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Control of noise exposure for employees in the music sector

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ABSTRACT

There exist potential risks of hearing damage for those workers in the music and entertainment sector who are repeatedly exposed to loud music over years of their working life. According to this the European Directive 2003/10/EC on occupational noise refers to all workers expressly including those in the music and entertainment industry. In the Directive the fundamental principles of noise control are implemented e.g. the general obligation for noise reduction at source or the priority of collective protection measures over individual protection measures. Where noise exposure exceeds action values further measures have to be applied: implementation of noise reduction programmes, marking of noisy work places, use of hearing protection and health surveillance. The approved way of noise control corresponding to these regulations is noise reduction at source, on the transmission path, by organizational measures and the application of hearing protection. But in the music sector sound is intended and no waste-product, so this procedure appears to be a challenge. As options for noise control directly at the source are almost limited, measures on the transmission path from the sound sources to the individual workers are advantageous. This contribution covers the sectors of orchestra musicians and workers in music clubs. The sound exposure of these employees as well as options for exposure limitation are described, in particular with regard to technical measures. The fundamental goal is to protect workers but guide the sound to the audience. Nevertheless, there exists no general solution, but often only a combination of several individually adapted measures can yield an applicable exposure control.

INTRODUCTION

Music means pleasure and passion to both consumers and performers. However there are potential risks of hearing damage for those workers in the music and entertainment sector who are repeatedly exposed to loud music over years of their working life. The scope of affected employees covers musicians and performers, disk jockeys, technical or service staff, security, first aiders, ushers etc. These people are frequently exposed to sound levels loud enough to cause hearing impairment. A rather harmless pleasure for consumers during one evening therefore becomes an occupational hazard for employees due to their repeated exposure over years.

According to this the European Directive 2003/10/EC on occupational noise refers to all workers expressly including those in the music and entertainment industry. Besides the national conversion by the European member states the Directive required to provide national guidelines for the music sector to support the practical implementation. The German guideline was published by the BAuA and developed within a working group including different professional associations and social partners. Certainly, the challenge was and is to adapt strategies of sound exposure control to the field of music where sound itself is the product.

Legislation

The Directive 2003/10/EC of the European Parliament and of the Council of February 2003 on "the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)" aims at the protection of workers from risks to their health and safety and particularly to their hearing arising from the exposure to noise. The risks from noise are permanent hearing loss, due to long term noise exposure or impulsive noise of high levels, or other hearing disorders. Such disorders are Tinnitus, which is the perception of sound in the ear in the absence of corresponding external sound (e.g. ringing in the ear), or Hyperacusis which stands for an increase of the sensitivity to sound which can cause discomfort or even pain.

The regulations in 2003/10/EC require employers to check whether their employees are at risk from noise, to assess the degree of risk and to minimise the risk due to noise by introducing noise reduction measures as far as reasonably possible. It introduces action values requiring employers to reduce the noise exposure of their employees by establishing a noise control programme, delimiting especial noisy areas, providing hearing protectors, informing the workers about potential risks due to noise, checking workers hearing, etc.. The action values refer to two physical parameters on which the risk assessment is based. These quantities are the daily noise exposure level $L_{EX,8h}$ in dB(A) and the peak sound pressure level $L_{pC,peak}$ in dB(C) both re. to 20µPa. According to ISO 1999 $L_{EX,8h}$ is defined as

$$L_{EX,\,8h} = L_{pAeq,Te} + (T_e/T_0)$$

with T_e the effective duration of the working day in hours, T_0 the reference duration of 8 hours and $L_{pAeq,Te}$ the A-weighted equivalent continuous sound pressure level during T_e. As a further quantity the weekly noise exposure level $L_{EX,40h}$ is mentioned in the Directive. The latter can only be applied under defined circumstances. The Directive establishes lower and upper action values both for the daily noise exposure value $L_{EX,8h}$ and the C-weighted peak sound pressure value $L_{pC,peak}$. Moreover maximum exposure limit values are mandatory. Applying the exposure level limit values, shall take into account the attenuation of an individual hearing protector worn by the worker. This is not the case for applying the action values.

Table 1. Exposure action values and exposure limit values given in the European Directive 2003/10/EC

	$L_{EX, 8h}$ dB(A)	$L_{pC,peak}$ dB(C)
lower action value	80	135
upper action value	85	137
exposure limit value	87	140

In the national German conversion of the Directive the values of the exposure limit are set equal to the values of the upper action values. When exceeding the upper exposure action levels measures have to be taken such as the implementation of a noise reduction program, the marking of noisy workplaces, the application of hearing protection and health surveillance.

The avoidance or reduction of noise is basically not limited to the exceedance of action or limit values but is a general requirement of the Directive. In Article 5(1) it is required that taking account of technical progress and of the availability of measures to control the risk at source, the risks arising from exposure to noise shall be eliminated at their source or reduced to a minimum. This minimisation requirement underlines the preventive character of the Directive. However, the options to apply noise reduction at source are rather limited for the music and entertainment sector. As already said, the sound is the product, therefore it is only the question whether the generated sound pressure levels are sufficient to comply with the artistic claim and the expectations of the audience. Thus further noise reduction in the music and entertainment sector following article 5 of the Directive will have to concentrate on

- the design and layout of workplaces and work stations;
- the application of noise reduction by technical means like:
  - shields, partial enclosures and sound-absorbent products to reduce the airborne sound
  - or damping or isolating elements to reduce structure-borne noise;
- adequate information and training to instruct workers to use the work equipment correctly in order to reduce their exposure to noise to a minimum;
- the organization of work:
  - by limiting the duration and intensity of the exposure to noise
  - through appropriate work schedules with adequate rest periods.

The established way of noise control at the workplace that is given in the legislation, and as it is also approved in practice, consists of: noise reduction at the sound source, on the transmission path from the source to the workplace, by organizational measures and finally by the application of hearing protection. This ranking in the choice of measures appears to be difficult to realize in the entertainment sector. So in practical live there is a risk that for reasons of simplification this priority in noise control measures is turned upside down. As a result noise control would start with the application of hearing protection and would primarily rely on this measure. But taking into account the experiences on the effectiveness of hearing protection in practical working life this would only partially improve the protection of workers and would not comply with the preventive goal of the legislation.

However the classic strategy of noise control may not fully be transposed it essentially helps to check which options of sound reduction can be applied in an individual case.

WORKERS IN MUSIC AND ENTERTAINMENT

The professional profiles in music and entertainment as well as the employment relationships are very divers. The scope of workers affected can be structured in four main groups:

- musicians,
- performers (singers, actors, dancers, DJs, etc.),
- technical staff (sound/light engineers, roadies, etc.) and
- service personnel (security, catering, paramedics, etc.).

Their field of activity may be live music, recorded music or a mixture of it. Their work place might be a fixed venue or non-stationary. Nevertheless in every case the general procedure of noise reduction as described before gives guidance to develop a suitable bunch of measures to a strategy of exposure control. But certainly the central question will ever be what can reduce the sound load of workers preferably not derogating the performance for the audience. Examples on the noise exposure and options for exposure control for two particular groups of workers in the music and entertainment sector - orchestra musicians and workers in music clubs - are given in the following.

ORCHESTRA MUSICIANS

Exposure levels of musicians

Naturally, professional musicians are most directly affected by music sound. Remarkably, this not only the case when using electrical amplified instruments but also for acoustic musicians when playing in big ensembles as orchestras. The average sound pressure levels of a single acoustic instrument measured close to the ear of the musician during individual practice is within the range of 80-96 dB(A) [1, 2]. At certain instruments the sound levels at the right and the left ear differ substantially, depending on the distance between the ear and the instrument and the sound radiation of the instrument. For the case of a violin or viola the left ear is exposed up to 7dB more. Higher sound levels at the right ear occur in case of a horn or a harp. The table below shows average sound pressure levels measured during individual practice at the more exposed ear.

Table 2. Equivalent sound pressure levels of musicians during individual practice [2]

Instrument	$L_{A,eq}$ dB(A)
Violin	90
Viola	90
Cello	84
Double bass	81
Harp	87
Flute	91
Clarinet	92
Oboe	85
Bassoon	87
Trumpet	93
Horn	93
Tuba	93
Trombone	96
Percussion	93

Source: (Hohmann, 2008)

Generally, for a musician playing in an ensemble the individual sound level is characterized by three factors: the sound of his own instrument, the sound field of the instruments in his proximity and the reflections given by the room acoustics. Not surprisingly, most often the subjective impression of musicians is that their major sound exposure results from the sound of other instruments in their proximity. Actually, this is only the case for the quieter instruments or those positioned distant from the player ears as a cello or a double bass. Here the average sound levels when playing in an ensemble are considerably higher. On the other hand for the case of some louder instruments which often just play intermittently, the actual time of playing during a performance or a rehearsal influences the average sound pressure level, e.g. the percussions. For these instruments the $L_{A,eq}$ within the orchestra may even be lower than during the individual practice playing.

In summary for orchestra musicians the typical average sound pressure level L_{Aeq} during rehearsals or performances is within the range of 85-95 dB(A) (Table 3). The highest levels have been measured with the brass, woodwind and percussion players and situational at musicians positioned in front of these instruments [2, 3, 4, 5]. The lowest sound levels within orchestras typically are measured at the position of the conductor. For some musicians momentary the sound levels might get close to the pain threshold as expressed by the sound levels of the loudest second $L_{A,Smax}$. These $L_{A,Smax}$ values do not indicate a hazard for hearing impairment but might express what is frequently reported by musicians and can explain some spectacular maximum sound levels reported in the media. Actually, the measured peak sound pressure levels of acoustic instruments are not critical for causing acute hearing losses. But the average sound pressure levels mentioned are in a range which gives a risk for hearing impairment on a long-term exposure over years of working time.

Table 3 Sound pressure levels in orchestras

Player	Average $L_{A,eq}$ dB(A)	Maximum $L_{AS, max}$ dB(A)	Peak $L_{pC, peak}$ dB(C)
Percussion	89	121	132
Brass	91-96	107-116	115-129
Woodwind	88-91	99-109	111-119
Violin, Viola	89	107-109	121-122
Cello, Bass	87	99-100	111-119
Choir	92	-	-
Conductor	84	-	-

Source: (Hohmann, 2008, Laitinen 2003)

The average noise exposure of workers as musicians with a markedly varying daily noise exposure is best characterized by the weekly noise exposure level $L_{EX,40h}$. To determine a common average long-term exposure of orchestra musicians it is necessary to consider all phases of work as performance, rehearsal, warm-up playing and individual practice. Typically, performances and rehearsals with the ensemble take about 15-25 hours per week plus 10-15 hours per week spent with individual practice and warm-up playing, which gives an average exposure time about 35 hour per week. Depending on the instrument and the position within an orchestra, the weekly exposure levels of orchestra musicians are within the range of 85-95 dB(A) [2] (Figure 1). Thus they are almost comparable to the noise doses many industrial workers are exposed to. Other studies have calculated exposure levels lower than 85 dB(A). But these values can only come about when individual practice and warm-up playing are not taken into account and moreover by averaging the sound exposure to a yearly noise exposure level including off-season periods [3, 6]. In conclusion the typical exposure levels of musicians playing in orchestras has principally to be considered as hazardous for hearing.

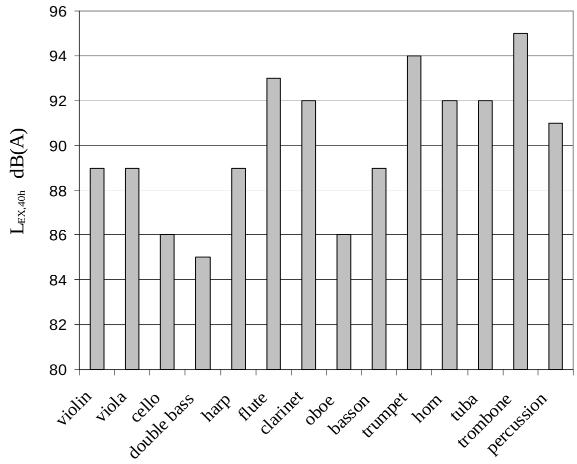

Figure 1. Weekly noise exposure levels $L_{EX,40h}$ of orchestra musicians [2]

Technical measures in orchestras

As mentioned, for orchestra musicians a large amount of the individual exposure results from their own instrument but playing in big ensembles increases the exposure considerably if certain conditions of room acoustics or the positioning of the musicians are disadvantageous for the individual sound exposure.

In a typical *orchestra alignment* the woodwind and brass players often almost play right in the direction of their colleagues ears in front of them. Naturally, this results from the way of holding these instruments directed slightly downwards, their collimated sound radiation and the traditional ensemble setup on small rising steps. Positioning theses musicians on higher risers of most suitable one meter height or more lifts the bells of the brass instruments above the heads of the musicians in front and additionally enhances the radiation of high frequencies to the audience. Increasing the distance between the musicians e.g. by deeper steps provides a simple option for sound reduction. Increasing the distance between musicians is an effective measure if the distances are small and the individual sound load is dominated by the direct sound field of the nearest instruments and not by the sound field of the own instrument and not by the reverberant sound field of room reflections. Then a sound reduction or 4-6 dB per doubling of the distance can be achievable. Further repositioning within an orchestra can be useful to avoid certain hot spots within the ensemble. For example an elongated single line setup of the brass instruments will produced reduced sound levels in front compared to a compact double or triple line setup. Basically, several lines of loud instruments one after another produce a loud area proximate in front. Certainly an orchestra setup is arranged with regard to the artistic claim, but experiences show that repositioning the musicians primarily changes the sound at the position of the conductor but much less within the auditorium more distant [2, 4] .

If the sound level at the ear of musicians is dominated by other instruments in their proximity, *sound screens* can give some protection. However currently the discussions and opinions about sound screens are often conflictive which might result from different experiences. There are diverse types of sound screens and ideas on how they should be designed. Generally, screens can be distinguished into two major groups with regard to their acoustic properties, acoustically reflective screens and acoustically absorbent screens. Hybrid types can combine these functions. Purely reflective screens often made of perspex give an acoustic shield in the high and mid frequencies but their reflections may increase the exposure of the musicians close-by. So e.g. string players sitting in front of a perspex screen may receive some protection from the sound of brass players behind. But the brass players themselves will play against a kind of reflecting wall and receive an additional sound exposure which is often complained. Just as well the string players will percept unfamiliar reflected parts of their own sound now reflected at the screen in their back. Absorbent screens avoid this effects but too much absorption will dampen the sound impression unfamiliar for the musicians or even for the conductor. Both might be initiated to a louder playing which even might result in an exhausting overplaying of the musicians. The suitable adapted combination of acoustically absorbing and reflecting surfaces and their design is essential for the performance of a screen. Because a sound screen has the function to reduce the sound level for the musician leaving a sufficient acoustic feedback and ideally helps to guide the instrument's sound to the conductor and the audience. The latter for example can be achieved by a one-sided reflecting upper part of a screen tilted forward so as to route the sound above the heads of the musicians in front (Figure 2).

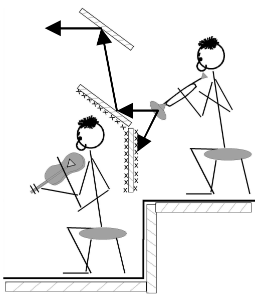

Figure 2. Concept of a sound screen (drawing after R.Pangert)

The sound reduction of examples for absorbing screens has been quantified within a range of 6-10 dB for the direct sound field of a source positioned behind the screen [2, 8, 9, 13]. The sound protection of a screen that can be realized in an individual case depends on numerous parameters: its size, absorbance of its surfaces, distance of seating position, frequency spectrum and directivity of the screened instruments, distance from walls or ceiling and finally the room reverberation. Basically, all types of screens get considerably less effective with decreasing size especially at lower frequencies. Moreover the visual transparency of screens has to be considered. Usually, an eye contact to the conductor or other musicians is desired on stage or in recording studios which requires screens at least transparent in their upper regions. Modern micro-perforated materials which are absorbent and transparent simultaneously can be an option in these cases. At present there is a clear potential for further specific developments of sounds screens for different application in musicians ensembles. Finally sound screens can not be considered as a kind of personal protection equipment as they have always consequences at least for a number of musicians within an orchestra. Hence appropriate consultancy in the implementation of screens is essential because misapplication may easily impair the situation within an ensemble.

In *orchestra pits* musicians are more likely exposed to high sound levels. There are three factors that increase the sound levels in a pit: small distances between musician inside many tight pits, sound reflecting walls and frequently an overhang producing further sound reflections. The consequences are high sound levels, multiple reflections, inhomogeneous sound fields and resonances especially at low frequencies. These effects impair the acoustic transparency and as a consequence the musicians are playing against a kind of unwanted background noise produced by the room acoustics which even makes them to play louder. Avoiding a seating under the overhang or enlarging the pits is no practicable option in most cases. But room acoustic improvements can reduce the reflections from the walls and the overhang. To reduce sound reflections in the middle and low frequencies by classical fibrous absorbers would occupy a plenty of volume inside a crowded pit. As an alternative dedicated absorbent elements based on the principle of plate resonators can be effective at middle and lower frequencies without occupying much space [10]. In practice such panels can almost be suspended like pictures on a wall. These arrangements do not only reduce the sound levels but also improve the acoustic transparency and perception between the musicians and thus improve the musical interaction and the orchestral performance. Another constructural measure is to open the orchestra pit acoustically e.g. by designing the balustrade or parts of the overhang acoustically transparent but optically intransparent. This avoids reflections within the pit and let the sound escape to the audience. Such constructural modifications should particularly be considered at refurbishments and new building.

In other *rooms* where an orchestra always has the same or a similar seating arrangement, permanently installed measures can be taken to reduce the sound levels. The same applies with regard to teaching and practice rooms in music colleges or tuning up rooms in theatres. Increasing the sound absorption on room boundary surfaces of a music room gives a reduction of the sound level, but due to the shortened reverberation at the same time the volume of sound and the brilliance are adversely affected. Therefore only such absorbers should be selected which are adjusted to suit the particular circumstances and which act in the respective frequency ranges. Walls and ceilings close to loud instruments as trumpets, trombones or horns should be lined with sound absorbers which preferably absorb the middle and higher frequency ranges. In order to avoid room resonances in the low frequency range low-frequency absorbers should be mounted to the wall and ceiling surfaces in the area of low-tone instruments as double basses, kettle drums.

Organizational measures

A reduction of the sound exposure by taking organizational measures relates to the organization of the activity or the organization of the time system. Time-related organizational measures act primarily on the noise exposure level L_{EX}. The exposure due to noise pulses is normally not affected. When organising work schedules the sound exposure levels to be expected should be taken into account in order to avoid periods with unusually high exposure levels. Planning music performances or rehearsals a change of repertoire or venue should also be considered. In terms of conservation of hearing an adequate regeneration time for the hearing is of major importance after periods of sound exposure. Recuperation times must therefore be included in work schedules and any agreements on wages and conditions must be taken into account. Preventive measures, technical or organizational, are often easier to apply during rehearsals than during performances. Thus special considerations on sound control measures for the arrangements of rehearsals, including individual rehearsals, give an extra opportunity for an effective exposure reduction.

Hearing protection

When the options for sound reduction at the sound source and on the transmission path to the worker as well as organizational measures are exhausted, the use of suitable personal hearing protection becomes indispensable even for musicians. But Musicians often refuse even ear plugs with a flat frequency response. An unsatisfactory sound impression as well as restrictions in the instrument control and the interaction within the orchestra are complained most often. These problems predominantly result from the occlusion effect which influences the perception of bone conduction and thus changes the sound of the own instrument for the player. Brass-, woodwind- and players or other instruments which induce a lot of structure-borne sound into the jaw or skull are highly affected. Individual consulting on the choice and application of hearing protection is the issue to adapt to playing with ear plugs [1, 5]. Consequently hearing Protection should be a topic in musician's education as a matter of course.

WORKERS IN ENTERTAINMENT VENUES

The sound of recorded music can give a considerable noise exposure to workers in many kind of venues. The working conditions in the entertainment sector are most diverse and often handled flexible and therefore the noise exposure of workers may cover a wider range. As an example for this branch the following table displays the daily noise exposure levels for different groups of workers in British music clubs [7].

Table 4. Daily noise exposure levels of workers in music clubs

Job	Range $L_{EX,8h}$ dB(A)	Average $L_{EX,8h}$ dB(A)
Bar staff	89-99	92
Floor staff	90-100	93
DJ	93-99	96
Security	-	96

Source: (Smeatham, 2002)

In average the daily noise exposure level values are in a range of 92-96 dB(A). Hence it is to assume that most workers in entertainment venues are exposed over the upper action level given in the Directive and that there is a definite risk of hearing impairment. However the risk for the public may be much lower due to commonly much shorter exposure times.

Actually in Germany there exists no binding legislation defining a quantitative limit for the sound exposure of the audience in order to protect from hearing damages. However there is a general legislative obligation on the liability of organizers regarding the safety of an audience which includes noise induced hazards. With reference to this legislation is the national German standard DIN 15905-5 "Event-Technology - Sound Engineering - Part 5: Measures to prevent the risk of hearing loss of the audience by high sound exposure of electroacoustic sound systems". This non-binding technical standard can provide legal certainty for organizers with respect to the required liability. In legal practice of compensation payments it has been applied in cases of hearing impairments after single loud events as concerts. The standard in its revised state from 2007 amongst other things demands the limitation of the half-hourly averaged sound pressure level $L_{Aeq,30min}$ to 99 dB(A) for events with electroacoustic sound equipment, which should not be exceeded on any position accessible to the audience. Furthermore it gives a specification on the safety liability of the organizer which leads to the necessity of measurements and extended reporting requirements as well as to obligations on informing the audience or the provision of hearing protection. While requirements and possibilities on the launch of further binding legislations regarding the protection of consumers are under discussion, other preventive activities have been launched by the federal states authorities and local authorities. These campaigns aim at the public information to support the awareness and the personal responsibility of visitants as well as to the voluntary self-restriction of operators and club-owners. Such voluntary actions include the recommendation to visualize the sound levels for DJs and guests in the responsibility of club operators. A quality certificate is promoted for those discotheques which are equipped with an appropriate display and whose DJs have a proof of competence, the so-called DJ license. The later is a campaign offering a one day training imparting knowledge to the DJs about health effects of loud music, the technical and tactical possibilities for the visitors' acceptance of sound levels and the aspects of liability law. Since 2004 about 2500 DJs attended these trainings. Nevertheless, the request of venue operators in applying voluntary self-restriction to sound levels is almost contained and random inspections of federal state authorities reveal that up to now information campaigns and voluntary self-restriction such as mentioned did not sufficiently succeed in limiting the average sound levels at 100 dB(A).

However even if the sound level limit for the audience as aimed for in the standard would be complied in practice, there would be still be demand for further specific measures to reduce the noise exposure of employees.

Technical measures in music clubs

Noise reduction in discotheques or clubs seems to be limited by the consumer's preference to attend loud venues. But this seems to be half the truth. In fact there exist studies revealing that about the half of adolescent visitors of discotheques have the perception that discotheques are more loud than pleasant and that they would accept sound level limits [11, 12]. It has come out that the crucial range for the average sound pressure level is 95-100 dB(A) where the expectations of the visitors of discotheques seems to polarize. Here the percentage of visitors who rated the sound levels as "very" or "extremely" loud rises from 13% to 88%. Moreover there was no statistical difference in the acceptance of discotheques where the music levels were within this range [12].

Another problem are the limited options to separate workers from loud areas. Unavoidable at least a number of workplaces have to be close to the visitors of entertainment venues staying right in noisy areas. In order at least to reduce the number of workplaces affected, the main goal in discotheques and clubs is to focus high sound levels to areas where it is essentially wanted and needed i.e. on the dance floors. The fundamental design elements to realize this are:

- separation,
- adequate absorption,
- suitable sound equipment.

In order achieve a separation of workplaces from noisy areas e.g. bars should be positioned away from the dance floor and no extra speakers should be installed at the bars. Preferable bars should be located in quieter areas as so called chill-out rooms. An acoustic separation can be realized by the use acoustic screens at specific workplaces e.g. at the bar or the DJs desk. Furthermore acoustic insulation should protect the non-public work areas and off-duty areas from noise sources.

Absorption within a club is a key issue to keep high sound levels in certain areas. At many positions and workplaces in a venue the sound level is not dominated by the direct sound field of a loudspeaker but the reverberant sound field inside the venue. Absorbent materials on ceilings and walls avoid unintended reflections of sound energy from the dance floor throughout the whole venue. In particular absorbent linings are recommended at ceilings above dance floors as well as at ceilings and walls of workstations. Additionally, in most cases absorption will improve the room acoustics with respect to music reproduction. Therefore acoustic consultancy is required for a purposeful design of an entertainment venue.

The idea of focusing the sound to specific areas is supported by suitable absorption within a venue but the design of the sound system is crucial as well. Dedicated sound equipment should have directed loudspeakers aiming at the dance floor and e.g. just not at the bar. It should consist of multiple loudspeakers to provide a uniform sound field on the dance floor without hot spots. Loudspeakers should not be placed on the ground so that people might get too close to them. Lifted or hanging constructions can prevent this. Anti-vibration mounts of speakers avoid that vibration energy is induced in the building structure and thus spread through the whole venue. Equipment with low distortion and proper equalizer settings achieve an improved sound quality with a subjective more intense sound perception but objective lower sound levels. Finally monitoring of sound levels and the use of sound limiter systems help to control the average level in entertainment venues.

Work organization and hearing protection

Substantially the methods for reducing the exposure of workers in entertainment venues are the same as mentioned above. But mostly in this sector there are more possibilities to reduce the noise exposure of individual workers by rotating the staff between noisy and quite areas. Just as well this applies to staff rotation between relative quieter and louder shifts or events.

Reservations against the use hearing protection are common in all groups of affected workers. Workers in the service sector mainly criticize the restrictions in communication under hearing protection. However the speech intelligibility primarily depends on the ratio of speech level to background level which is actually not changed by a hearing protection. Hearing protection with a flat frequency response enhances the speech intelligibility and improves the situation for these workers as well. For the case DJs it is recommended and widely accepted to wear earmuffs with built-in sound system to monitor the music but receive a sound attenuation from the ambient noise in the venue.

CONCLUSIONS

For workers in the music- and entertainment industry the noise exposure is a potential occupational hazard and it often exceeds the action values or exposure limit values given in regulations as the European Directive 2003/10/EC. But musicians and other workers in this sector need their hearing at least as much or probably even more than any other workers. So the peculiarity of this sector is not the question if exposure control makes sense but what are the suitable measures and methods to achieve it.

The challenge is to consider that hearing damage may be caused by sound but that the performance of music, live or recorded, is a more complex and subjective process than can be expressed in decibel. The auditor's subjective perception of loudness depends on characteristics such as the time structure, the dynamic and the frequency spectrum of music. The goal is to optimize any performance with respect to an impressive sensation for the audience without necessarily increasing the average sound pressure levels or the noise exposure of workers.

Noise exposure control for workers is possible but only the choice of highly individually adapted measures of exposure control can realize hearing conservation and ensure a performance product that satisfies the expectations of the audience. In occupational noise control, after reducing risks preferable at the source, collective measures have the highest priority and efficiency over individual measures, although in terms of music this seems to be counterproductive at a first glance. But the application of technical measures for sound reduction as described give an approach to this effort. However as there exists no general solution for sound reduction in the music sectors, most often only a combination of several individually chosen measures can yield a practicable exposure control. Nevertheless there is demand for further adapted technical developments to meet the users requests in practical live. Finally, a key issue to support the implementation of any sound exposure control measures will be information and training in a way which addresses the experts working in this sector. Because primarily the professionals themselves, many of them affected personally, are in the position to put adapted concepts into practice.

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