in all lessons observed in the schools involved in the study. The circles identify the median values, the beams downwards the 10th percentile, and upwards beams, the 90th percentile. The schools I, II, III and V are primary schools, school IV is a central secondary level I school

Here the 'quiet' schools (III and V), which concentrate on the 'learning of social behaviour' from the first day at school are in contrast to the 'loud' schools (I and II), where there is no uniformly applied approach to behaviour control (including 'noisy' behaviour). Because of the limited number of classes observed, the conclusion is illustrative.

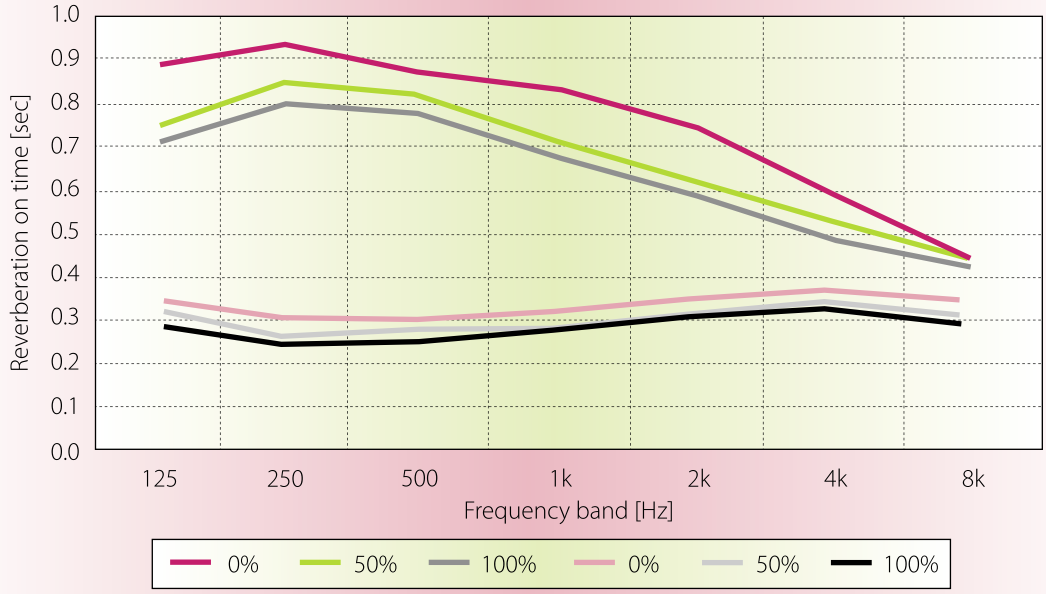
The structural and 'pedagogical' intervention measures taken in the study show the effects both of the room acoustics on behaviour and the significance of modified behaviour for the noise situation in lessons.

Improvement of room acoustics

The refurbishment measures taken on the acoustics in three classrooms testify to the improvement of the reverberation time and speech intelligibility in a number of ways. The reverberation times measured in these rooms before the refurbishment did not even satisfy the requirements of the old standard ([107]), whereas after refurbishment they even met the conditions for the integrative schooling of children with impaired hearing.

([106]) Schick, A., Klatte, M., Meis, M., Nocke, C. (eds), *Hören in Schulen*. Ergebnisse des 9. Oldenburger Symposiums zur psychologischen Akustik, Oldenburg: Bibliotheks- und Informationssystem der Universität Oldenburg, 2003.

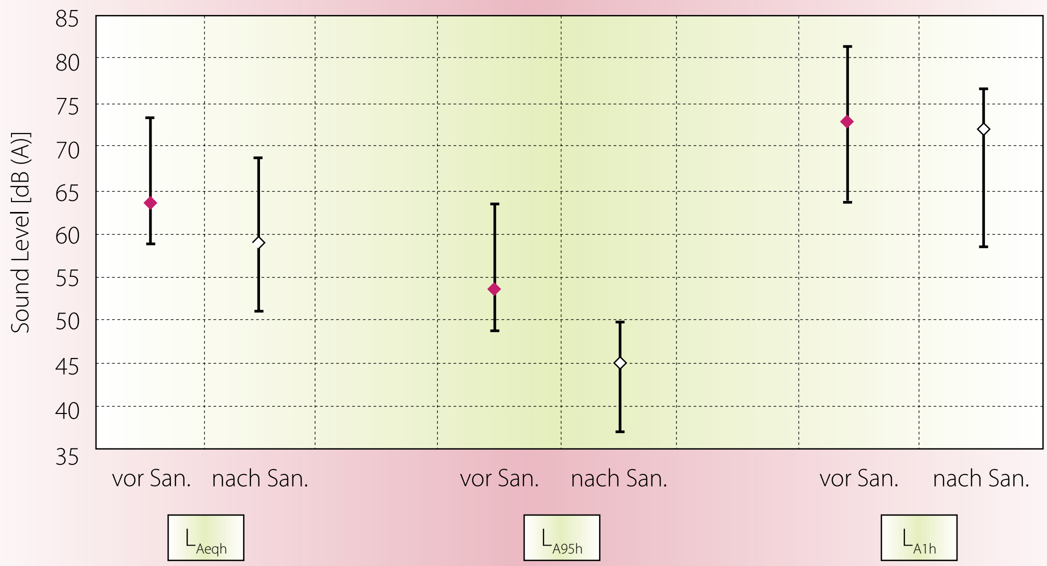
([107]) DIN 18041: Hörsamkeit in kleinen bis mittelgroßen Räumen, 1968-10 Neufassung: 2004–05.



Reverberation times before and after the refurbishment of class C

As a consequence the speech intelligibility is rated as 'very good' in the form of the calculated STI after refurbishment in all three rooms, in contrast to 'satisfactory' previously.

The improvement in sound absorption in the classroom means in physical terms a reduction of the sound level by a maximum of 3 dB(A); that the reduction actually measured of 6 to 8 dB(A) is due to the interaction between the improvement in speech intelligibility and the resulting social conduct of the pupils. 'If everything is quiet, I don't need to speak so loudly', say students. 'I have the feeling that I'm standing in front of a new class', claimed one teacher after moving into the refurbished classroom. By this she did not mean the classroom, but the pupils.



Sound levels in lessons before and after refurbishment in class — median values (diamonds), 10th (bar downwards) and 90th percentiles (bar upwards)

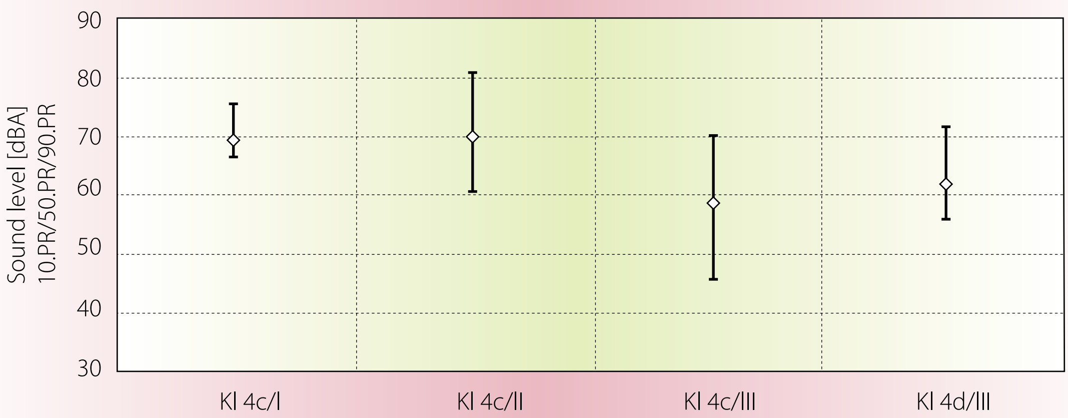
The refurbishment examples make clear how important good room acoustics are for the noise situation during lessons. In the 'loud' school there is a reduction in the average sound level in lessons of about 6 dB(A), while in the 'quiet' school the reduction is only approximately 3 dB(A). In both schools, however, the basic noise level drops by about 6 dB(A), which contributes to a substantial improvement in the signal-to-noise ratio.

Pedagogical intervention to reduce noise

The background noise levels in nearly all lessons were much more than 30–40 dB(A), which were those given as recommended maxima for mental work related to imparting information, for example in classrooms ([108]). Once again the principle is 'the quieter the better'. In terms of the demands involved, classroom teaching must be classified as a highly difficult cognitive activity both for pupils and for teachers. The noise levels we measured during lessons must therefore normally be described as too high. Clear differences were ascertained between individual lessons, schools and, not least, even between individual schools with similar room acoustics.

Pedagogical approaches to noise reduction

The primary school III, described as 'quiet', fulfils a certain model function. In a forward-looking extended project (integration of pupils with special needs; integration of pupils with foreign mother tongue and from other cultures), the educationally very active and committed staff there developed and introduced, together with the headmaster, a systematic behavioural training with new school entrants and began this years ago.



Classroom teaching sound levels in four fourth year classes from three primary schools. Median values (diamonds), 10th (bars downwards) and 90th percentiles (bars upwards)

The approach works with visual and acoustic signals and with controlling behavioural rituals, which are practised with the pupils and are applied and maintained by all members of staff. A major portion of these rules, which were introduced on entry into the schools and then continuously practised, is concerned with noise reduction or noise avoidance.

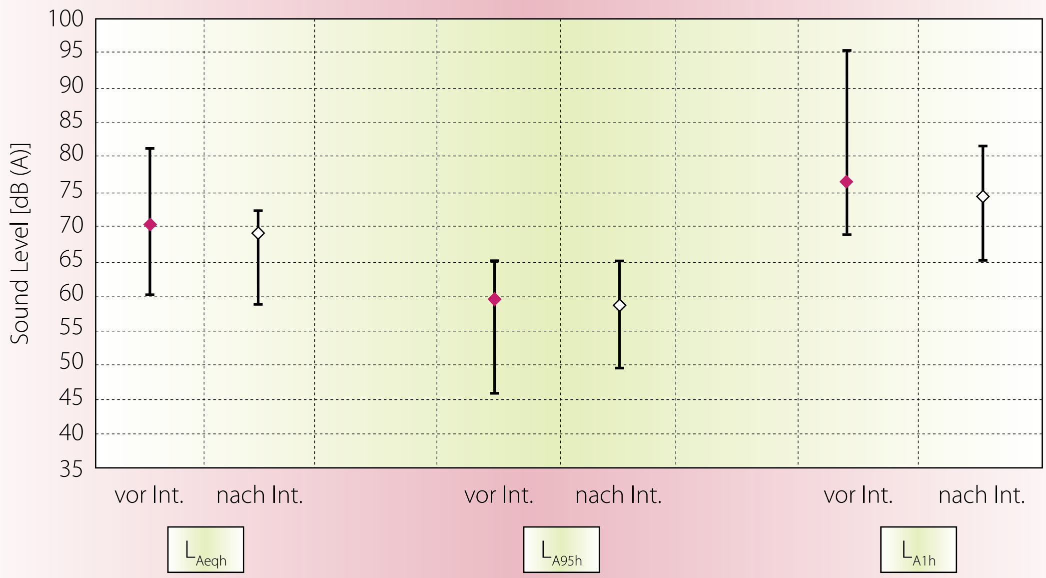
The same applies to a primary school in a neighbouring federal State (school V), where a strikingly low noise level was measured despite unfavourable room-acoustic conditions in the only class observed. Observation of lessons and questioning revealed that in this class systematic training of noise-avoiding modes of behaviour was conducted during the lesson. In this class the noise level was so low that it was tacitly feared the sound refurbishment instigated because of the room-acoustic conditions would bring about hardly any change or

([108]) DIN EN ISO 11690, Teil 1: Akustik — Richtlinien für die Gestaltung lärmarmer maschinenbestückter Arbeitsstätten; Teil 1: Allgemeine Grundlagen; Berlin, Beuth Verlag, 1997.

no change at all in the noise situation during lessons. This expectation was refuted; even under these conditions the refurbishment led to a clearly evident improvement not only in the room-acoustic data, but also in the sound level during lessons.

Noise reduction through education and optical indication of noise level

A further test of the 'pedagogical' influence on the noise situation during lessons was conducted in two classes of the second and fourth years in primary school II: this school is conspicuous because of its relatively high noise level; here an external test leader dealt with the subject of 'ear and hearing' in a teaching unit of five periods in each case. Rules for noise avoidance were agreed and practised; this also included the proper reaction to an indication of the sound level by the SoundEar ([109]) introduced as a signal transmitter. At the end of each hour a reward was given if the behaviour aimed at and agreed was kept to. Before and after this teaching experiment the teaching was observed in both classes for a week and during the lessons the sound level was recorded continuously. The procedure was agreed in consultation with the teachers.



Sound level in lessons (average, minimum and peak values) before and after implementation of the intervention project — median (diamonds), 10th (bars downwards) and 90th percentiles. Class E (fourth year)

This intervention test also had a noise-reducing effect, but it was very small in one of the two classes. This was attributed to the short time for the test, to its late implementation years after school entry and to the fact that the cooperation of the respective teacher was ensured, but not that of the whole staff.

Significance of the intervention measures

Four different noise reduction measures were monitored with the methods used in the project (continuous recording of sound level, observation of lessons) over one week before and after their implementation:

- acoustic refurbishment of two classrooms;
- long-term pedagogical intervention to reduce noise;
- long-term pedagogical intervention plus room refurbishment;
- education, practice of rules, optical signal transmission by the 'SoundEar'.

([109]) This device works on the traffic light principle with the signal colours green, amber and red, which are changed as a function of the sound level in the classroom; the switching thresholds can be freely selected.

For all four measures noise reduction effects could be verified to differing degrees; this is understandable since all measures take effect at different points in the process of noise development and its propagation.

The most important 'noise generator' in education institutions is the human voice. If it is possible to achieve a situation where, during lessons, only what has to be said is said and quietly, then the teaching noises decline in frequency and intensity.

Here is where the pedagogical (more accurately, social-pedagogical) approaches of the two 'quiet' primary schools take effect. Pupils learn only to speak when it is required and then only quietly; teachers react to this because they can also speak more quietly. In both schools it gets quieter: the noise reduction already sets in the phase of noise emergence. It has an effect even if the room-acoustic conditions are not ideal.

The noises produced by speech only last a few seconds. They persist for longer if their 'reverberation' continues beyond the necessary degree because they are not absorbed, but are reflected by the surfaces and the ceiling in the room. What is spoken encounters the remains of what is still in the room from what was said previously. The reaction is that speaking becomes a little louder and then even louder. There thus arises a higher sound level in a 'reverberating' room with longer reverberation time than in a sound-insulated room with a much shorter reverberation time. At this point the 'room-acoustic refurbishment' comes into play; it prevents traces of the noise that has already developed from remaining for a disproportionately long time and then building up on the way described. It is not necessary to boost the speaking volume. This effect was observed directly in school V: during teaching what was happening in the lesson in all classrooms could clearly be followed from the corridor; only from the refurbished classroom it was not possible to hear anything of the lesson in progress.

When both measures coincide, it can be expected that there will be a reinforcement of the individual effects. This was confirmed in school V, which was one of the 'quiet' primary schools from the beginning, and in which it was possible to reduce the noise level again during lessons after the classroom concerned had been refurbished. In terms of 'teaching acoustics' it would therefore certainly be necessary to recommend that both measures be applied simultaneously.

Whether the pupils have learned to be quiet or not, both adults and younger users of education institutions and those employed there only avoid the great effort of having to speak loudly and the problem of restricted speech intelligibility by optimised room acoustics. Improved acoustics in the teaching environment help ensure that errors and shortcomings in the teaching/learning process are avoided. They make possible:

- improved information transfer;
- less interference with cognitive processes;
- lower strain on the teacher's voice;
- reduced fatigue;
- enhanced attentiveness.

The requirement that can be concluded from this must be to integrate the room acoustics early in the planning stage of rooms for educational institutions. If this is done from the beginning, there will be little extra cost for an acoustically optimised learning environment. There are similar circumstances regarding general structural refurbishment. Higher costs are incurred when acoustically absorptive surfaces have to be installed as a separate action.

The behavioural attitudes that pupils bring into the school and into lessons are a further variable in the process of noise generation. This would suggest that younger pupils produce more noise and older ones less. Although not recorded in detail, some characteristic features of different schools are striking. School V, which is 'quiet' despite unfavourable room acoustics, is located in a solid middle-class/academically dominated urban district in a small Westphalian town. The location of the 'quiet' school III in Bremen can certainly be described difficult in social terms (a so-called 'hotbed' school), but the composition of the student body displays perceptible differences from the 'louder' school II that has similar conditions in terms of structure and room acoustics.

By measuring sound levels, it is possible to allocate the terms loud and quiet, but this feature depends not only on room-acoustic parameters and the social-pedagogical skill of teachers. When pupils come from very different ethnic origins (including those exhibiting different noise patterns), cultures and language areas, when they form ethnically defined groups which are in competition and conflict with one another, it will probably be difficult to interest them in noise and to motivate them to adopt noise-reducing modes of behaviour. It may be that teachers then have to apply mainly disciplinary measures; this should not be underestimated under such conditions.

Noise and stress for teachers

Lessons are a common working situation for learners and teachers. High basic sound level demands from teachers at least a raised vocal volume through to shouting. One concern here, but not the only one, is irritation of teachers' vocal chords: higher sound levels during lessons also signal disturbed communication, require corrective reactions (disciplining) and deflect attention away from the actual goals of the lesson.

Disproportionate and avoidable ambient sound is a stressor. This can be verified by objective measurement as well as by verbal statements based on subjective perception. How this stressor acts depends on the physical properties of the sound (such as its intensity or frequency), on the conditions of the situation in which it arises and on the noise sensitivity of the people making the judgment. If it has a sufficiently high and enduring intensity (rating level of 80 dB(A) and above), the risk of hearing damage is demonstrated. But even at low intensity typical stress reactions are demonstrated on a physiological level (e.g. reactions of the cardiovascular system or the hormone system).

What is more difficult to classify is the 'noise of medium intensity' such as is characteristic of education institutions. A direct effect, for example on bodily organs and systems, can normally be discounted; this noise tends to act more on people's mental processes. It is perceived, interferes with the intake and processing of 'more important' sound events, i.e. ones more significant for people, and it hinders (or completely prevents) understanding of such sound events. It annoys, places a burden on the processes of attention control, renders concentration more difficult and may prevent relaxation and sleep. People who experience such noise in situations requiring concentration and attention feel they are no longer up to the demands they would be able to cope with under different conditions. They react with irritation, anger and annoyance. The 'stress hormones' (adrenalin and noradrenalin, cortisol) are produced in greater quantities; blood pressure and the frequency of the heartbeat rise, the organism's level of excitation increases. It becomes more difficult and more strenuous to fulfil requirements, and fatigue processes intensify the problem.

Even so, it would be difficult or impossible to prove that 'noise of medium intensity' makes people 'sick' if one considers these stressors alone. But if one considers that many other stress-inducing factors are operative simultaneously in educational institutions (conspicuous behaviour, learning difficulties, lack of a sense of responsibility, problems with willingness to work and make an effort, and much more), then the phenomenon of 'noise' contributes to the exposure and stress on teachers together with such causes; it is responsible with other factors for the fact that education institutions cannot fulfil their mission in the way that can be expected of them. Premature wear, including burnout, which may end in leaving the profession can be explained among other things by high noise exposure.

Noise as one among many stress factors plays a special role in that it is named by many teachers as a stress factor and at the same time methods are known by which it can be successfully combated. 'Pedagogical' noise control is also free and would not only make it easier for teachers to concentrate on the more important aspects of their mission, but also create improved learning conditions for pupils. High sound levels are present to a disproportionate extent in educational institutions, and they are avoidable, as the present study has shown. The fact that successful refurbishment of the room-acoustic situation and its effect on the behaviour of pupils is perceived is documented by comments from teachers. The latter would 'prefer to teach only such classes' and they feel as though they are 'standing in front of a new class'.

Adult education institutions

When adult education institutions are being discussed, the institutions concerned are mostly evening institutes, academies, vocational colleges, universities, or institutions for political or vocational further and in-service training. Such institutions have a lot in common with schools: there are teachers (professors, lecturers, trainers, master craftsmen or simply: qualified specialists) who work in the field in which the institutions operate, who have special skills, and there are the learners (e.g. students, pupils, apprentices), who want to gain qualifications in this field.

In such institutions, speaking and understanding speech as the medium of the teaching-learning process again plays a central role. To this extent the standards for ergonomic (including acoustic) features of the teaching-learning environment are similar to those in schools. In all probability the requirements for reverberation times and speech intelligibility have to be interpreted somewhat less strictly because the adult brain has many routines to fill in gaps in speech comprehension; because adults are aware of their own shortcomings in learning processes and have learnt to handle them and because they have experience in how to develop concentration and attention.

The learning steps in the school are evidently smaller and more elementary from an adult point of view, especially for younger age groups. But for children these steps often approach the limits of comprehensibility and performance and occasionally surpass them. Measured in terms of the 'cognitive development age', the cognitive requirements for schoolchildren and adolescents in the school years appropriate to their ages are often very high. Under these circumstances the requirements for the learning conditions must also be very high. While adults can improvise, children and adolescents are less capable of doing so, and the younger they are the less capable they are of improvising. Furthermore, in schools (of the conventional kind) the subjects to be learnt are set, not freely chosen. Children and adolescents are intrinsically motivated to learn by virtue of their curiosity, and their emotionally and intellectually stimulated interest; but they are motivated in real terms by pressure and compulsion, by reward and the promise of reward.

Adults involved in institutionalised educational processes are in a fundamentally different situation from that of children and adolescents. They have often chosen to study, and are subsequently more motivated by goals they hope to achieve with a successful education phase and by the insight that they have acquired in the relationship between educational processes and life competence. But this is only true in an 'ideal' world where people have the choice from a wide range of alternatives and it assumes creativity, the willingness to work hard, a sense of responsibility and willingness to cooperate — things also lacking in many adults.

For both adults and younger students, noise can hinder the learning processes. Many adults know this and try to create a noise-free environment in learning situations. Children first have to recognise this relationship, and since they are often the ones (as a group) who make the noise for the reasons mentioned, they also have to learn how to behave without generating a lot of noise. If this process is not stimulated and initiated by adults, it can take years, years of less effective learning. Even many students who are young adults seem not yet to understand that the lecturer can only speak when they have stopped.

It would be possible to take other examples than that of noise to show the ergonomic problems arising in 'informative' or 'mental' work, or in processes of education and training. Complaints about noise in educational institutions are often heard, and they are increasing in our world as it gets steadily louder. A lot less is said or written about the poor quality of classroom chairs (as compared with the ergonomically optimised, multiple-positioning, gas-sprung office chairs at desks and computer workstations for adults), about poorly ventilated classrooms as compared with ideally air-conditioned offices. The ergonomics of educational institutions, which was an important subject of scientific study in the 19th century under the heading of 'school hygiene', has become a forgotten subject, along with many of its still-valid results and insights.

Bibliography

Schönwälder, H. G., J. Berndt, F. Ströver, G. Tiesler, *Belastung und Beanspruchung von Lehrerinnen und Lehrern*, Publication series of the BAuA, Fb 989, NW-Verlag Bremerhaven, 2003.

Schönwälder, H. G., J. Berndt, F. Ströver, G. Tiesler, Lärm in Bildungsstätten — Ursachen und Minderung, Publication series of the BAuA, Fb 1030, NW-Verlag Bremerhaven, 2004.

Burgerstein, L. und A. Netolitzky, Handbuch der Schulhygiene, second edition, Verlag Gustav Fischer, Jena, 1902.

Noise protection for orchestra musicians

The 2003 noise directive generally relates to all workers, however Article 14 of the directive explicitly addresses employees in the music and entertainment sector.

With respect to the insulating effect of ear protection, the directive demands adherence to the limit of 87 dB(A) for the daily noise exposure level (with the possibility of using a weekly exposure level where there are strong fluctuations in the sound level). The implementation of this directive is a challenge for orchestras because the classical concepts of noise protection are not applicable. A noise reduction at the source is of only limited use, wearing hearing protection might make it impossible to play. There is no obvious solution to avoid the temporary high sound exposure and to guarantee an utmost artistic expression at the same time. Only with a combination of various measures for sound reduction can a practical solution be found that implements the 2003 noise directive and protects musicians' hearing.

There are different studies on the sound pressure level to which orchestra musicians are exposed ([110]). There is agreement on the sound pressure level of various instruments, however differences arise in the measurements within orchestras and the exposure times. Since the measurement results strongly depend on the work performed, its musical interpretation, and the location in which it is performed, it is always difficult to arrive at valid conclusions about the level of exposure on the basis of these specific single measurements. A differentiated approach is necessary in order to identify hearing damaging sound levels.

The highest exposure can be found among percussionists, wind instruments (brass and wood) and for those musicians who are positioned in front of these instruments. Lower exposures can be typically found for bass and cello players and for the conductor. Their own instrument causes a large part of the sound pressure levels to which musicians are exposed. The other instruments and reflection from the walls raise the individual dose of noise exposure by 3 dB. Despite this, most musicians are of the opinion that it is their neighbouring colleagues who cause the greatest risk. With the exception of percussion and piccolo flute, the sound level of one's own instrument is perceived as comfortable. Some instruments like the violin, the viola, the harp and the cornet create an asymmetrical exposure with a difference of 3–8 dB between both ears. Even solo singers experience an exposure of between 87 dB (bass) and 109 dB (alto).

Due to the limited space, the typical architecture and the lack of variation in the repertoire one can expect the sound level in the orchestra pit to be some decibels higher as compared with a stage.

Exposure by instrument group

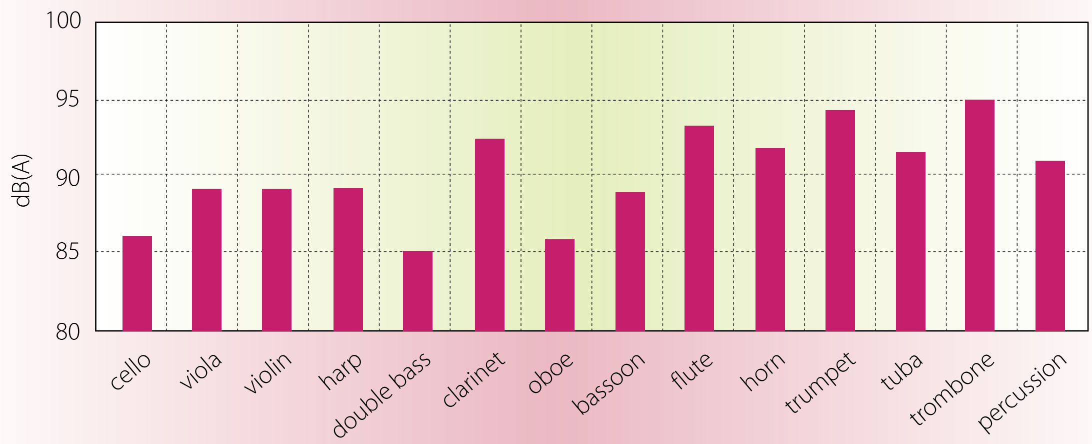
Instrument group	Average (dB(A))	Maximum (dB(A))
Percussion	93	130
Brass instruments	93	108–123
Woodwind instruments	93	102–117
Violin, viola	89	98–111
Cello, bass	87	—
Choir	92	—
Conductor	84	106–110

All studies so far have shown that the average sound pressure level during the work time of musicians of symphony or opera orchestras is between 80 and 100 dB(A) with maximum levels of 110 to 130 dB(A). Thus

([110]) For example: *El ruido y los músicos de la orquesta sinfónica*, Pilar Cáceres Armendáriz, Jerónimo García González, Centro Nacional de Medios de Protección, INSHT, 2001 at: http://www.mtas.es/Insht/research/PCaceresP.htm there is no question; orchestra musicians are exposed to sound pressure levels in their daily work that can cause hearing damage.

Since musicians are not permanently exposed to the maximum sound level, there are phases of recuperation counteracting permanent hearing damage. However, recovering from temporary hearing loss is an exponential process and therefore needs long periods of time in which noise exposure has to be avoided, and musicians are exposed to noise outside their orchestra work due to activities such as practice, teaching, and playing in smaller ensembles. The exposition times within the framework of performances and practice are typically 15 to 25 hours a week, followed by 10 to 15 hours of sound exposition due to individual practice and teaching. On this basis, depending on the instruments, a weekly and yearly exposition level of 85 to 95 dB(A) was calculated.

Weekly exposure level of orchestra musicians



This figure is taken from T. Billeter, B. Hohmann from Suva/Swiss, Gehörbelastung bei Orchestermusikern, Fortschritte der Akustik 27 (2001), pp. 386–387

Even though the individual sound exposure of the musician is hard to predict, it is safe to say that the daily and weekly exposition limits of the 2003 noise directive cannot be adhered to in many cases. This results in a requirement for employers and musicians to reduce the sound exposition.

There are possibilities for a noise reduction by organisational measures, through technical and architectural measures and by using hearing protection.

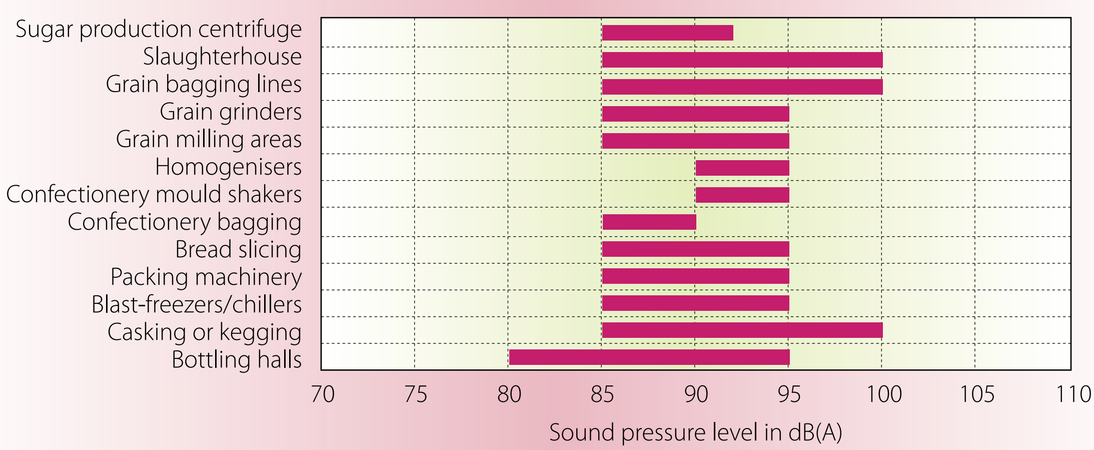
- Work schedules can be planned according to the repertoire and the sound exposure and recuperation phases can be built in.
- It may be possible to avoid locally excessive high sound levels by positioning the orchestra in a different way.
- The design of stages with high and deep steps widens the space between the musicians and reduces the noise exposure.
- Broadband absorbers can improve the cramped and often acoustically poor designs of orchestra pits.
- The balustrade can be designed to be open for sound.
- Increasing the size of the practice rooms (>17m^3 per person) and installing proper absorption can also lower the sound level.
- Good acoustic design with absorbers and reflectors improves the perception of the music, leading to a more sophisticated sound and a lower sound level.

Even for musicians the last mean for noise protection is personal hearing protection. Modern, tailor-made otoplastics with membrane filters (Elacin) show a linear insulation across frequencies and allow the hearing of music without changing the sound characteristics. However, there is an increase in the perception of boneborne noise caused by the closure of the auditory canal (occlusion effect), which changes the perception of one's own instrument. This effect is the main hindrance for using hearing protection while playing music and is especially difficult for wind instruments.

When putting in place sound protection measures it needs to be remembered that orchestras face considerable time and cost pressures. Constructional measures usually allow a reduction of the sound exposure of the musicians without negatively influencing the sound characteristics. They should be kept in mind especially when designing new buildings or renovating old ones. Personal hearing protection for musicians can only be the last resort in specific situations. Its use needs long-term practice and expert advice, and should therefore already be part of the musician's training. Next to information and training, audiometric examination should be used in order to diagnose hearing damage early enough to be able to counteract it.

Removing glass jars from pallets

Noise levels in food and drink manufacture



Food and drink production can be a noisy process. Whether abattoirs, beer bottling plants, or bakeries, there are many potential sources of noise ([111]). In one food-processing factory, jars were unstacked by hand onto cardboard covered sheets before being transported by conveyor to the filling line via a narrow passageway. In addition to being subjected to physical and postural stresses likely to lead to work-related musculoskeletal disorders, workers were being exposed to loud noise levels, particularly from the impact noise from the jars.

Changing the process, and enclosing part of the process to reduce the propagation in air reduced noise exposures from 89 to 77 dB(A), a gain of 12 dB(A) at the workstation. This was achieved by carrying out various actions to attenuate the acoustic and physical stresses.

- The pushing of glass layers was mechanised, enabling the operator to stay at a distance.
- The unstacking machine and the conveyer were enclosed.
- The conveyer was split up into several components for which the rate of travel can be adjusted, enabling impacts between jars to be reduced.

([111]) Health and Safety Executive, Food information sheet, 32.

Quiet nightclubs

The prevention of risks to workers from noise in the entertainment sector is a challenging task. Unlike in the manufacturing sector, in nightclubs and similar venues, the noise is the main attraction, rather than a by-product of the production process. A report by the Health and Safety Laboratory for the Health and Safety Executive reported that 'the [entertainment] industry has not often taken action to reduce the volume level of the music [in pubs and clubs] because of their perception for the need to maintain a commercially viable business based on a fundamental demand to provide a venue which offers loud amplified music. In addition, the design of many pubs and clubs is not conducive to effective noise control for employees ([112])'.

The report goes on to say that 'there is a definite potential for harm to employees but it is not possible to establish the number of individuals whose hearing will be impaired as a result of this noise exposure'.

The case study below, published online by the Association of Noise Consultants, examined the way in which the exposure of workers could be reduced while maintaining the attraction of load music for the clients.

The venue under consideration has two clubs in one building. Club 1 caters for the younger age group of 18 to 24-year-olds, whilst Club 2 is for the over 24-year-olds. The first club is located on the ground floor with a mezzanine floor overlooking the dance floor. The second club is at first floor level. Club 1 has four bars and Club 2 only one.

An ideal opportunity presented itself for introducing noise reduction measures in the form of a complete refit. Periodically all clubs refurbish their internal finishes and décor, which takes a lot of wear and tear in normal or perhaps abnormal usage. In this case we were almost given a free hand to introduce as much noise control as the refurbishment budget would allow.

A full noise survey was carried out on the site, displaying some high exposure levels, particularly for bar staff and glass collectors. The venue has some added problems all of which are exacerbated by lack of space — one bar being located only two paces from the dance floor. This nearness of bars to the dance floors was common to all five bars. Even worse, the cloakroom for Club 2 was equally close to the dance floor. The concept of a 'quiet area' would be impossible to realise in such a small venue.

The two clubs, whilst small, had little acoustic absorption in them apart from people and had mid frequency reverberation times of about one second. The effect of this was to produce high reverberant sound pressure levels and little apparent attenuation with distance. A by-product was that the music system did not sound particularly good. This is a not uncommon feature of nightclubs.

The actions taken to reduce noise exposures included the following.

In Club 2:

- movement of the cloakroom and paydesk to the club entrance, separated from the dance floor by a wall;

([112]) Health and Safety Laboratory, *Research report*, 26, 'Noise levels and noise exposure of workers in pubs and clubs — a review of the literature', 2002.

- movement of the bar further away from the dance floor;
- reorientation of the loudspeakers to point away from the new bar;
- facing the ceiling with acoustically absorbent material;
- coverage of as much of the walls as possible with acoustic-absorbent material faced with a purple cloth;
- the bass bins (speakers) put on vibration isolation mounts and are direct radiators. The mounts prevent the low frequency energy entering the structure and producing unpleasant buzzing and rattling;
- the bar opening is kept to the minimum commensurate with operational requirements.

In Club 1:

- the wall areas out of reach of the clientele were finished with a sprayed acoustic absorber;
- some wall areas and ceilings under the bars were finished with mineral wool behind galvanised perforated sheet steel. This is an unusual finish but just happened to meet with the approval of the interior designer;
- a large glass screen was introduced in front of Bar 1 at the side of the stairs to screen the bar from the dance floor;
- the disc jockey (DJ) console was built as an acoustic screen to provide some screening to Bar 2;
- the sound system was based on downward facing loudspeakers with narrow directivity patterns. The basic idea is to direct the sound only onto the dance floor with as little overspill as possible;
- as with Club 1, the bass bins were mounted on vibration isolation mounts in dummy cabinets at dance floor level.

Following the actions, the sound systems were set up and tested using the type of music preferred and played in the clubs. The system was set to produce a typical music level of 103 dB(A) L_{eq} on the dance floor and carefully equalised. The result was a loud but very crisp and clear sound. Subjectively the DJs felt it sounded much louder than it actually was and this was due to the much reduced reverberation time of about 0.3 seconds at mid-frequency. Following the reopening of the club, a further sound survey was carried out to assess the results.

Noise exposure of nightclub workers ($L_{EP,d}$)

Location	Exposure before the action	Exposure after the action
Club 1		
Cashier	69.6	72.1
Cloakroom attendant	69.6	72.1
Worker in diner	85.8	86.3
Worker in Bar 1	93.7	86.6
DJ	98.6	98.2
Worker in Bar 2	90.3	89
Worker in Bar 3	95.5	88.4
Glass collector, ground floor	96.3	96.8
Worker in Bar 4	93.2	89.1
Glass collector, Bar 4	95.2	94.5
Club 2		
Glass collector, Bar 5	98.1	97
Worker in Bar 5	95.9	86.9
DJ	99.8	97.3
Doormen between the two clubs	86.5	86.5
Cashier	76.6	77.5
Cloakroom attendant	95.3	73.7

The only workers who now have exposures above the second action level are the glass collectors and the DJs. The glass collectors are perfectly able to wear hearing protection in the form of earplugs since their job does not involve communication.

The exposure of DJs is problematic, as their high exposure comes from the 'monitor' loudspeaker. Given the closeness of the DJs to the dance floor these monitor loudspeakers are totally unnecessary, but are viewed as essential by the DJs themselves.

From the clientele point of view the sound system is very good and they do not have to scream at the bar staff in order to get a drink. The level on the dance floor was 103 dB(A) L_{eq} which fell to 89 dB(A) L_{eq} behind Bar 3. In physically larger venues the same techniques are even more effective and easier to put in place. These basic measures can be designed into new nightclubs and retrofitted to most clubs undergoing a refurbishment.

Case study — DJ suffers hearing damage

A 24-year-old DJ suffered permanent hearing loss through exposure to loud music. He said 'One night in particular I was DJ-ing in a club where the sound system was particularly loud: that night I went home with a ringing sensation so bad that it took my ears several days to get back to normal. In one ear, the ringing has never completely stopped. Nowadays I am very sensitive to loud music (particularly high/treble frequencies) and the mild tinnitus I have normally increases dramatically if I expose myself to loud music. This can cause some problems for me as I work in a recording studio. I very rarely DJ these days, but if I do I am careful to wear earplugs (113).'

Noise control programme for broadcasting company personnel

Leisure noise exposure is a growing problem, which is typically associated with noisy hobbies, rock concerts, discothèques, and music clubs. In addition to the exposure of public there has been growing interest in musicians' hearing-related occupational health problems. As well as the artists, technical staff and the production team of the broadcasting companies may be exposed to high noise levels. They talk extensively during events using electronic devices. For good communication, a signal to noise ratio of 5–15 dB is typically required. As a result the sound level of the communication device may exceed the ambient noise level. Headphones do not provide a good attenuation of ambient noise. Also earmuffs with communication electronics can be used. They attenuate the ambient noise level, but still for good communication the signal has to exceed the ambient noise level.

Workers' concern over their noise exposure was due to:

- an increase in the sound levels to which they were exposed, particularly at sports events;
- a recognition that employees' working hours and hence exposure times are long, with production sometimes starting before noon and ending after midnight. The team is exposed to noise most of the time during rehearsals, sound checks and actual performance. For example, in rock festivals exposure time of production crews is much longer than that of any other group including performers or audience;
- the complicating factor that noise exposure is due both to the ambient noise and noise from the communication systems.

According to Finnish legislation, in concerts the average noise level of four hours must not exceed 100 dB. Also L_{FAmax} must not exceed 115 dB. The measurement location must be selected in such a way that the exposure of 95 % of the audience is smaller than the exposure at measurement location.

According to the 2003 noise directive, the first task is to evaluate the exposure. No one is allowed to be exposed to noise levels over 87 dB(A). If this is possible action must be taken to reduce the exposure below

(113) From: *A noise hangover*, RNID, May 2004. Part of the 'Don't lose the music' campaign.

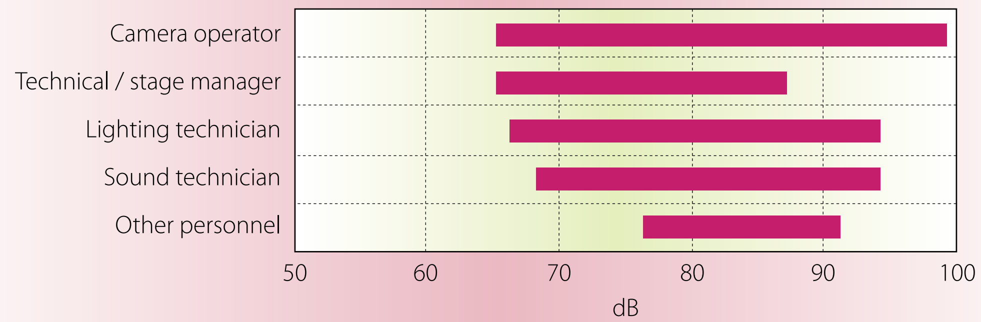
this limit. Actions to this may consist of organisational actions, reduction of noise emission of sources and use of hearing protectors. Also in exposure evaluation the noise impulsiveness, exposure to ototoxic chemical and vibration must be taken into account. All these actions are documented in a noise control programme, which also includes the information provided to the workers, and how persons in risk groups are taken into account.

Development of the noise control programme

As the noise levels were known to exceed the limit value, the task to develop a noise control programme was given to a board consisting of representatives of workers, companies, and occupational healthcare and noise control experts. The board nominated a project manager to organise the work.

The first task was to measure the exposure and inform the workers. The sound level was measured in different productions by occupation. Due to the use of communications equipment that may be contributing to noise exposure, the measuring microphone was placed at the entrance of the ear canal (so called MIRE technique) ([114]). As can be seen in the graph, the measurements daily sound exposure levels (L_{EPd}) ranged from 65 to 99 dB, and the overall average was 85 dB. The highest noise doses were observed in concerts.

Noise exposure by occupation



Exposure by type of production

Production	Average (dB)	Standard deviation (dB)	Range (dB)	Number
Concert	88	7	68–99	56
Sports	85	4	69–93	97
Other	77	7	69–86	29

Noise exposure from communication sound

The overall average of equivalent sound pressure levels (L_{Aeq}) was 81 dB (n = 48), ranging from 62 to 101 dB. The corresponding measurements from outside the communication device ranged from 69 to 105 dB, and the average was 87 dB. Daily sound exposure levels calculated from this data are presented below.

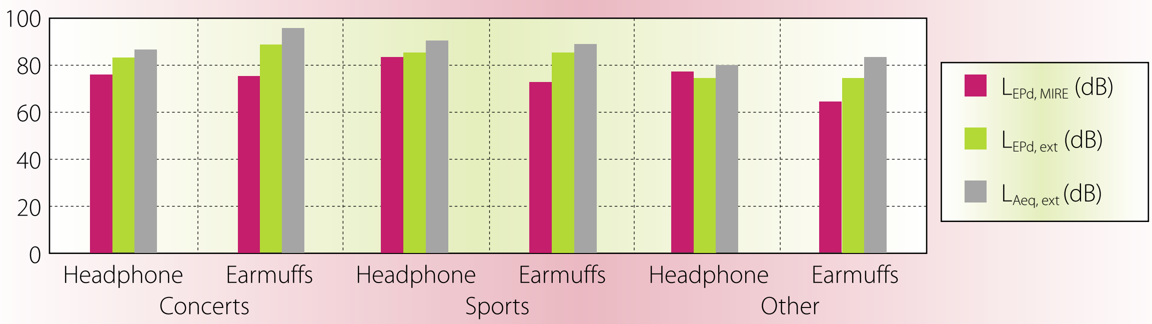
([114]) ISO 11904-1:2002 has been published which specifies basic framework measurement methods for sound emmissions from sound sources placed close to the ear. These measurements are carried out with miniature or probe microphones inserted in the ear canals of human subjects. The measured values are subsequently converted into corresponding free-field or diffuse-field levels. The results can be given as free-field-related or diffuse-field-related equivalent continuous A-weighted sound pressure levels. The technique is denoted the microphone-in-real-ear technique (MIRE technique).

Exposure by headset type

Headset type	$L_{EPd,MIRE}$ (dB)	Range (dB)	$L_{EPd,ext}$ (dB)	Number
Earmuff	73	53–92	85	29
Headphone	81	64–96	83	19
Total	76	53–96	84	49

For headphones the attenuation was, on average, 2 dB, and 11 dB for earmuffs. In addition to the type of headset, the type of the event had an effect on the attenuation of the sound. The highest attenuations were found in concerts. Calculated daily sound exposure level of nine subjects exceeded 85 dB. The subject was using a headphone type communication headset in seven of these cases.

Noise exposure by occupation



Noise control programme

The noise control programme contains information about who is responsible for maintaining and updating the programme. In this case, a board was set up to do this task. The board is responsible for follow-up of exposure, for the development of the noise control in the company, and finally for keeping the noise control programme up-to-date. The major part of the noise control programme consists of providing information to workers and introducing noise control measures The workers were already being informed about the development of the noise control programme once results became available. When the measurements were done and the noise control programme was set up, two presentations with the same contents were given to the staff.

For each broadcasting unit an information leaflet of no more than two pages was written explaining how to arrange hearing protection in different events. The hearing protection consists of suitable individual hearing protection and organisational measures.

As Finnish law regulates the ambient noise level, no additional requirements were regarded as possible. To ensure that this limit is not exceeded, the teams were equipped with sound level meters and simple instructions show how to make a fast evaluation of sound level. According to instructions the average sound level of one minute must not exceed 106 dB(A) in front of the stage and 100 dB(A) at the mixing table. In the contract with the organiser of the event, too high sound level is grounds to interrupt the recording. During the event the broadcasting team should measure the sound level according to these instructions three times.

For each type of production a recommendation for hearing protection was given. In a noisy concert a double protection consisting of communication plug and earmuff is recommended. For less noisy production earmuffs are recommended. In talk shows, headphones can be used.

The noise control board initiates new work items for improving noise control. At present such tasks are the improvement of the communication system and development of an evaluation method for non-auditory effects of noise.

6.

APPENDIXES

Appendix 1: European directives referred to in this report

- Council Directive 86/188/EEC of 12 May 1986 on the protection of workers from the risks related to exposure to noise at work
- Council Directive 89/391/EEC of 12 June 1989 on the introduction of measure to encourage improvements in the safety and health of workers at work
- Council Directive 89/656/EEC of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace
- Council Directive 89/686/EEC of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment
- Council Directive 92/85/EEC of 19 October 1992 on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding
- Council Directive 94/33/EC of 22 June 1994 on the protection of young people at work
- Directive 98/37/EC of the European Parliament and of the Council of 22 June 1998 on the approximation of the laws of the Member States relating to machinery
- Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors
- Council Directive 2000/78/EC of 27 November 2000 establishing a general framework for equal treatment in employment and occupation
- Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)

Appendix 2: Standards referred to in this report

- EN 1746:1998, Safety of machinery — Guidance for the drafting of the noise clauses of safety standards
- EN ISO 11688, Acoustics — Recommended practice for the design of low-noise machinery and equipment, Part 1: Planning (1995), Part 2: Introduction to the physics of low-noise design (2001)
- EN ISO 11200:1996, Acoustics — Noise emitted by machinery and equipment — Guidelines for the use of basic standards for the determination of emission sound pressure levels at a work station and at other specified positions
- EN ISO 3740:2000, Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards
- EN ISO 3741:1999, Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms
- EN ISO 3743-1:1995, Acoustics — Determination of sound power levels of noise sources — Engineering methods for small, movable sources in reverberant fields — Part 1: Comparison method for hard-walled test rooms
- EN ISO 3747:2000, Acoustics — Determination of sound power levels of noise sources using sound pressure — Comparison method for use *in situ*
- EN ISO 9614, Acoustics — Determination of sound power levels of noise sources using sound intensity, Part 1: Measurement at discrete points (1995), Part 2: Measurement by scanning (1996), Part 3: Precision method for measurement by scanning (2002)

- EN ISO 4871:1996, Acoustics — Declaration and verification of noise emission values of machinery and equipment
- EN ISO 11689:1996, Acoustics — Procedure for the comparison of noise emission data for machinery and equipment
- EN ISO 12001:1996, Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code
- EN ISO 11690, Acoustics — Recommended practice for the design of low-noise workplaces containing machinery, Part 1: Noise control strategies (1996), Part 2: Noise control measures (1996), Part 3: Sound propagation and noise prediction in workrooms (1997)
- EN ISO 15667:2000, Acoustics — Guidelines for noise control by enclosures and cabins
- EN ISO 11546:1995, Acoustics — Determination of sound insulation performance of enclosures — Part 1: Measurements under laboratory conditions (for declaration purposes); Part 2: Measurements *in situ* (for acceptance and verification purposes)
- EN ISO 11957:1996, Acoustics — Determination of sound insulation performance of cabins — Laboratory and *in situ* measurements
- EN ISO 11821:1997, Acoustics — Measurement of *in situ* attenuation of a removable screen
- EN ISO 14163:1998, Acoustics — Guidelines for noise control by silencers
- EN ISO 11691:1995, Acoustics — Measurement of insertion loss of ducted silencers without flow — Laboratory survey method
- EN ISO 11820:1996, Acoustics — Measurements on silencers *in situ*
- EN ISO 14257:2001, Acoustics — Measurement and parametric description of spatial sound distribution curves in workrooms for evaluation of their acoustical performance
- ISO 9612:1997, Acoustics — Guidelines for the measurement and assessment of exposure to noise in a working environment
- DIN EN 13023: 1998, Noise measurement methods for printing — Paper converting — Paper making machines and auxiliary equipment — Accuracy Categories 2 and 3
- DIN EN 13525: 1999, Forestry machinery — Wood chippers — Safety
- DIN EN 13683: 2002, Garden equipment — integrally powered shredders/chippers — Safety
- DIN EN 1553: 2000, Agricultural machinery — Agricultural self propelled, mounted, semi-mounted and trailed machines — Common safety requirements
- DIN EN 12053: 1995, Safety of industrial trucks — Test methods for measuring noise emissions
- DIN EN 13000: 1997, Cranes, safety of industrial trucks — Test methods for measuring noise emissions
- DIN EN 774: 1997, Garden equipment — Hand held, integrally powered hedge trimmers — Safety
- DIN EN 786: 2001, Garden equipment — Electrically powered walk-behind and hand-held lawn trimmers and lawn edge-trimmers
- DIN EN 836: 1997, Garden equipment — Powered lawnmowers — Safety
- DIN EN 12418: 2000, Masonry and stone cutting-off machines for job site — Safety
- DIN EN 13778: 2000, Mobile demolition machinery — Safety requirements
- DIN EN 13862: 2001, Construction equipment and building material machines — Floor sawing machines — Safety and hygiene requirements
- DIN EN 13591: 1999, Food processing machinery — Fixed deck oven loaders — safety and hygiene requirements
- DIN EN 12331: 1997, Food processing machinery — Mincing machines — Safety and hygiene requirements
- DIN EN 1265: 2000, Noise test code for foundry machines and equipment (grade 2 and 3)
- EN 12545: 1999, Footwear leather and imitation leather goods manufacture machines noise test code — Common requirements
- EN 1547: 2000, Industrial thermoprocessing equipment — Noise test code for industrial thermoprocessing equipment including ancillary handling
- DIN EN 12012: 1995, Rubber and plastics machines — Safety — Size reduction machines — Requirements for the design and construction
- DIN EN 12267: 1996, Food processing machinery — Circular saw machines — Safety and hygiene specifications

- DIN EN 12549:1999, Acoustics — Noise test code for fastener driving tools — Engineering method
- ISO 2151: 2001, Compressors and vacuum pumps — Engineering method (grade 2)
- ISO 9902: 2000, Textile machinery — Noise test code
- ISO 15744: 2002, Hand-held non-electric power tools — Noise measurement code — Engineering method (grade 2)
- ISO 6393: 2002, Acoustics — Determination of sound power level of earth-moving machinery — Stationary test conditions
- ISO 10884: 1995, Manually portable brush cutters and grass trimmers with internal combustion engine — Determination of sound power levels — Engineering method (Grade 2)
- ISO 6396: 1992, Acoustics, measurement at the operators position of noise emitted by earth-moving machinery — Dynamic test conditions
- ISO 9207: 1995, Manually portable chain saws with internal combustion engine: Determination of sound power levels — Engineering method (Grade 2)
- DIN EN 352; 1993, Hearing protectors — Safety requirements and testing
- DIN EN 458: 1994, Hearing protectors — Recommendations for selections, use, care, and maintenance — Guidance document
- EN 24869: 1992, Acoustics — Hearing protectors — Subjective method for the measurement of sound attenuation
- EN 352-1: 2002, Hearing protectors — General requirements
- EN 458: 2000, Hearing protectors — Recommendations for selection, use, care and maintenance — Guardians document
- DIN EN ISO 12100-1: 2003, Safety of machinery — Basic concepts, general principles for design, Part 1, Basic terminology, methodology
- DIN EN ISO 12100-2: 2003, Safety of machinery — Basic concepts, general principles for design: Technical principles
- DIN EN 60745-1: 2002, Safety of hand-held motor-operated electric tools — Part 1: General requirements
- DIN EN 60745-2-1: 2002, Hand-held-operated electric tools — Safety, Part 2-1: Particular requirements
- ISO 22520: 2002, Portable hand-held-forestry machines — A weighted emission sound pressure level
- DIN ISO 7731: 2002, Ergonomics — Danger signals for public and work areas — Auditory danger signals
- ISO 8201: 1987, Acoustics — Audible emergency evacuation signal
- ISO 12100-1: 1992, Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology methodology
- ISO 12100-2: 1992, Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specification
- DIN EN 1995: 1994, Eurocode 5 — Design of timber structures
- DIN EN 12100: 1997, Plastics piping system — Polyethylene (PE) valves — Test method for the resistance to bending between supports
- DIN EN 12868: 1999, Child use and care articles — Methods for determining the release of N-nitrosamines and N-nitrosatable substances from elastomer or rubber teats and soothers
- DIN EN 12348: 2000, Core drilling machines on stand — Safety
- DIN EN 12852: 2001, Food processing machinery — Food processors and blenders — Safety and hygiene requirements
- DIN EN 12855: 2004, Food processing machinery — Rotating bowl cutters — Safety and hygiene requirements
- ISO 6396: 1992, Acoustics — Measurement at the operator's position of noise emitted by earth-moving machinery — Dynamic test conditions
- DIN EN 13621: 1999, Food processing machinery — Salad dryers — Safety and hygiene requirements
- EN 13684: 2004, Garden equipment — Pedestrian controlled lawn aerators and scarifiers — Safety
- DIN EN 774: 1997, Garden equipment — Hand-held, integrally powered hedge trimmers — Safety
- ISO 1999:1990, Acoustics — Determination of occupational noise exposure and estimation of noise-induced hearing impairment

Appendix 3: Bibliography

Publications from international organisations

- *Guide to the expression of uncertainty in measurement*, International Organisation for Standardisation, First edition 1993, corrected and reprinted 1995
- 'Prevention of noise-induced hearing loss', informal consultation held at the World Health Organisation, Geneva, 28–30 October 1997 at: http://www.who.int/pbd/deafness/en/noise.pdf
- *Assessing the burden of disease from work-related hearing impairment at national and local levels*, World Health Organisation, 2004
- *Factsheet*, 258, 'Occupational and community noise', World Health Organisation, revised 2001 at: http://www.who.int/mediacentre/factsheets/fs258/en/

Publications from European organisations

European Commission

- *Position paper on guidelines for the application of the European Parliament and Council Directive 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment used outdoors*, Directorate-General for the Environment, Brussels, December 2001
- *Employment in Europe 2004*, European Commission, Employment and Social Affairs DG, ISBN 92-894-7986-8
- Communication from the Commission entitled 'Adapting for change in work and society: a new Community strategy on health and safety at work 2002–06'
- *Guidelines on assessing the risks to pregnant workers and new mothers*, European Commission, at: http://europa.eu.int/eur-lex/en/com/cnc/2000/com2000_0466en02.pdf
- *European social statistics — Accidents at work and work-related health problems*, European Commission, ISBN 92-894-3601-8

European Agency for Safety and Health at Work (115)

- *Report*, 106, 'The practical prevention of risks from dangerous substances at work', European Agency for Safety and Health at Work, 2003, ISBN 92-9191-050-3
- *Report*, 203, 'Research on work-related stress', European Agency for Safety and Health at Work, 2000, ISBN 92-828-9255-7
- *Report*, 209, 'Gender issues in safety and health at work: A review', European Agency for Safety and Health at Work, ISBN 92-9191-045-7
- *Report*, 304, 'Occupational safety and health in marketing and procurement', European Agency for Safety and Health at Work, 2000, ISBN 92-95007-01-8
- *Report*, 308, 'Recognition schemes in occupational safety and health', European Agency for Safety and Health at Work, 2002, ISBN 92-9191 011-2
- *Report*, 314, 'Achieving better safety and health in construction', European Agency for Safety and Health at Work, 2004, ISBN 92-9191-073-2
- *Report*, 402, 'The state of occupational safety and health in the European Union — A pilot study', European Agency for Safety and Health at Work, 2000, ISBN 92-95007-00-X
- *Factsheet*, 53, 'Ensuring the health and safety of workers with disabilities', European Agency for Safety and Health at Work, 2004
- *Magazine*, 5, 'Working on stress', European Agency for Safety and Health at Work, 2002, ISSN 1608-4144

(115) All publications of the European Agency for Safety and Health at Work are available for download at: http://osha.eu.int

Eurostat

- *Work and health in the EU. A statistical portrait. Data 1994–2002*, Eurostat, 2004, ISBN 92-894-7006-2.

European Foundation for the Improvement of Living and Working Conditions

- *Third European survey on working conditions 2000*, European Foundation for the Improvement of Living and Working Conditions, ISBN 92-897-0130-7

Further publications

- *Linee Guida per la Valutazione del richio rumore negli ambienti di lavoro*, L'Istituto superiore per la prevenzione e la sicurezza del lavoro (ISPESL) at: http://www.ispesl.it/linee_guida/fattore_di_rischio/rumore.htm
- *Research report*, 26, 'Noise levels and noise exposure of workers in pubs and clubs — a review of the literature', Health and Safety Laboratory, 2002
- *Experience with ISO 11200 series and possibilities of improvement*, W. Probst, Euronoise 2003, Naples, 2003
- *The revision of the EN ISO 3740 standards on sound power measurement*, R. Higginson, Euronoise 2003, Naples, 2003
- *Dealing with uncertainty in noise measurement standards*, R. Higginson, P. Kurtz, J. Jacques, Euronoise 2003, Naples, 2003
- *Indicative values of noise emission in safety standards — A pilot action*, J. Jacques, J. P. Lacore, Internoise 2001, The Hague, August 2001
- *Comparative emission values in standards*, P. Kurtz, R. Higginson, J. Jacques, Euronoise 2003, Naples, 2003
- *Noise and standardisaion, focusing on machinery and workplace domains,* J. Jacques, Joint Baltic-Nordic Acoustics Meeting 2004, Mariehamn, Sweden
- 'Lärmarm, Konstruieren, Wunsch oder Verpflichtung', Kurtz, P., 1999, in: *VDI Berichte*, 1491, S. 65–82
- Lärm, Lazarus, H.; Parthey, W.; Schust, M. (2001), in: *Ratgeber zur Ermittlung gefährdungsbezogener Arbeitsschutzmaßnahmen im Betrieb*. BAuA, S42 (3. aktualisierte. Aufl.), S. 235–256. Wirtschaftsverlag NW, Bremerhaven
- 'Quieter computer workplaces by using noise emission data', Becker, P., 2002, in: *WWDU 2002*, Proceedings of the sixth International Scientific Conference on Work with Displays Units, Berchtesgaden, 22–25 May 2002, Hrsg: Ergonomic Institut für Arbeits-und Sozialforschung Forschungsgesellschaft mbH, Berlin, S. 692–694
- 'Bedeutung von Emissionskennwerten für den Lärmschutz am Arbeitsplatz', Kurtz, P., 2002, in: *Luftqualität und Lärmminderung am Arbeitsplatz auch unter Berücksichtigung wirtschaftlicher Aspekte*, S. 51–63, VDI-Berichte 1710, Hrsg.: VDI-Koordinierungsstelle Umwelttechnik, Düsseldorf, VDI-Verlag
- *Der systematische Weg zum leisen Produkt, Vortrag auf der VDI Tagung Maschinenakustik*, Kurtz, P., 2003, FH Koblenz am 1.4.2003
- *Technische Arbeitsmittel sicher gestalten und benutzenWeinmann*, Bux, K., Eggert, S., Fischer H., Hofert, R., Jäger, B., Kirchberg S., Kittelmann, M., Kurtz, P., Lazarus, H., Lohse, G., Melzig-Thiel, R., Nagel, J., Poppendick, K.E., Uhlig, D., Weißgerger, B., Windberg, J., Windel, A., W. E. Verlag, Taschenbuch, ISBN: 3921262291
- *Richtlinie 2003/10 EG — Neue Impulse für die Gestaltung von Maschinen und Arbeitsplätzen*, Kurtz, P., 2003, Vortrag auf dem A+A Kongreß 2003
- *Implementation of European occupational noise control directives*, Sehrndt, G., Kurtz, P. 2004, the 33rd International Congress and Exposition on Noise Control Engineering
- *Schallschutz bei Orchestermusikern — 87 dB(A) Expositionspegel als Grenzwert*, Brockt, G., 2004, Vortrag auf der 30. Jahrestagung für Akustik DAGA, am 22.3.2004 in Straßburg proceedings of the joint congress CFA/DAGA´04, Vol. 1 pp. 99–100 (2004)
- *Lärmschutz an Maschine und Arbeitsplatz Vorschriften technische Regeln Gefährdungsbewertung*, Kurtz, P., Lazarus, H., Parthey, W., 2004, Rw 30, Hrsg: BauA, Wirtschaftsverlag NW
- 'Noise emission — A part of risk assessment with a view to machine safety', Lazarus, H., Kurtz, P., *International Journal of Occupational Safety and Ergonomics* (JOSE), 2003, Vol. 9, No. 3, 351–364
- *Occupational exposure to noise: evaluation, prevention and control*, Sehrndt, G. A., Goelzer, B., Hansen Colin, H., BAuA special report S64, published for the World Health Organisation

- 'Noise — Loud noise can damage your health', *Factsheet* (1999), Workers' health
- *Noise at work — Advice for employers*, Health and Safety Executive, 2002
- *Occupational noise — National standard for occupational health, national code of practice for noise management and protection of hearing at work*, Second edition, 2000, Commonwealth of Australia
- *V Encuesta Nacional de Condiciones de Trabajo*, Ministerio de Trabajo y Asuntos Sociales, Instituto Nacional de Seguridad e Higiene en El Trabajo, 2004, ISBN 84-7425-667-4
- *El ruido y los músicos de la orquesta sinfónica, Pilar Cáceres Armendáriz*, Jerónimo García González, Centro Nacional de Medios de Protección INSHT, 2001 at: http://www.mtas.es/Insht/research/PCaceresP.htm
- *Los niveles acústicos durante el horario laboral y las disfonías en los docentes*, Mª Josefa Ruiz Figueroa, Francisco Bernier Herrera, Ester Carrasco Pavon, Francisco J. Gómez López, Centro Nacional de Medios de Protección INSHT, Delgación de la Consejeria de Educación y Ciencia de la Junta de Andalucía en Sevilla, 2001 at: http://www.mtas.es/Insht/research/PruizNJ2.htm

Appendix 4: Web addresses of organisations

International institutions

World Health Organisation, http://www.who.int
International Labour Organisation, http://www.ilo.org/

European institutions

European Commission, http://europa.eu.int/
Eurostat, http://www.europa.eu.int/comm/eurostat/
European Foundation for the Improvement of Living and Working Conditions, http://www.eurofound.eu.int/
European Agency for Safety and Health at Work , http://osha.eu.int
EUR-Lex (European legislation) , http://europa.eu.int/eur-lex
European Committee for Standardisation, http://www.cenorm.be
Cenelec, http://www.cenelec.org/
European Free Trade Association, http://www.efta.int/

National institutions

The Danish National Institute of Social Research (Socialforskningsinstituttet), http://www.sfi.dk/
The Danish National Institute of Occupational Research (Arbejdsmilj¢instituttet), http://ami.dk
Instituto Nacional de Seguridad e Higiene en el Trabajo, http://www.mtas.es/insht/
L'Institut National de Recherche et de Sécurité pour la prévention des accidents du travail et des maladies professionnelles (INRS), http://www.inrs.fr
Hellenic Institute for Health and Safety at Work (Elinyae), http://www.elinyae.gr/
Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA), http://www.baua.de/
Faculdade de Ciencias e Tecnologia da Universidade Nova de Lisboa/Seccao de Ergonomia do DEMI (Dep. En. Mecanica e Industrial), http://www.demi.fct.unl.pt/
Finnish Institute of Occupational Health (FIOH), http://www.ttl.fi/
Groupement de l'Institution Prévention de la Sécurité sociale pour l'Europe (Eurogip), http://www.eurogip.fr/
L'Istituto superiore per la prevenzione e la sicurezza del lavoro (Ispesl), http://www.ispesl.it/
Health and Safety Executive, http://www.hse.gov.uk
Health and Safety Laboratory, http://www.hsl.gov.uk/

Other bodies

Better Hearing Institute, http://www.betterhearing.org/
Royal National Institute for the Deaf, http://www.rnid.org.uk/
Trades Union Congress (TUC), http://www.tuc.org.uk/
Seafish, http://www.seafish.org
TCO, http://www.tco.se
Institute of Occupational Medicine, http://www.iom-world.org/
Association of Noise Consultants, http://www.association-of-noise-consultants.co.uk/

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Project Manager

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European Agency for Safety and Health at Work

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European Agency for Safety and Health at Work

Gran Vía 33, E-48009 Bilbao
Tel.: +34 944 794 360
Fax: +34 944 794 383
E-mail: information@osha.eu.int

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