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ERGONOMIC EVALUATION OF ACOUSTIC ENVIRONMENT IN THE LIVESTOCK BUILDING CONVERTED FOR INDUSTRIAL PURPOSES

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Abstract. Research related to ergonomic evaluation of acoustic environment in PCPW EKO-KARPATY in Tarnowiec during production of agricultural anti-weed fabric. The scope of the paper included noise measurement and spectrum analysis at particular unassisted work stations of the process line. The conducted analysis indicated that applicable standards were exceeded in all cases and that there was justified fear that conversion of spaces designed for agricultural production for industrial applications will have a negative impact on health of people working in these conditions. Some suggestions were developed regarding modifications that will ensure conformity with the applicable standards regarding noise level.

Key words: production process, noise, work environment, ergonomics

Introduction

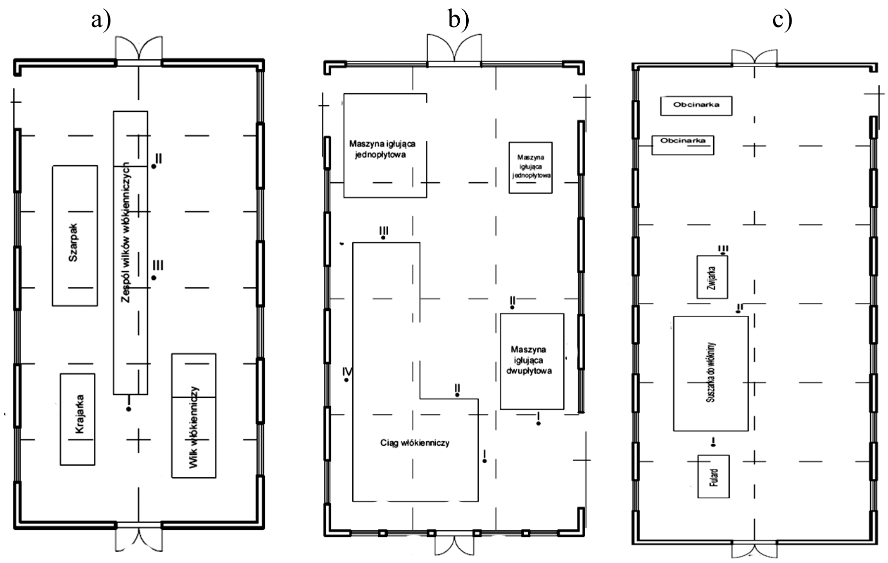
It is economy and market for production activity that makes necessary conversion of existing livestock buildings into spaces for industrial purposes. Many times minimizing of costs results in assembly of machines comprising processing lines in spaces actually designed for other applications. Change of building and use of maintained existing structure results in a change of work organization, as well as the nature of performed operations which leads to the change of factors that have impact on comfort of the worker's work. Noise generated by machines is a factor inseparably linked to machines operation that has a negative impact on human health and efficiency. Noise is the most essential risk for health of an agri-food industry worker at both phase of preparation and production (Wilkus, 2007). Speed and scope of changes taking place in human organism as a result of noise depends on: sound pressure level, frequency, exposure time, nature of noise and individual personal sensitivity (Górska, 2007). As specified by Puzyna (1981), noise has impact on the quality and precision of performed work, and influence is more evident, if work requires more concentration or precision. According to Olszewski (1993) because of noise it is necessary to increase stock, reduce flow of funds, and it results in increased sick absenteeism, idle capacity losses, increased overtime work, more errors and deficiencies. Noise also affects comprehensibility and masking of speech as well as emergency sound signals (Engel, 1993). According to Lines et al. (1994) during 10 years (studies regarding the turn of 80- and 90-ties) the rate of people complaining because of noise increased three times. According to the Polish Central Statistical Office (GUS) in 2012, as many as 293.3 thousand of people (including 41.4 thousand of women) worked in conditions under risk of hazards related to work environment (respectively 5.5% and 0.8% of total number of workers who participated in the research). Considering all factors related to work environment, the biggest hazard was related to noise to which as many as 195.5 thousand people (53.2% of person-hazard related to work environment) were exposed to. Note that GUS statistical data included only plants that employed at least 10 workers, thus the issue of noise most probably concerns a higher number of people. The characteristic values of noise at work place, as well as permitted maximum concentration were specified in the Attachment to the Regulation of the Minister of Labour and Social Policy of 29 November 2002 on the maximum admissible concentrations and intensities for agents harmful to health in the working environment (Journal of Laws [Dz.U.] of 2002. No 217, item. 1833). Noise thresholds levels were specified in the Ordinance of the Minister of Economy and Labour of 5 August 2005 on occupational safety and health in occupational exposure to noise and mechanical vibrations (JoL of 2005 No 157, item. 1318).

The objective and scope of the research

The purpose of the research was ergonomic evaluation of acoustic environment in PCPW EKO-KARPATY in Tarnowiec during manufacture of agricultural anti-weed fabric. The scope of the study included measurement of noise level determined in dB(A) and spectrum analysis of noise at particular unassisted work places of fabric process line. The research specified the degree in which the cowhouse converted into industrial purposes complies with requirements of standards and some suggestions were developed regarding modifications to ensure conformity to the applicable standards regarding the noise level and improved work comfort.

Research methodology

Measurements of noise were made on basis of PN-N-1307 Polish Standard. Measuring points, building A – textile machine operator work place – operation of shear-grinder machine – point I, II, II (figure 1a), building B – textile machine operator work place – operation of textile machine line– point I, II, III, IV (figure 1b), textile machine operator work place – operation of needling machine – point I, II (figure 1b), building C – textile machine operator work place – operation of non-woven drying machine – point I, II, II (figure 1c) were determined on basis of analysis of locations where employees were present during work performance. On the basis of time records regarding presence of particular workers at above places, the daily exposure to noise was determined for these workers.



Slitter – cutting machine; Szarpak –shredder; Zespół wilków włókienniczych – shear grinder textile machines unit; Wilk włókienniczy – shear-gridner textile machine; Ciąg włókienniczy – textile machine line; Maszyna iglująca jednoplytowa – single-plate needling machine; Maszyna iglująca dwuplytowa – double-plate needling machine; Fulard – padding machine; Zwijarka – coiling machine; Obcinarka – cutter

Figure 1. Layout of production floor: a – operation of shear-grinder textile machine, b – operation of textile machine line and operation of needling machine, c – operation of non-woven fabric drying machine

Production process of agricultural fabric includes a few phases and follows on a few work places. At the first phase two operators take particular types of raw material according to the specified recipe and carry it to the assembly of two shear-grinder textile machines (figure 2a) where total and precise mixing is provided. Next polyester fibre mixture is carried with pneumatic conveyors to transport cages and is transported to the production building. Next the material is introduced into the feeder that ensures automatic weighing of fibre batches, as well as dosing to the initial shredder. Next precise mixing of fibre follows with two carding machines, as well as combing and shearing follows on the stacker (fig. 2b).

Wool layers then are inserted by crushing rolls, into an initial needling machine throat where connection follows of many thin wool layers to produce non-woven fabric. This fabric upon initial needling is then wound on as a bale with a winding machine. During the next phase needling follows with two needling plates that make reciprocating movement on double-plate needling machine (fig. 3a). This intensive needling enables to impart appropriate structure for the non-woven fabric. The last phase of production relates to thermal treatment of non-woven fabric (fig. 3b).

This process includes the "passage" of non-woven fabric through a tunnel dryer heated with air of temperature approximately 140ºC which results in contraction of heat shrink fibres and imparting the product the final form in respect of thickness, basic weight and hardening of structure.

a) b)

Figure 2. Agricultural textile production process; a – assembly of shear-grinder textile machines and transport cage, b – Textile machine line (feeder and carding machine)

a) b)

Figure 3. Production process of non-woven fabric; double-plate needling machine, b – non-woven fabric drying machine

Measurement of sound followed with digital sound analyzer DSA-50 with a function of a noise dosimeter. Because a worker during performance of his tasks changes his location, the position of measuring points was specified to be at height of 1.55 m ± 0.075 m from the plain, where worker was standing (pursuant to PN-EN ISO 9612:2011). Measurements were made in accordance with 1 method – Measurements for individual activities.

Calculation of equivalent sound level $L_{Aeq,Te}$ followed with the use of the following formula [PN-N-1307:1994].

$$L_{Aeq,Te} = 10 \log \left[\frac{1}{T_e} \int_0^{T_e} \left(\frac{p_{A(t)}}{p_0} \right)^2 dt \right] \quad [\text{dB}] \qquad (1)$$

where:

- T_e – exposure time during workday or longer specified period, e.g. working week (s),
- p_A – momentary value of sound pressure, corrected according to frequency A characteristic (Pa),
- p_0 – reference sound pressure $2 \cdot 10^{-5}$ (Pa).

Calculation regarding exposure to the noise level attributed to 8-hour workday $L_{EX,8h}$ according to PN-N-01307 followed with formula.

$$L_{EX,8h} = L_{Aeq,Te} + 10\log\left(\frac{T_e}{T_0}\right) \quad \text{(dB)} \tag{2}$$

where:

$L_{A,eqTe}$ – equivalent sound level according to frequency A characteristic within T_e time period, (dB),

T_e – exposure time during workday or longer specified period, e.g. working week, (s),

T_0 – reference time, T_0 = 8h.

Selection of ear protection followed with the use of Tarbonus software with the octaves method.

Research results

Table 1 included the sound level measurement results made at specified measuring points with ”A” correcting filter at a work station of a textile machine operator (shear-grinder textile machine operation). The equivalent sound level $L_{A,eq,\ Te}$ referred to the total exposure time T_e of 420 min was 84.4 dB, whereas the level of exposure to noise attributed to 8 hour workday $L_{EX,8h}$ was 84.1 dB.

Table 1

Level A of sound at textile machine operator work place – shear-grinder textile machine operation

Measuring point	Measurement No.	Exposure Time T_i (min)	$L_{A,eq,i}$ (dB)	$L_{A,eq,\ Te}$ / $L_{EX,8h}$ (dB)
I	1	140	81.4	81.5
	2		81.5	
	3		81.4	76.1
	4		81.4	
	5		81.6	
II	1	140	87.5	87.3
	2		87.2	
	3		87.1	81.9
	4		87.4	
	5		87.1	
III	1	140	83.4	83.4
	2		83.4	
	3		83.4	78.1
	4		83.5	
	5		83.4	

In the analyzed case the level of exposure to noise attributed to 8- hour workday $L_{EX.8h}$ in relation to applicable standards was not exceeded; whereas the threshold value was exceeded of noise specified in standard as 80 dB. On the basis of the obtained results the multiplicity as determined of highest permitted noise level (*NDN*) that was 0.82. The Table No. 2 included values of sound pressure level recorded in respect of frequency.

Table 2
Sound pressure level in respect of frequency at work place of textile machine operator – shear-grinder textile machine operation

Medium Frequency of Octaves Band Resolution (Hz)	Sound Pressure Level (*L*) (dB)		
	Measuring Point		
	I	II	III
31.5	42.5	49.0	42.8
63	54.0	59.3	57.2
125	63.5	71.4	68.9
250	72.2	82.5	75.6
500	76.9	81.1	78.9
1k	76.1	83.1	78.6
2k	73.6	82.9	76.4
4k	67.5	75.4	72.4
8k	62.1	66.9	60.6

On the basis of the measurement results (table 2) the selection of a hearing protector followed with the use of Tarbonus software for specified measuring points (table 3).

Table 3
List of selected hearing protectors at work place of textile machine operator – shear-grinder textile machine operation

Measuring Point	Product Name	Sound Level under hearing protector (dB)	Hearing protector Attenuation (dB)
I	P.O.P Bilsom SWED-POLEXI earplugs	67.0	14.5
II	P.O.P Bilsom SWED-POLEXI earplugs	73.5	15.3
III	P.O.P Bilsom SWED-POLEXI earplugs	67.9	14.6

Taking into account the fact that particular workers during a shift circulate between each of three measuring points, Bilsom SWED-POLEXI branded earplugs would be the best solution as the most universal and ones which ensure the sound level under ear protection at particular points from 67.0 dB to 73.5 dB which would be within the range specified in PN-EN 458: 2006.

Analysis of the sound level at the work place of a textile machine operator – operation of machine textile (table 4) recorded at III measuring point the equivalent sound level $L_{A.eq.Te}$ of 74.5 dB which was by 9.7 dB lower than the value of the sound equivalent level recorded at IV measuring point. Globally in case of the analyzed work place the sound level $L_{A.eq.Te}$ was 80.9 dB whereas the level of exposure to noise attributed to 8-hour workday $L_{EX.8h}$ was 80.3 dB.

Table 4
Level A of sound at work place of textile machine operator - operation of textile machine line

Measuring Point	Measurement No.	Exposure Time T_i (min)	$L_{A.eq.i}$ (dB)	$L_{A.eq.\ Ti}$ $L_{EX.8h}$ (dB)
I	1	105	81.4	80.6
	2		80.2	
	3		80.6	
	4		81.0	74.0
	5		79.6	
II	1	105	79.6	79.5
	2		79.5	
	3		79.6	
	4		79.4	72.9
	5		79.5	
III	1	105	74.6	74.5
	2		74.6	
	3		74.5	
	4		74.4	67.9
	5		74.4	
IV	1	105	83.9	84.2
	2		83.6	
	3		84.4	
	4		84.4	77.6
	5		84.5	

NDN multiplicity of the highest permitted level of exposure to noise at the work place of a textile machine operator – operation of textile machine line – was 0.34. Consequently tests of noise at this work place shall be carried out at least once within the period of two years according to the JoLof 2011. No. 33. item 166. Table 5 specified the sound pressure level in respect of frequency.

As permitted threshold was exceeded regarding the permitted noise exposure of 0.3 dB for the worker operating the textile line. Bilson branded P.O.P. earplugs were selected as a hearing protector.

Level A of sound at the work place of a textile machine operator (operation of a double-plate needling machine) at the specified measuring points (table 6) was within the range from 83 dB(A) in case of the first measurement at II measuring point to 89.7 dB(A) recorded at I measuring point. The equivalent sound level ($L_{A.eq.\ Te}$) attributed to the total exposure time T_e of 420 min. was 87.5 dB, whereas the level of exposure to noise attributed to 8-hour workday $L_{EX.8h}$ was 86.9 dB.

Table 5
Sound pressure level in respect of frequency at work place of textile machine operator – operation of textile machine line

Medium Frequency of Octaves Band Resolution (Hz)	Sound Pressure Level (L) (dB)			
	Measuring Point			
	I	II	III	IV
31.5	51.6	42.0	37.1	39.3
63	59.6	48.1	44.9	49.4
125	62.5	60.5	58.1	63.2
250	70.8	70.3	62.8	71.5
500	74.4	73.2	70.2	74.4
1k	72.8	75.6	71.0	79.1
2k	71.2	75.3	67.4	76.3
4k	70.0	72.4	65.5	77.9
8k	64.4	66.7	61.6	79

Table 6
Level A of sound at work place of textile machine operator – operation of double-plate needling machine

Measuring Point	Measurement No.	Exposure Time (T_i) (min)	$L_{A.eq.i}$ (dB)	$L_{A.eq.\ Ti}$ $L_{EX.8h}$ (dB)
I	1	210	89.7	89.6
	2		89.6	
	3		89.6	
	4		89.5	86.9
	5		89.6	
II	1	210	83.0	83.4
	2		83.5	
	3		83.4	
	4		83.7	79.8
	5		83.5	

The permitted level of exposure to noise attributed to 8-hour workday was exceeded by 1.9 dB, whose permitted value was 85 dB and at the same time the noise permitted threshold was exceeded. *NDN* multiplicity was 1.36 which pursuant to the JoL of 2011 No. 33. item 166 obliged the employer to conduct noise measurements at least once a year. Moreover the employer shall upgrade the work place to prevent any similar situation in future. Table 7 included sound pressure level in respect of frequency – operations of double-plate needling machine.

Table 7
Sound pressure level in respect of frequency at work place of textile machine operator – operation of double- plate needling machine

Medium Frequency of Octaves Band Resolution (Hz)	Sound Pressure Level (L) (dB)	
	Measuring Point	
	I	II
31.5	51.5	53.5
63	61.5	63.5
125	79.0	73.1
250	87.2	80.2
500	83.8	79.5
1k	81.7	76.2
2k	80.4	76.9
4k	75.6	72.5
8k	58.8	56.1

On the basis of measurement results (table No. 7) the appropriate hearing protector was suggested with position of measuring points (table No. 8).

Table 8
The list of selected hearing protectors at work place of textile machine operator – operation of double-plate needling machine

Measuring Point	Product Name	Sound Level under Ear Protection (dB)	Ear Protection Attenuation (dB)
I	P.O.P Bilsom SWED-POLEXI earplugs	73.8	16.8
I	Bilsom earmuffles	72.8	17.7
II	P.O.P Bilsom SWED-POLEXI earplugs	68.6	16.5

From the suggested hearing protectors, actually P.O.P Bilsom branded SWED-POLEXI earplugs were selected which ensured noise level reduction at the work place of a textile machine operator – operation of a double-plate needling machine from 89.7 dB to 68.6 dB – 73.8 dB which would be within the range permitted by an applicable standard.

Table No. 9 included the sound pressure level of drying machine operation corrected according to frequency "A" characteristic at particular measuring points. The highest sound levels were recorded at III measuring point where the equivalent sound level was 92 dB(A). The equivalent sound level $L_{A.eq.Te}$ attributed to the total exposure time T_e of 420 min. was 88.2 dB(A), whereas the level of exposure to noise attributed to 8-hour workday $L_{EX.8h}$ was 87.6 dB (A).

Table 9
Level of A sound at work place of textile machine operator – operation of fibre drying machine

Measuring Point	Measurement No.	Exposure Time (T_i) (min)	$L_{A.eq.i}$ (dB)	$L_{A.eq.\,Ti}$ $L_{EX.8h}$ (dB)
I	1	140	80.6	80.8
	2		81.0	
	3		81.0	75.4
	4		80.8	
	5		80.6	
II	1	140	84.3	84.2
	2		84.2	
	3		84.2	78.9
	4		84.1	
	5		84.3	
III	1	140	92.0	92.0
	2		92.1	
	3		92.0	86.6
	4		91.9	
	5		92.0	

The noise threshold was exceeded, as well as the level of exposure to noise attributed to 8-hour workday was exceeded by 2.6 dB. *NDN* multiplicity at the work place of a textile machine operator – operation of a fibre drying machine was 1.59 and in case of these results according to the JoL of 2011, No. 33, item 166 noise tests shall be conducted at least once a year and actions shall be taken pursuant to JoL of 2005. No. 157. item 1318 §9.2. Table 10 included the sound pressure level in respect of frequency at the work place of a fibre drying machine operator.

Table 10
Sound pressure level in respect of frequency at work place of textile machine operator – operation of fibre drying machine

Medium Frequency of Octaves Band Resolution (Hz)	Sound Pressure Level (L) (dB)		
	Measuring Point		
	I	II	III
31.5	53.7	40.9	44.9
63	59.6	58.4	62.7
125	79.2	74.3	76.8
250	74.9	79.2	85.4
500	79.4	77.8	98.5
1k	80.5	78.6	85.5
2k	71.4	76.9	83.4
4k	70.2	69.7	77.5

8k	57.9	58.4	66.4

On the basis of measurement results (table 10) the appropriate ear protection was proposed along with position of measuring points (table 11).

Table 11
The statement of selected ear protection at work place of textile machine operator – operation of fibre drying machine

Measuring Point	Product Name	Sound Level Under Ear Protection (dB)	Ear Protection Attenuation (dB)
I	P.O.P Bilsom earplugs	69.3	15.5
II	P.O.P Bilsom earplugs	70.7	14.6
III	Bilsom 717 earmuffles	75.0	24.1

The optimal selection with regard to hearing protectors at the work place of a textile machine operator – operation of a fibre drying machine referred to earplugs that reduced noise level to 74.6 dB under a hearing protector at III measuring point.

Conclusion

The research identified that values specified in the standards regarding the noise level were exceeded at each work station. There is a justified fear that conversion of spaces designed for agricultural production for industrial applications, that most often follows quickly without required preparation, although is justified in terms of economy will have a negative impact on health of people working in these conditions. In case of work of people at the analyzed production process the individual hearing protectors will provide for sufficient solution. Whereas to ensure work comfort, the essential parts of machines shall be fitted with additional noise –reduction guards.

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ERGONOMICZNA OCENA ŚRODOWISKA AKUSTYCZNEGO W ADAPTOWANYM DO CELÓW PRZEMYSŁOWYCH BUDYNKU INWENTARSKIM

Streszczenie. Badania dotyczyły ergonomicznej oceny środowiska akustycznego w PCPW EKO-KARPATY w Tarnowcu podczas produkcji włókniny przeciwchwastowej. Zakres pracy obejmował pomiar poziomu hałasu oraz przeprowadzenie jego analizy widmowej na wyszczególnionych samodzielnych stanowiskach roboczych wchodzących w skład ciągu technologicznego. Przeprowadzona analiza wykazała, że obowiązujące normy zostały przekroczone we wszystkich przypadkach i istnieje uzasadniona obawa, że modyfikacja pomieszczeń projektowanych z myślą o produkcji rolniczej na pomieszczenia, w których odbywa się produkcja przemysłowa będzie miała negatywny wpływ na zdrowie pracujących w takich warunkach ludzi. Opracowano propozycje zmian prowadzących do spełnienia obecnie obowiązujących norm dotyczących hałasu.

Słowa kluczowe: proces produkcyjny, hałas, środowisko pracy, ergonomia

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