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SPECIFIC PROTECTION REQUIREMENTS AND PSYCHOSENSORY EFFECTS TO THE NOISE GENERATED BY CONSTRUCTION EQUIPMENT

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Abstract: *The paper presents the psycho-sensory and pathophysiological effects caused by vibrations and noise generated by construction equipment while technological work processes. Thus, the causes of the occurrence of mental and auditory disorders as result of the spectral content of the noises were analyzed, as well as the level of sound pressure taken both in the driver's cabin and outside. The results of vibrations and acoustic pressure levels for earthmoving equipment were obtained by "in situ" measurements on construction sites in Romania.*
Key words: *noise, acoustic pressure level, physiological effects, cabin noise.*

1. INTRODUCTION

This paper presents the syntheses of some method and experimental results on the direct influence of noise level and spectral composition on health and psychosensory effects generated while human exposure while working on construction sites.

Thus, there were studied aspects of the harmful effects of noise on the auditory organ, as well as effects with mental syndrome or changes in health conditions at work [1 - 4].

The protection of person at work and in particular of mechanics working with construction equipment is the main objective of the study. In this context, it is pointed out that the paper presents results of the noise measurements carried out on various earthmoving machines while construction works for the motorways in Romania.

2. NOISE IMPACT ON HUMAN HEALTH

2.1 Noise effects on human

a) Effects of noise on health in industrial processes, construction and transport traffic

Noise is defined as the complex parasitic, unwanted sound (with no informational content) which depends on particular working and living conditions, leading to mental and physiological states that are harmful to exposed people [5, 6]

Noise is a main factor of fatigue and nervousness with direct negative influences on work and health. From the point of view of its propagation and perception by humans, noise evaluation is mainly done by three characteristics, as follows:

- frequency which is perceived as a physiological parameter that signifies the "pitch" of the sound (high, low, thin, thick sounds): audibility range 16 - 16,000 Hz (nine octaves) or 20,000 Hz; high sensitivity within the range 2,000-5,000 Hz and intelligible perceptions for the human voice within the range 500 - 2,000 Hz;
- acoustic pressure or intensity, which physiologically corresponds to sound strength;
- propagation speed - depends on the environment (330 m/s in air, 1,400 m/s in water and 6,000 m/s in steel).

b) Harmful effects of noise

The harmfulness of noise is the physical process (agent) that could be dangerous to the

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health of employees, conditioned by exceeding admissible limits

The effects of noise are:
- communication dysfunctions in the work process by the effect of masking words (communication sound signals);
- psychosensory dysfunctions (psychological and physiological) such as auditory fatigue, deafness, insecurity of movement, confused thinking, lack of concentration.

These categories of dysfunctions must be diminished so that the work system (man - means of production - environment) could meet the safety and health requirements set by reference documents (laws, norms, norms, standards, technical documentation and instructions) in order to prevent work accidents (communication dysfunctions) and occupational diseases (psychosensory dysfunctions).

The noise level is accepted based on the equal loudness curves, Cz, drawn in the audible range 31.5 Hz – 8,000 Hz (in eight octave frequency ranges). Depending on the duration of exposure and intensity, there can be noticed (Figure 1) the various limit values while exceeding the duration of exposure leads to auditory disorders.

Communication is possible only when the sound signals are intelligible, which leads to the requirement that the ambient sound level does not exceed 55 – 60 dB

Auditory fatigue is specific to noise containing high sounds that lead to a temporary increase in the perception of the auditory threshold (Figure 2). This leads to a decrease in hearing, decreased attention and concentration specific to the workplace. It also increases nervousness and mental instability. Auditory perception changes are temporary and reversible.

Auditory receptor trauma occurs when the sound pressure increases by high values in short time intervals, when signal variability is characterized by high speeds. The immediate effect stands in the appearance of dizziness and excessive pain in the inner ear with the possibility of deafness.

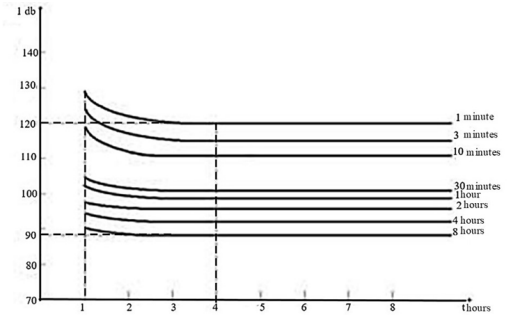

Fig. 1. Plots of the harmful effect of noise depending on the duration of exposure and intensity

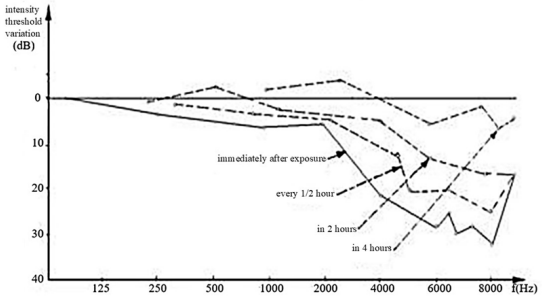

Fig. 2. Noise with high sounds

Occupational deafness is the most serious form of damage to the auditory receptors determined by high frequencies and intensities of about 100 dB for a long exposure time. Deafness starts at frequencies of about 4,000 Hz and then progresses at lower frequencies. The importance of the risk of hearing loss (according to Wisner and Javille) is evidenced by the curves shown in Figure 3.

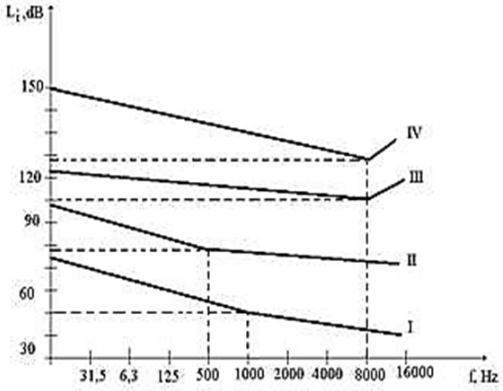

Fig. 3. Hearing loss risk, after Wisner and Javille

Curve I - at lower Li values points out the permissible sound ambience for a quality work with right ability to concentrate. The area between curves I and II corresponds to a noisy

but not dangerous environment. The area between curves II and III corresponds to the risk of hearing loss at exposure of 1/2 hours per day and intensifies by risks of 25% on curve II. The area between curves III and IV leads to high risks of hearing loss by 50-80%. Curve IV and above leads to the appearance of occupational deafness even in the case of accidental exposures.

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3. SPECIFIC REQUIREMENTS FOR NOISE PROTECTION

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3.1 Regulatory requirements

Human safety and health must not be affected by noise transmitted to the workplace, either it is physical or intellectual.

Basically, there has been accepted the idea that different regulatory is required for different workplaces, so that there is the need for separate rules governing industrial noise, buildings and means of transportation [7, 8].

The permissible limits are established according to two objectives, namely:

• ensuring protection against local effects (avoiding the onset of occupational hearing loss and deafness);

• ensuring protection against to general effects (avoiding the embarrassment effect, maintaining concentration and attention to the work process).

The general regulations of safety work environment set the limit values for categories of work according to the neuropsychological and psychosensory demand, according to the daily exposure and according to the variability of the noise level over a working day.

The maximum regulated limits are grouped as follows:

a) the maximum limit allowed at workplace with daily exposure is 87 dB(A);

b) the maximum limits allowed for workplace with high and special neuropsychic and psychosensory demand, at daily exposure are given in Table 1.

Table 1

Maximum permissible limits for noise at workplace with increased and special neuropsychic and psychosensory demand (attention, responsibility, decision, temporal constraint)

Work complexity	Workplace	Allowed noise level $L_{ec,z}$ dB(A)
Workplace with increased neuropsychic and psychosensory demand	- Testing or service laboratories -Technological processes surveillance cabins - Customs points	75
Workplace with special neuropsychic and psychosensory demand	- RTV studios and cinemas - Commnad and control cabins (as for example: energy dispatch; road, railway, maritime transport dispatch); - Laboratoaries for measurements, research and design; - Offices, computer rooms; - Treatment rooms; - Counters where they work with the public, value handling, postal mapping - Rooms for writing in print and audio media - Medical offices, study rooms, classrooms, amphitheaters, libraries	60
	- Surgery and treatment rooms; -Creative workshops; -Air traffic management and information rooms	50

3.2 Parametric requirements

The continuous equivalent noise level, Lech, is the level of a constant noise over time, which acting continuously over a given period of time

(one day or one week) gives the same noise exposure compound index as the weighted global noise levels of the actual noises measured in the time interval considered.

a) *Daily personal exposure of a worker*

Daily personal noise exposure of a worker is expressed in dB(A) by the relationship:

$$L_{EP,z} = L_{Aech,T_e} + 10\lg\frac{T_e}{T_0} \qquad (1)$$

where:

$$L_{Aech,T_e} = 10\lg\left\{\frac{1}{T_e}\int_0^{T_e}\left[\frac{p_A(t)}{p_0}\right]^2 dt\right\} \qquad (2)$$

where:

T_e is the daily duration of the employee's personal exposure to noise (it can be greater or less than 8 h);

$T_0 = 8\text{h} = 28.,800\text{s};\ p_0 = 20\,\mu\text{ Pa};$

p_A - instantaneous A-weighted sound pressure [Pa], in the air at atmospheric pressure, to which is exposed an employee who may or may not move from one place to another during work.

This pressure is determined from measurements made at the position occupied by the employee's ears during work, preferably in his absence, using a technique that minimizes the action on the acoustic field.

L_{Aech,T_e} - represents the continuous equivalent sound level during the daily exposure to noise Te defined as the sound level in dB(A) of a constant noise and which, acting continuously throughout the working day, has an auditory effect similar to the effect of variable noise really measured at the workplace.

If the microphone is to be placed very close to the person's body, appropriate corrections must be made in order to determine an equivalent pressure in the undisturbed field.

Daily personal exposure to noise does not take into account the effect of personal noise protection equipment.

b) *Weekly average of daily values*

Weekly average of daily values is determined by the relation:

$$L_{EP,s} = 10\lg\left[\frac{1}{5}\sum_{k=1}^{m} 10^{0,1(L_{EP,z})_k}\right] \qquad (3)$$

where: $(L_{EP,z})_k$ represent the $L_{EP,z}$ values for each of the "m" working days in the considered week.

In table 2 there are presented the values for noise values measured in the construction equipment within the period 2018-2023 in Romania.

Table 2

Noise level and vibrations measured in construction equipment

No.	Equipment	Noise level dB(A)	
		interior Leq	exterior Lp
Excavators (bucket, rotor, scrapers)			
1	P 802 (PROMEX)	79	76,5
2	P 851 HyEl (PROMEX)	76,1	78,16
3	S 1204 HyEl (PROMEX)	76,9	77,39
	S 1203 (PROMEX)	74	78
Buldoexcavators			
1	Buldoexcavator CATERPILLAR type 428 D	77,8	-
2	Buldoexcavator FIAT - HITACHI type FB 90 / 2 – 4PT	74,5	-
3	Excavator – Loader BOREX, tip 2101	88,2	-
4	Multifunctional front loader COMELF, type 50.25	91	-
5	Buldoexcavator FIAT – HITACHI , type FB 100 – 4PT/A	74	-
6	Hidromek TR HMK type 102B	79,4	-
7	model JCB, type 2CX Streetmaster	79	-
8	model KOMATSU, tip WB 93R – 2	77	
Front loaders (wheels, tracks, skid)			
1	Multifunctonal compact equipment, model ROBOT, tip 170, JCB	91,6	-
2	Front loader GEHL, model SL 4625	85,5	-
3	Front loader IF 130 (NICOLINA)	-	-

4	model JCB, tip 407B ZX	67	-
5	model KOMATSU, typee WA 270 - 3	74	-
6	Container Frontlift type MO-G 36-4CH-5BI (forks)	80,1	80,9
Compactors			
1	Vibratory compactor roller, type W 554 (Vibromax)	81,2	-
2	Vibratory compactor roller type BW 141 AD-2 (BOMAG)	-	-
3	Vibratory compactor roller type BW 211 D-3 (BOMAG)	-	-
4	Roller compactor with tires, model DYNAPAC, type CP 201	86,6	71,3
5	Vibratory compactor roller, model VIBROMAX, type W 1601	87	80
Pickaxes, Demolition hammers or drills			
1	Portable Power Demolition Tool, model SPIT, type 490 (PRAKT)	92,8	-
2	Portable Power Demolition Tool, model SPIT, type 331 (PRAKT)	84,8	-
Asphalt mixing plants			
1	IMA E (NICOLINA)	77,4	86,2
2	Model NICOLINA - MARINI, type 80 – 90	70	-
Vibratory plates, Vibratory tampers			
1	Vibratory Plate Compactor, model AMMANN, type AVH 6020	96,7	-
2	Unidirectional vibratory plate, model BOMAG, type BP 18/45 D -2	97,4	-
3	Vibratory tamper, model: SL 2R (VIBROMAX)	96	-
4	Vibratory plate – type VD 450/22	85	-
5	Vibratory plate RAVI model: RRP 21 DY	96	-

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3.3 Evaluation method

If the noise level varies while the working day, but it is constant over time intervals, the continuous equivalent noise level is calculated with the relationship:

$$L_{eq,z} = 10\lg\left[\frac{1}{100}\sum f_i \cdot 10^{\frac{L_i}{10}}\right] \qquad (4)$$

where: L_i – is the noise level over the time interval f_i ;

f_i – is expressed as percentages of the length of the working day.

In order to identify the employees and the jobs that fall within the limits of these norms, noise measurements must be carried out periodically or whenever there are changes in the workplace. Noise measurements must be planned and carried out competently at regular intervals and stand as the responsibility of employers. Any sampling must be representative of an employee's daily personal exposure to noise.

The methods and equipment used must be adapted to the prevailing conditions, especially when there are envisaged the characteristics of the noise to be measured, the duration of exposure, the environmental factors and the characteristics of the measuring equipment.

Employees and/or their representatives must participate in the noise determinations and measurements carried out. Measurements must be repeated when there is a belief that they are incorrect or that there has been a significant change in the workplace. The employer has the obligation to ensure the preservation of the noise measurement reports and the sheets on the hearing status of the employees.

The doctor and/or the authorities responsible in the field, as well as the employees and/or their representatives in the company must have access to these data.

If exposures are found to exceed the limit value, the employer:

- immediately takes measures to reduce the exposure to a level below the exposure limit values;
- determines the causes of excessive exposure and adapts protection and prevention measures in order to avoid any exceedance.

In places where an employee's daily personal exposure exceeds 20 dB(A) or when the maximum unweighted instantaneous acoustic pressure value is greater than 112 Pa (135 dB from the reference pressure of 20 μPa), appropriate measures shall be taken to ensure that:

• employees and/or their representatives in the enterprise or institution do get adequate information and, where appropriate, training regarding:

- the potential risks to their hearing due to exposure to noise; - the measures taken to comply with the provisions of this regulatory;

- the obligation to comply with the protection and prevention measures, in accordance with the legislation in force;

- wearing personal noise protection equipment and the role of hearing checks in accordance with art.611 of the General Norms of Labor Protection.

• employees and/or their representatives in the enterprise or institution must have access to the noise determinations and measurements carried out in accordance with Article 597 and may receive explanations regarding the significance of these results.

Workplaces where the daily personal exposure to noise exceeds 85dB(A) or where the maximum value of the unweighted instantaneous sound pressure exceeds 200 Pa, must be marked with signs showing that wearing of personal noise protection equipment is mandatory according to the Minimum Requirements for Safety and/or Health Signs at Work. The signs must be placed at the entrances to the areas and, if necessary, inside them.

These areas must also be delimitated and where the risk of exposure justifies it and it is technically possible, access to them must be restricted.

The risk resulting from exposure to noise must be eliminated at source or minimised, taking into account technical progress and the possibility of applying noise reduction measures at source.

In the workplace where an employee's daily personal exposure exceeds 85 dB(A) or, the maximum value of the unweighted instantaneous acoustic pressure is greater than 200 Pa, some measures are to be taken, as follows:

a) must identify the causes of the high level;

b) the employer must establish and apply a program of technical measures and/or organization of the activity in order to reduce the employees' exposure to noise;

c) the employees and their representatives in the unit must receive adequate information regarding the high level and the measures taken.

In the workplace where an employee's personal daily noise exposure exceeds 80dB(A), or the maximum unweighted instantaneous acoustic pressure value is greater than 112Pa, the employer shall provide employees with personal noise protection equipment.

In the workplace where an employee's daily personal noise exposure exceeds 85dB(A) or the maximum value of the unweighted instantaneous acoustic pressure is greater than 200Pa, the wearing of personal noise protection equipment is mandatory. The employer must provide a sufficient number of personal noise protection equipment, the models being chosen together with the affected personnel.

Personal noise protection equipment must be adapted to each employee and his working conditions, considering his safety and health. They are considered appropriate and adequate if, when worn correctly, the noise level at the person's ear is below 80dB(A). At workplaces where the daily personal exposure of employees cannot be reduced below 85 dB(A), the hearing status of the staff must be examined at the time of employment and periodically by a physician or other qualified person under the responsibility of a physician.

The aim of the check should be to diagnose noise-induced hearing loss and preserve hearing. At the design of units, of technical equipment and at their construction, measures will be provided to reduce noise to the lowest possible level through constructive characteristics (insulation and acoustic absorption of building elements based on

evaluations of the level of noise sources, criteria for the location of noise sources, etc.).

Where it is likely that a new technical equipment (tool, machine, apparatus, etc.), which is to be put into operation will produce to the employee who uses it correctly over a conventional period of eight hours, a daily personal exposure to noise equal to or greater than 85 dB(A) or, an unweighted instantaneous acoustic pressure with a maximum value equal to or greater than 200 Pa, information on noise under specified conditions of use must be provided.

4. CONCLUSION

In order to reduce the harmful effects of noise at workplaces, according to the data presented, the actions required are either individually, or grouped as follows:

a) measures to fight against noise at the source - carried out by constructive changes to the technical equipment or by fitting special attenuating devices; when choosing the technical equipment, under comparable technological conditions, priority will be given to those that produce the least noise;

b) measures to isolate noise sources - achieved by increasing the resistance of the environment to the transmission of acoustic energy; the most commonly used solutions consist in the placing soundproofing screens or in soundproofing casing of the technical equipment;

c) measures to fight against noise at the receiver - isolating the personnel working in a noisy area, the best known solution being that of using use of soundproofing booths.

The previous technical measures must be completed by the following organizational measures:

d) training the personnel on the risk of exposure to noise action and on how to use personal noise protection equipment;

e) examining the hearing status of personnel working in workplaces with high noise levels (at the time of employment and periodically);

f) establishing the work schedule on workstations according to the duration of exposure to noise.

In the case of workplaces where an employee's noise exposure varies considerably from one working day to another, it is accepted to exceed the maximum permissible limit during a working day provided that the average weekly noise exposure of that employee does not exceed the maximum permissible limit.

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CERINȚE SPECIFICE DE PROTECȚIE ȘI EFECTE PSIHOSENZORIALE LA ACTIUNEA ZGOMOTULUI EMIS DE MAȘINILE DE CONSTRUCȚII

Abstract: În lucrare se prezintă efectele psiho-senzoriale și fiziopatologice cauzate de vibrațiile și zgomotul emis de mașinile de construcții în timpul proceselor tehnologice de lucru. Astfel, au fost analizate cauzele apariției unor afecțiuni psihice și auditive ca urmare a conținutului spectral al zgomotelor, cât și nivelul de presiune acustică aveluat atât în cabina mecanicului cât și în exterior. Rezultatele vibrațiilor și a nivelurilor de presiune acustică pentru mașinile de terasamente au fost obținute prin măsurători ,,in situ" pe șantierele de construcții din România.

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