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NOISE DOSE INDEX BASED ON HEARING DETERIORATION EQUIVALENCIES ADAPTED FROM ISO 1999

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ABSTRACT

Within occupational medical care fair accurate specifications for the risk assessment are needed to enable the estimation of noise-induced aggravation in addition to an already existing hearing deterioration. Therefore within occupational medical care and within the framework of the appraisal of occupational hearing impairment a noise dose index is required, which determines the long-term occupational noise dose according to acknowledged scientific findings using the details presented on the exposure periods or expected coming periods.

Noise-induced equivalent hearing threshold shift curves were calculated based on ISO 1999:1990. The Noise Dose Index used was developed for the report of the occupational noise dose, which allows to consider hearing-threshold-shift equivalently the noise exposures of all periods. For its calculation procedures have to be used, which are different from those known for the energy equivalent approach

INTRODUCTION

SPECIFIC VALUES FOR NOISE EXPOSURE

Within the risk assessment at work the noise exposure level ($L_{EX,8h}$) according to Directive 2003/10/EC [1] is consulted to decide whether exposure action values are exceeded and measures of noise control have to be applied. With regard to $L_{EX,8h}$ the Directive [1] refers within its "Definitions" to ISO 1999:1990 [2], point 3.6:

$$L_{EX,8h} = L_{Aeq,T_e} + 10\,\lg\left({T_e}/{T_0} \right) \qquad (1)$$

Where T_e is the effective duration of the working day and T_0 is the reference duration (= 8 h).

$L_{Aeq,T}$ is defined as follows [2]:

$$L_{Aeq,T} = 10\,\log\left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2(t)}{p_0^2}\, dt \right] \qquad (2)$$

Where t_2-t_1 is the period T over which the average is taken starting at t_1 and ending at t_2, p_A is the A-weighted sound pressure, in pascals and p_0 is 20 µPa.

The concept represented by formula (1) and (2) is called the equal energy principle, which is well accepted for noise measurements, when assessing the risk of noise-induced hearing deterioration within prevention. ISO 1999 [2] restricts the application of this concept to time periods up to one week. In case it is applied to longer periods ISO 1999 [2] requires, that $L_{EX,8h}$ on the worst day does not exceed, by more than 10 dB, the $L_{Aeq.T}$ averaged over a longer period; but the longer period shall not exceed 1 year.

The noise exposure level only accounts for long-term representative exposure over an exposure period of time (e.g. activity with long-term invariant exposure extending over several month, years or decades). Therefore reaching or exceeding exposure action values ($L_{EX,8h}$ = 80 dB(A) respectively 85 dB(A) or $L_{C,peak}$ = 135 dB respectively 137 dB) is not sufficient, to generate hearing impairment. Within prevention the noise exposure level only represents the risk of hearing deterioration for single exposure periods of time without taking into account the duration (e.g. in years).

EXAMPLE FOR AN EQUAL ENERGY NOISE DOSE INDEX

In 1975 the „Risikomaß“ R (risk index) was published to calculate the risk of a hearing deterioration for the total exposure of a working life. It uses the energy equivalent sum of single period exposures [3]:

$$R = 2 * \lg\left[\sum_i \left({t_i}/{t_0} \right) * 10^{0,1 * {D_i}/{D_0}} \right] \qquad (3)$$

Where t_0 = 1 year, D_0 = 1 dB, D_i = $L_{EX,8h}$ – 85 dB and time periods with $L_{EX,8h} < 85$ dB are not considered.

The lines in Figure 1 connect points of equivalent risk for formation of noise-induced hearing impairment. The equal energy principle is extended to the whole working life (here 40 years of noise exposure). That is observed from the increase of exposure level by 3 dB when halving the exposure duration and from straight lines in the double logarithmic presentation.

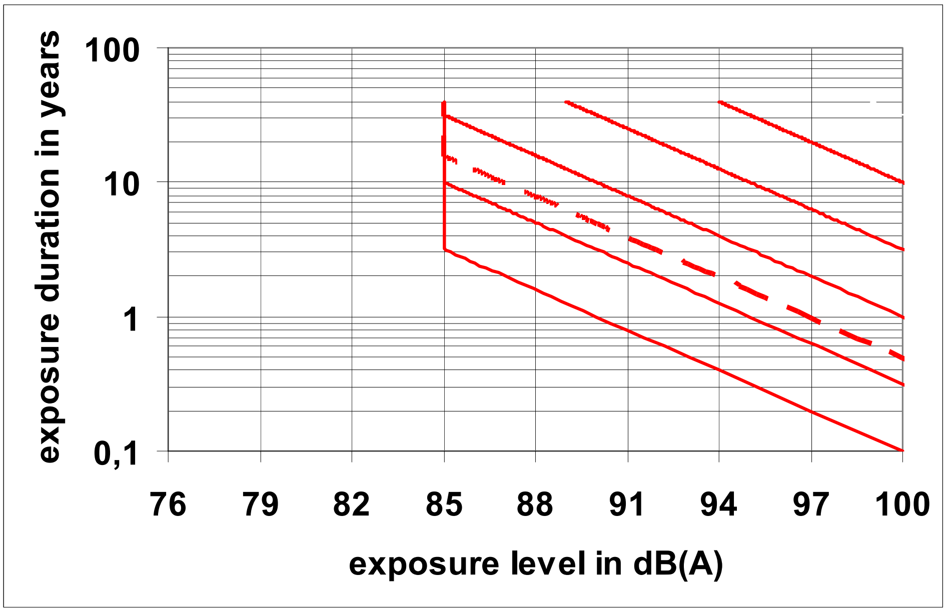

Figure 1. Lines from bottom to top: R = 1, 2, 2.4 (dashed line), 3, 4, 5. Formation of a compulsory compensation of noise-induced hearing impairment is for R 0-1: not possible, 1-2: unlikely, 2-3: not fully excluded; 3-4: possible, 4-5: likely [3].

The dashed line showing R=2.4 is recommended being the threshold for noise-induced hearing damage specified as a threshold shift exceeding 40 dB at 3 kHz [4].

CURRENT REQUIREMENTS FOR A NOISE DOSE INDEX

The European Noise Directive [1] considers exposures reaching or exceeding $L_{EX,8h}$ = 80 dB(A) relevant for prevention of noise-induced hearing deterioration. Therefore ignoring exposures below 85 dB(A) - like the example for an equal energy noise dose index presented - is no longer appropriate.

For the work-related occurrence of occupational hearing impairment publications often specify imprecisely only “long lasting” and “perennial” as the required exposure duration relating to a daily noise exposure level of 90 dB(A) respectively 85 dB(A). Within occupational medical care these specifications are not adequate to enable the estimation of noise-induced aggravation in addition to an already existing hearing deterioration. Therefore within occupational medical care and within the framework of the appraisal of occupational hearing impairment a noise dose index is required, which determines the occupational noise dose according to acknowledged scientific findings using the details presented on the exposure periods or expected coming periods. In this paper a noise dose index is briefly presented, which is based on ISO 1999.

NOISE DOSE INDEX BASED ON ISO 1999

ISO 1999 presents the relationship between noise exposures and the "noise-induced permanent threshold shift" (NIPTS) in people of various ages. This relationship is specified in statistical terms, i.e. for a large population exposed to a specific noise changes in the statistical distribution of hearing threshold levels can be determined. ISO 1999 can be applied to calculate the risk of sustaining hearing impairment due to any daily repeated or regular occupational noise exposure.

ISO 1999 presents formulae to calculate NIPTS for the audiometric frequencies 0.5, 1, 2, 3, 4, and 6 kHz, for a noise exposure level normalized to a nominal 8 h working day ($L_{Ex,8h}$) from 75 dB(A) to 100 dB(A), for periods of exposure lasting from 0 to 40 years, and for the statistical distribution from 0.05 to 0.95 fractile. NIPTS is treated by ISO 1999 as an additive term independent of other components of hearing threshold level.

ISO 1999 is the only comprehensive estimation of noise-induced hearing impairment, which was published as an international standard. Because an increasing quantity of employees are exposed to various sound pressure levels during various periods, even small noise-induced effects on hearing have to be considered within the assessment of the total hazard arising from noise. Therefore within this paper formula for long-term noise exposure effects specified by ISO 1999 are applied for short exposure times as well. For time periods shorter than 0.52 years Liedtke modified the ISO 1999 formula for 4 kHz [5].

HEARING DETERIORATION EQUIVALENCIES ADAPTED FROM ISO 1999

It was demonstrated, that the equivalent hearing threshold shift curves are independent of sex, of age and of fractile for fractiles $Q < 0.50$ [5]. The Noise Dose Index was calculated using mathematical formula and algorithms deduced from ISO 1999 [5].

According to ISO 1999 the largest noise-induced permanent threshold shift (NIPTS) for a given exposure is found at 4 kHz. This is in line with established findings described in a large number of publications. Because the largest noise effects were found at 4 kHz, it can be assumed, that ISO 1999 describes those effects most precisely at 4 kHz. Therefore the 4 kHz NIPTS-equivalent curves constitutes a good foundation for the Noise Dose Index. The cut-off sound pressure level at 4 kHz is 75 dB(A) [2]. This is the smallest cut-off sound pressure level specified by ISO 1999. Therefore the 4-kHz-NIPTS-equivalent curves are consulted for the development of the Noise Dose Index. This means, that exposures exceeding 75 dB(A) are considered by the Noise Dose Index.

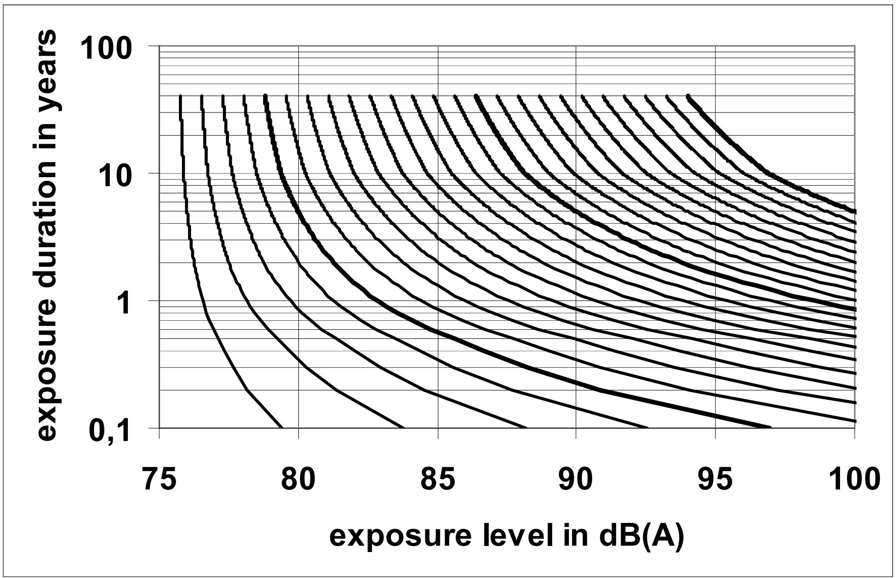

Figure 2. Lines from left to right: Noise-induced hearing threshold shift curves equivalent to $L_{EX,8h}$ = 76 dB(A), 77 dB(A), 78 dB(A), … 100 dB(A) in each case referring to an exposure duration of 5 years.

By calculation of hearing threshold shifts, which are equivalent to a pair of values, e.g. $L_{EX,8h}$ = 90 dB(A) and t = 5 years, the noise-induced equivalent hearing threshold shift curve is obtained. In case this is arranged for $L_{EX,8h}$ = 76 dB(A) up to 100 dB(A) in steps of 1 dB(A) Figure 2 can be plotted.

Comparison of Figure 2 and Figure 1 reveals that the Noise Dose Index used does not comply with the energy equivalent principle, i.e. the curves shown in Figure 2 are not straight lines in the double logarithmic presentation. As a result the commutative law and the associative law do not apply to the operation of combination of exposure periods, which show different values of exposure levels. That means that the correct consideration of the chronological order of exposure periods is important for the result of the Noise Dose Index.

The characteristics described by the Noise Dose Index are consistently valid for that half of the population, which shows the most susceptible hearing, independent from the specific fractile (for $Q<0.50$). Therefore the Noise Dose Index provides an estimate of the risk of NIPTS for every single individual of the fractiles $Q < 0.50$, without specifying the absolute level of threshold shift. Although the permanent threshold shifts (PTS) exhibit a large statistical spread [2], this applies to the age related threshold shift as well as to the NIPTS, the Noise Dose Index manages to do describe consistently threshold curves of the same deterioration by use of relations (equivalent relations) instead of absolute values of PTS.

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