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ASSESSING THE RISK OF NOISE-INDUCED HEARING LOSS OF WORKERS IN THE FOOD INDUSTRY

Taneva A.D.St., doctor, head assistant, Prokopov Ts.V., doctor, associate professor
University of Food Technologies, Department of Environmental Engineering, Plovdiv, Bulgaria

Estimation of noise-induced hearing loss of workers in the food industry was done on the basis of BG ISO 1999:2004. Results on the risk of permanent hearing loss due to noise exposure and combination of noise and age impact have been presented for men and women at the age of 40, 50 and 60 years, working for 10, 20 and 30 years in food industry at noise level $L_{EX,8h}$ = 85, 90, 95, 100 dB(A), two frequency combinations of 500, 1000, 2000, 4000 and 1000, 2000, 3000, 4000 Hz, and two hearing threshold level of >25 and >40 dB. It was found that the highest risk of 77.6 % is for a 60-year old male with a 30-year working period at noise level $L_{EX,8h}$ = 100 dB(A), frequency combination of 1000, 2000, 3000, 4000 Hz and hearing threshold level of >25 dB. For a female of the same conditions the risk is also the highest and it was 72.9 %. These results show that employers have to take appropriate technical, administrative and individual measures to protect workers from the harmful effects of noise.

Определена оценка риска постоянной потери слуха для работников в пищевой промышленности на основе стандарта БДС ISO 1999:2004. Представленные результаты потери слуха от воздействия шума на работе и сочетание шума и влияние возраста для мужчин и женщин в 40, 50 и 60 лет, работающих в пищевой промышленности на период воздействия 10, 20 и 30 лет, при средносуточном уровене экспозиции $L_{EX,8h}$ = 85, 90, 95, 100 дБ(А), две комбинации частот 500, 1000, 2000, 4000 и 1000, 2000, 3000, 4000 Гц, и два прага слышимости >25 and >40 дБ. Наибольший риск 77.6 % был установлен для 60-летних мужчин с 30-летним стажем на уровне шума $L_{EX,8h}$ = 100 dB(A), сочетание частот 1000, 2000, 3000, 4000 Hz и порог слышимости >25 dB. Для женщин самый высокий риск 72.9 % был получен при тех же условиях. Результаты показывают, что работодатели должны принимать необходимые технические, административные и индивидуальные меры для защиты работников от вредного воздействия шума.

Key words: risk assessment, noise, hearing loss, food industry.

Introduction

Exposure to noise at work can cause irreversible hearing damage. It is one of the commonest health problems and can difficult to detect as the effects build up gradually over time. Hearing loss caused by noise is the most common occupational disease in Europe, accounting for about one third of all diseases related to work before skin and respiratory problems. The cost of hearing loss represents about 10 % of the total cost of occupational diseases. Hearing damage is usually caused by long-term exposure to excessive noise. The first symptom is commonly the inability to hear high, and later low, sounds. Usually this happens in both ears and the damage is permanent [8].

A national survey of working conditions in Bulgaria shows that 9.7 % of workers are exposed to loud noise almost all the time, and 14.5 % are exposed for about half of the time [3].

Throughout all industry, industrial hearing loss remains the occupational disease with the highest number of civil claims accounting for about 75% of all occupational disease claims. Most food and drink industries have processes which emit high noise levels exceeding the required limits. It was found that some of the following processes in the food industry are particularly associated with high noise levels: glass bottling lines (85-100 dB), product impact on hoppers (90-100 dB), wrapping, cutting wrap, bagging etc. (85-95 dB), bowl choppers (>90 dB), pneumatic noise and compressed air (85-95 dB), milling operations (85-100 dB), blast chillers/freezers (85-107 dB), packing machinery (85-95 dB) and wheeled trolleys racks up to 107 dB [7, 10, 11].

The risks of permanent hearing loss due to noise and the impact of age, or to the influence of noise only are commonly used indicators of the harmful effects of noise exposure. A limit of the hearing threshold level can be accepted, above which permanent hearing damage is expected. Then the percentage of the population with an average hearing threshold level equal to or exceeding the selected limit can be calculated. Noise-induced hearing loss is assessed in accordance with ISO 1999 [1].

Several definitions of hearing impairment are available in the literature. According to NIOSH (1998), as widely used definition, hearing impairment is generally defined as «a binaural pure-tone average for the frequencies of 1000, 2000, 3000 and 4000 Hz of greater than 25 dB». The WHO (1991) defined hearing impairment as «permanent unaided hearing threshold level for the better ear of 41 dB or greater for the four frequencies 500,

1000, 2000, and 4000 Hz». According to this definition no impairment is defined at <25 dB, slight impairment is defined at 26-40 dB, moderate impairment is defined at 41-60 dB and etc. [4, 6].

Employers are obliged to provide adequate assessment of risk for workers' health and safety. According to the «Noise Directive», in assessing the risk arising from exposure to noise, particular attention should be paid to the relation between noise and accidents. Furthermore, risk assessment must take into account the level, type and duration of the exposure, the exposure limit values and action values, any impact on workers' health and safety associated with noise exposure and other factors. According to Bulgarian legislation, the exposure limit value is $L_{EX,8h}$ = 87 dB(A), the upper exposure action value is $L_{EX,8h}$ = 85 dB(A) and the lower exposure action value is $L_{EX,8h}$ = 80 dB(A) [2, 5].

Potential hearing loss due to noise exposure at work can be evaluated directly by permanent hearing threshold shift caused by noise, taking into account the impact of exposure conditions and the group of people considered. Permanent hearing loss is usually calculated by means of a combination of hearing threshold levels at certain frequencies. Combinations of frequencies from 0.5 to 4.0 kHz are typically used for evaluation of permanent hearing loss for conversational speech [6].

In assessing the risk of noise-induced hearing loss two databases are most often used. The first one comes from otologically normal people (without any symptoms of ear diseases, the ear canal not blocked by earwax) who have not been exposed to noise. Statistical distribution of the threshold of such «carefully studied» groups of people is standardized in ISO 7029, separately for the populations of men and women. The second database covers hearing threshold level related to age of typical population of untested people (men and women) from industrialized countries [1,9].

The objective of this study was to assess the risk of hearing loss under the impact of noise at work in the food industry.

Materials and methods

Risk assessment was carried out in accordance with the methodology presented in BG ISO 1999:2004, which includes the following:

The A-weighted noise exposure level standardized to the nominal working day of 8 h was defined by the equation:

$$L_{EX,8h} = L_{Aeq,Te} + 10\lg\frac{T_e}{T_0}, \quad (1)$$

where:

T_e is the effective working day duration, h;

T_0 is the reference duration, h, T_0 = 8 h.

When the effective working day duration is equal to 8 h, $L_{EX,8h}$ is numerically equal to the A-weighted equivalent continuous sound pressure level ($L_{Aeq,8h}$). For the prolonged unchanging noise, the level of L_{Aeq} is numerically equal to the A-weighted sound pressure level (L_{PA}).

If an average effect for n days is required, then the average value of $\overline{L}_{EX,8h}$ is defined by:

$$\overline{L}_{EX,8h} = 10\lg\left[\frac{1}{k}\sum_{i=1}^{n} 10^{0,1\left(L_{EX,8h}\right)_i}\right] \quad (2)$$

The value of the k coefficient is selected to the purpose of averaging. For example, k = 5 for a daily noise impact level standardized for a normal week of 5 eight-hour working days.

The hearing threshold level H' (related to age and noise) of the group of people exposed to noise at work was calculated by the following formula:

$$H' = H + N - \frac{H.N}{120} \quad (3)$$

where:

H is the hearing threshold level that is associated with age, dB;

N is the actual or potential noise-induced permanent hearing threshold shift, dB.

The expression $\frac{N.H}{120}$ begins to change the results significantly only when H + N exceeds 40 dB approximately.

A database for carefully studied groups of people was used in risk assessment in accordance with ISO 7029 [9].

The risk was calculated for two hearing threshold level of >25 and >40 dB at two frequency combinations of 500, 1000, 2000, 4000 and 1000, 2000, 3000, 4000 Hz.

Results and discussion

Typical noise levels that have been recorded in the food industry are shown in table 1. These levels represent only a small sample of the many food processes but show that high exposure values will often be reached if employees spend a significant part of their time in these areas.

Table 1 – Typical noise levels recorded in the food industry [7]

Industry	Location	Noise level, dB(A)	Industry	Location	Noise level, dB(A)
Drinks	Bottling halls Bottle filling/ labeling Decrating/ washing Casking/ kegging Cooperage machines	85-95 85-95 85-96 85-100 Above 95	Bakery	Dough-mixing room Baking plant De-panning Bread slicing Fruit washing	85 85 90 85-90 92
Meat	Animals in lairage Powered saws Blast-freezers/chillers Bowl choppers Packaging machinery	80-110 Up to 100 85-107 Above 90 85-95	Dairy	Production areas Homogenisers Bottling lines Blast-chillers Pneumatics	85-95 90-95 90-95 87-95 85-95
Milling	Mill areas Hammer mills Grinders Seed-graders Bagging lines	85-95 95-100 85-95 90 85-90	Confectionery	Hopper feed Mould-shakers Wrap/bagging High boiling	95 90-95 85-95 85

The hearing of the group of people unexposed to noise as a function of age depends on the extent to which factors other than natural aging, medical conditions, ototoxic drugs and the unknown effects of noise at work or outside work, which can modify the hearing threshold level associated with age, are inadvertently included. Table 1 shows the risk of permanent hearing loss due to age. Obviously, the risk increases with age and the risk for men is higher than the risk for women. For both genders, the risk increases most quickly between 50 and 60 years.

Table 2 – Risk of permanent hearing loss due to age (%) for otologically normal group of people at two frequency combinations and two hearing threshold levels

Age	Men				Women			
	500, 1000, 2000, 4000, Hz		1000, 2000, 3000, 4000, Hz		500, 1000, 2000, 4000, Hz		1000, 2000, 3000, 4000, Hz	
	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB
40	0.8	0.002	1.7	0.01	0.2	0.0001	0.5	0.001
50	5.4	0.1	10.4	0.6	2.0	0.01	3.3	0.04
60	18.8	2.2	29.4	6.3	8.9	0.4	13.7	1.0

Tables 3 and 4 show the results for the risk of permanent hearing loss due to age and noise for periods of exposure 10, 20 and 30 years, respectively for men and women 40-, 50- and 60-year old, working in food industry at noise level $L_{EX,8h}$ = 85, 90, 95 and 100 dB. It was found that the highest risk of 77.6 % is for a 60-year old male with a 30-year working period at noise level $L_{EX,8h}$ = 100 dB(A), frequency combination of 1000, 2000, 3000, 4000 Hz and hearing threshold level of >25 dB. For a female of the same conditions the risk is also the highest and it was 72.9 %. The results show that the risk is greater for the greater frequency combination.

Table 3 – Risk of permanent hearing loss due to age and noise (%), for men, at different noise exposure level ($L_{EX,8h}$), two frequency combinations, exposure period 10, 20 and 30 years, for two hearing threshold levels

Period of exposure	$L_{EX,8h}$ = 85 dB											
	500, 1000, 2000, 4000, Hz						1000, 2000, 3000, 4000, Hz					
	40-year old		50-year old		60-year old		40-year old		50-year old		60-year old	
	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB
10 years	1.6	0.01	7.0	0.2	21.6	2.6	4.1	0.1	14.7	1.3	34.5	8.1
20 years	1.9	0.01	7.6	0.2	22.3	2.9	4.8	0.1	16.0	1.4	35.8	8.7
30 years	—	—	7.9	0.3	22.5	3.0	—	—	16.7	1.7	35.1	7.7
	$L_{EX,8h}$ = 90 dB											
10 years	4.1	0.1	11.0	0.5	25.6	4.1	10.7	0.7	22.3	2.8	42.3	12.3
20 years	4.3	0.1	12.7	0.7	28.0	4.9	12.7	0.8	26.0	3.7	44.4	14.1
30 years	—	—	13.5	0.7	28.8	5.1	—	—	27.9	4.3	46.1	15.1
	$L_{EX,8h}$ = 95 dB											
10 years	9.9	0.4	20.3	2.2	33.7	7.4	23.0	2.8	37.7	8.7	53.2	20.3
20 years	13.9	0.8	25.2	3.2	38.3	9.2	30.8	5.0	45.3	12.8	57.8	24.6
30 years	—	—	26.3	3.2	43.0	14.2	—	—	48.4	14.7	61.4	27.4
	$L_{EX,8h}$ = 100 dB											
10 years	25.0	4.8	34.6	8.4	46.9	16.7	43.8	13.6	53.5	21.1	63.6	32.9
20 years	35.3	7.4	44.9	13.0	56.4	22.7	49.4	19.4	63.4	30.4	73.0	42.8
30 years	—	—	51.2	16.8	61.9	27.1	—	—	69.1	36.4	77.6	48.5

Table 4 – Risk of permanent hearing loss due to age and noise (%), for women, at different noise exposure level ($L_{EX,8h}$), two frequency combinations, exposure period 10, 20 and 30 years, for two hearing threshold levels

Period of exposure	$L_{EX,8h}$ = 85 dB											
	500, 1000, 2000, 4000, Hz						1000, 2000, 3000, 4000, Hz					
	40-year old		50-year old		60-year old		40-year old		50-year old		60-year old	
	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB	>25 dB	>40 dB
10 years	0.6	0.001	3.4	0.04	11.2	0.5	1.7	0.01	6.8	0.2	18.9	1.9
20 years	0.8	0.001	3.9	0.1	12.0	0.6	2.1	0.01	7.8	0.3	20.3	2.2
30 years	—	—	4.2	0.1	12.2	0.7	—	—	8.5	0.4	20.9	2.5
	$L_{EX,8h}$ = 90 dB											
10 years	2.4	0.02	7.3	0.2	16.2	1.2	6.6	0.2	14.9	1.3	27.1	4.0
20 years	3.2	0.03	7.6	0.2	18.4	1.5	9.3	0.4	17.2	1.5	29.5	3.7
30 years	—	—	8.1	0.2	19.3	1.6	—	-	19.1	1.8	28.5	2.0
	$L_{EX,8h}$ = 95 dB											
10 years	7.5	0.2	9.3	0.2	26.4	3.8	19.4	2.1	28.3	4.3	43.2	11.6
20 years	11.0	0.5	13.8	0.4	30.9	4.5	26.0	3.5	36.4	7.4	50.7	14.8
30 years	—	—	16.8	0.5	33.0	5.3	—	—	41.9	9.4	53.9	17.3
	$L_{EX,8h}$ = 100 dB											
10 years	23.8	3.5	30.7	5.7	40.4	11.5	39.8	10.9	48.7	15.6	58.2	24.6
20 years	33.9	6.0	40.6	10.1	50.8	17.0	53.9	19.2	60.6	25.5	67.5	34.3
30 years	—	—	47.4	13.6	56.9	21.4	—	—	65.5	31.1	72.9	40.5

Figures 1 and 2 present the risk of permanent hearing loss due to noise alone for hearing threshold level > 25 dB, for 60-year old men and women working in the food industry with exposure periods of 10, 20 and 30 years at noise level $L_{EX,8h}$ = 85, 90, 95, 100 dB and frequency combination of 1000, 2000, 3000 and 4000 Hz. The risk of noise-induced hearing loss is defined as the percentage of the population of workers at a given age who would, for a given exposure period and a corresponding noise level $L_{EX,8h}$, develop a hearing deficit greater than a given threshold. The risk due to noise alone is defined as the difference between the percentages of the populations that were or were not exposed to noise with hearing threshold levels greater than the accepted limit value.

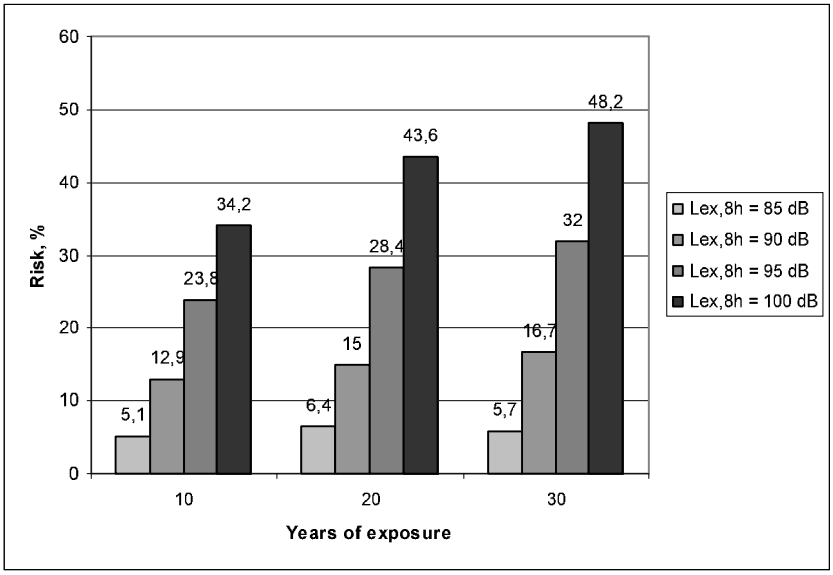

Fig. 1 – Risk of permanent hearing loss due to noise alone, for 60-year old men, at different noise exposure level ($L_{EX,8h}$), frequency combination of 1000, 2000, 3000 and 4000 Hz, exposure period of 10, 20, 30 years and hearing threshold level >25 dB

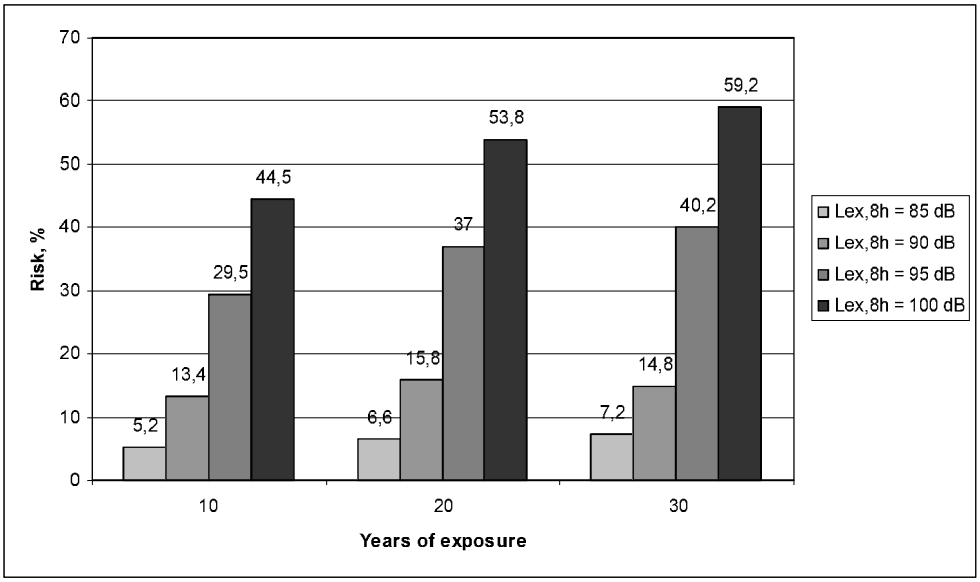

Fig. 2 – Risk of permanent hearing loss due to noise alone, for 60-year old women, at different noise exposure level ($L_{EX,8h}$), frequency combination of 1000, 2000, 3000 and 4000 Hz, exposure period of 10, 20, 30 years and hearing threshold level >25 dB

The results from figures 1 and 2 show that there is a greater risk increase for the early exposure period – between 10 and 20 years, compared to that between 20 to 30 years, probably due to the age-related shift in the hearing threshold.

Conclusions

Estimation of noise-induced hearing loss of workers in the food industry was done using the methodology of BG ISO 1999:2004. On the basis of the results obtained the following important conclusions can be made:

The risk of hearing loss due to noise and age for men is higher than for women. There is a greater increase in risk for men and women at the beginning of the working period between 10 and 20 years, compared to that between 20 to 30 years. Employers need to conduct risk assessment and have to take appropriate technical, administrative and individual measures to protect workers' health against the harmful effects of noise and to implement hearing conservation programs. The methodology used can be applied to risk assessment for workers in the food industry at different effective noise exposure levels (for effective working day duration less than 8 h), specifi-

cally selected threshold of hearing and combination of different frequencies. Future researches have to be carried out in risk assessment, including use of individual dosimeters and audiometric analysis.

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