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EVALUATION OF ANNUAL EXPOSURE TO NOISE AMONG PRIVATE FARMERS ON SELECTED FAMILY FARMS OF ANIMAL PRODUCTION PROFILE

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Abstract: The aim of the study was the recognition and evaluation of annual exposure to noise among private farmers on family farms of animal production profile. The study covered 16 family farms using arable land of the size of 14-50 ha (25.8 ha on average), equipped with agricultural tractors (working with a set of agricultural machines), machines for the production of fodder, workshop machines and woodworking saws. Based on the precise working time schedules concerning agricultural activities and dosimetric measurements conducted during the whole year, two acoustic parameters were determined: total exposure in individual months and equivalent daily exposure.

The study showed that the highest values of the total monthly exposure to noise occurred in two summer-autumn months (August, October) and during four winter-spring months (January, March, and May, June). High values of the total exposure observed in the summer-autumn season result from the performance of intensive field and transport work activities, with prolonged duration of work and a large number of workdays in these months. The occurrence of high total values of the total exposure in winter-spring months, however, is associated with logging wood for winter (saws) and intensive repair work activities. In the seasons of the year analysed, high values of equivalent daily exposure were obtained, within the range: 4.20-4.86 $Pa^2 \cdot h$. The average value of this parameter for the whole year reached the value: 3.61 $Pa^2 \cdot h$ (standard exceeded 3.6 times). This value is equivalent to the mean level of exposure to noise equal to 90.5 dB. In consideration of the moderate accuracy of mean values obtained and small degree of variability of the results, the data acquired in this study may be used in practice by proper State services for the evaluation of noise risk among private farmers specializing in animal production.

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Key words: annual exposure to noise, working time schedules, dosimetric measurements, monthly exposure, equivalent daily exposure.

INTRODUCTION

Noise is one of the most important and hazardous physical factors occurring in private farmers' working environment. Studies of the state of hearing, conducted in recent years among a selected group of 128 farmers by the Institute of Agricultural Medicine in Lublin, confirm high risk to the organ of hearing among this population group [6, 7]. The results of these studies showed great hearing loss, especially within the range of high audiometric frequencies (4–6 kHz); 35–40 dB on average. These are frequencies typical of acoustic trauma. In addition, a highly statistically significant correlation was observed ($p < 0.001$) between hearing loss and age of the people examined ($r = 0.32–0.53$; for 3–8 kHz), and a slightly lower correlation between hearing loss and the period of

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employment ($r = 0.20–0.27$; for 3–8 kHz; $p < 0.01–0.05$). The mean values of hearing loss obtained in the group of farmers were considerably higher than the values in the control group ($p < 0.001$), which confirms that this hearing loss is of a typically occupational character.

In order to recognize the degree of risk due to noise occurring in the occupational environment to the organ of hearing among private farmers, studies were undertaken within the statutory research problem [8]. The aim of the study was evaluation of annual exposure to noise among private farmers specializing in animal production on selected family farms.

MATERIALS AND METHODS

Studies were conducted on 16 family farms using arable land of the size 14–50 ha (25.8 on average) in the area of 6 communes in the Lublin Region. On the farms in the study, a total number of 42 tractors of various power (Polish, Czech and Belorussian manufacture), were used, among which the greatest number were low-powered (15 tractors, mainly of the C-330 type) and medium-power (13 tractors; C-360 type), followed by Czech made tractors (8 tractors, 'Zetor' type) and high-power tractors (6 tractors - various types, Polish made).

The farms in the study were equipped with a basic set of agricultural machinery coupled with a tractor (mounted, attached, driven by power take-off shaft) indispensable for agricultural production. The following machinery was used on these farms for the production of fodder for breeding animals: radial plate grinding mills, grinding mills of the 'Bąk' type, grain crushers and fodder mixing machines. In addition, some workshop machinery was applied for the repair of agricultural machines and equipment (e.g. angular grinders, bench-grinders, drill, welders, etc.), as well as machinery for logging (circular and chain saws) and construction machinery (concrete mixers). The above-mentioned machinery constituted the basic source of noise to which private farmers were exposed.

The selected farms specialized primarily in animal production (breeding dairy cattle and swine). For the production of animal fodder, mainly own raw materials were applied, based on cereals, green fodder, sweet corn, hay and beet pulp, carrot and beet leaves. Additional work activity on several farms was the production of vegetable and root crops (potatoes, sugar or fodder beets).

The farms in the study were engaged mainly in dairy cattle breeding (10 farms - 62% of the total number of farms). On these farms, the number of cattle bred was 21 - 62 (36 cows on average), including dairy cattle 10–47 (24 animals on average). The remaining 6 farms (38%) carried out swine production, the number of animals being 100–500 annually (270 swine on average annually).

The scope of studies covered:

- keeping time-schedule records of agricultural activities performed by farmers on their own farms, during which there occurred exposure to noise (these measurements were carried out by farmers under the supervision and control of the research team from the Institute);
- dosimetric measurements of noise emitted by agricultural machinery and equipment while performing selected agricultural activities.

Time-schedule measurements were performed throughout the whole year (2003). Dosimetric measurements were carried out with the use of the following noise dosimeters: Bruel-Kjaer Type 4436, Sonopan Type D-20 and Robotron Type 00080. The basic acoustic parameter characterizing risk was the so-called 'exposure to noise' [$E_{A,T}$] expressed in $Pa^2 \cdot h$, according to the Polish standard [4].

The following values were determined in order to evaluate exposure to noise: total monthly exposure to noise and mean equivalent daily exposure (referring to legally accepted workdays in a month). The mean equivalent daily exposure (for an individual month) is the value obtained from the ratio between the total monthly exposure to the number of days legally established as workdays in an individual month.

The results of the studies were statistically analysed by means of computer statistical package SPSS/PC [10]. Analysis covered such statistical parameters as: normality of the distribution (skewness, kurtosis, Kołmogorow-Smirnow test), mean value (arithmetic), the degree of data dispersion (range, standard deviation, confidence intervals). In order to define the degree of variation of the results of the studies obtained, one-way analysis of variance was conducted by means of F test. Leven test was applied to investigate the homogeneity of variance. In order to evaluate differences occurring between the obtained mean values referring to individual months of the year, Duncan test of multiple comparisons was used. The value of $p \geq 0.05$ was adopted as the evaluation criterion of statistical significance of the parameters analysed (Kołmogorow-Smirnow test, F test, Leven and Duncan tests).

RESULTS

Table 1 presents the basic statistical data covering the total exposure to noise in individual months of the year. The values obtained confirm the occurrence of great variability of the results of the studies and their considerable variation. The greatest data dispersion of the obtained value of the total exposure to noise was noted in 4 months of the year: March, January, June and December, due to the wide range of the values measured (range: min.–max.) and high values of standard deviations, considerably exceeding mean values.

Due to the high values of kurtosis coefficients k (3.94–9.73; leptokurtic distributions) and skewness coefficients α (2.07–3.01 positive skewed), the distribution of the data obtained in these months considerably differ from normal distribution, but according to Kołmogorow-Smirnow test still remain within the lower limit of normal distribution

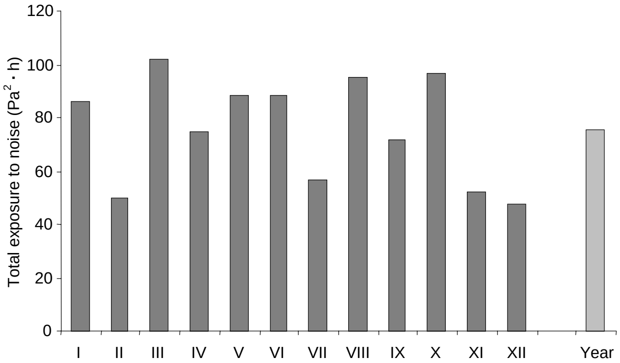

Figure 1. Mean values of total exposure to noise in individual months.

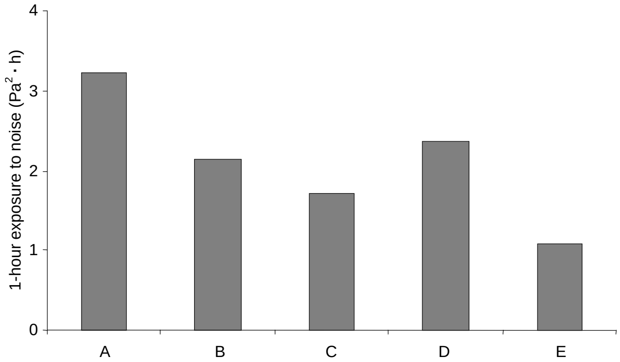

Figure 2. Values of 1-hour exposure to noise emitted by medium-power tractors for various agricultural work activities (A – grinding of green-fodder and sweet corn with the Orkan grinder; B – disk harrowing of soil; C - harrowing; D – work with the Cyclops; E – sugar beets and carrot digging with a combine).

(p = 0.04–0.22). The data distribution ideally consistent with the requirements of normal distribution concerns 3 months: August, October and November (p = 0.83–0.99), which results from low values of kurtosis and skewness coefficients and not very high values of standard deviations.

In order to estimate in which range of values, with the established level of confidence, the actual mean value of monthly exposure could be expected, confidence intervals were calculated (for the adopted confidence level equal to 95% and 2-sided Student test, 2.5% of the level of significance on each side). Confidence intervals in which mean values are contained (Tab. 1) cover a relatively varied scope, according to the month. The smallest width of confidence interval occurs in 5 months: May, August, September, October and November (the ratio between the upper limits of confidence to mean values achieves: 1.33–1.43, which in logarithmic scale of values is equivalent to 1.2–1.5 dB). The results obtained in the above-mentioned months should be classified as relatively precise. During the remaining months of the year (January–April, June, July and December) the width of the confidence intervals was greater, while the upper confidence limits with respect to the mean values take the data within the range from 1.46 x_{mean} (1.6 dB) in April to 1.87 x_{mean} (2.7 dB) in December. The mean values in these months are already characterised by some dispersion; however, they still remain within the range of moderate accuracy value.

The analysis of variance, in turn, conducted for total exposure to noise, showed that the level of variation of results in individual months was small (F test = 0.932; p = 0.511). Leven test performed for the homogeneity of variance indicates that the variance values obtained slightly differ from the proper homogeneity (S = 1.975; p = 0.034). Studies of the significance of differences between the pairs of individual months by means of Duncan test, did not show variation (p > 0.05).

Mean arithmetic values were selected for analysis and evaluation of the hygienic value of mean values of exposure to noise ($E_{A,T}$) to which private farmers are exposed, as the values most adequate with respect to acoustic energy. The highest values of the mean total exposure to noise were observed in the following months (Fig. 1): March (102.0 Pa^2· h), October (96.9 Pa^2· h), August (95.4 Pa^2· h) and in January, May and June (86.2

Table 1. Statistical values concerning total monthly exposure to noise in Pa^2· h.

Months	Mean ± SD	PU	α	k	Range	p
January	86.2 ±114.1	25.36–146.94	2.12	4.49	3.4–420.9	0.17
February	49.9 ±59.8	18.00–81.72	1.59	1.29	3.4–187.9	0.09
March	102.0 ±142.1	23.29–180.72	2.75	8.54	4.4–563.0	0.22
April	74.7 ±61.5	40.63–108.77	1.50	1.71	2.6–225.95	0.29
May	88.2 ±66.8	51.20–125.21	1.76	3.90	13.4–277.6	0.56
June	88.5 ±106.6	29.52–147.57	2.03	3.94	14.5–391.2	0.04
July	56.3 ±55.9	25.34–87.22	2.87	9.38	16.8–240.7	0.22
August	95.4 ±61.5	61.31–129.40	0.83	0.94	17.7–243.2	0.99
September	71.9 ±53.8	40.85–102.97	0.92	-0.10	8.7–187.7	0.41
October	96.9 ±58.9	64.35–129.53	0.78	0.73	16.4–233.7	0.83
November	52.1 ±31.0	34.92–69.21	0.45	-0.82	11.9–110.8	0.99
December	47.8 ±72.2	6.14–89.51	3.01	9.73	9.3–281.7	0.09
For whole year	75.8 ±19.9	64.20–87.63	-0.28	-1.61	47.8–102.0	0.73

Mean - mean arithmetic value; SD - standard deviation; PU - confidence interval; α - skewness coefficient; k - kurtosis; Range - (min-max) range; p - probability normal distribution.

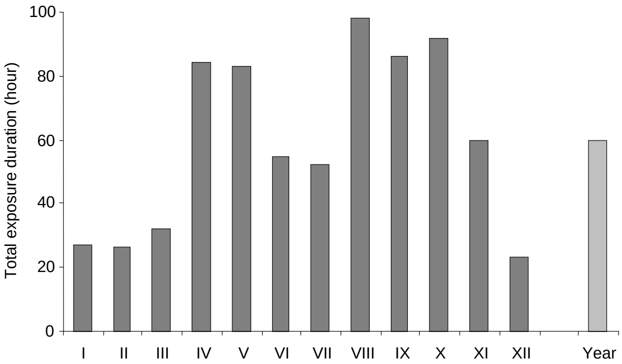

Figure 3. Mean values of total exposure time in individual months.

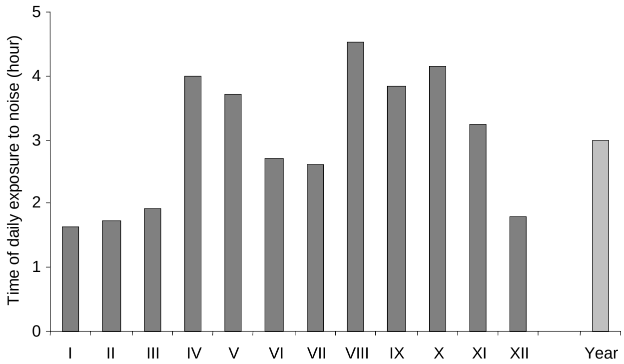

Figure 4. Mean values of duration of daily exposure to noise in individual months.

–88.5 Pa^2· h); while the lowest values were noted in December (47.8 Pa^2· h) and February (49.9 Pa^2· h).

High values of total exposure to noise in the summer-autumn months (August, October) result from the performance of intensive transport and field activities, such as: grinding of green-fodder and sweet corn with the Orkan grinder, disk harrowing of soil, ploughing, harrowing, work with the Cyclops, sugar beets and carrot digging with a combine (Fig. 2). Noise of a high level is emitted while performing these work activities. The occurrence of high total values of exposure to noise in these 2 months was also due to long exposure times to this factor (Fig. 3), frequently expressed by prolonged working time in individual workdays (Fig. 4) (18 hours maximum; 4.16–4.52 hours daily on average), and the greatest number of workdays in these months (Fig. 5) in conditions of noise (22–23 days on average).

High values of the total exposure to noise in such months as March, January, May and June are associated primarily with firewood logging with the use of the most noisy machine applied in agriculture - the circular saw (Fig. 6). During the 4 above-mentioned months, repair work activities were also performed by means of very noisy angular grinders, concrete vibrators, and selected field activities (grass cutting, hay pressing, ploughing), as well as transport activities. The presence of high intensity of total exposure was also due to noise emitted by machines for fodder production (Fig. 7) used during the whole year (the most noisy: grain crushers, fodder mixers, grinding mills of the 'Bąk' type). For the mean value referring to the whole year (Table 1 - for the whole year), the mean monthly exposure to noise reached a value equal to 75.8 ± 19.9 Pa^2· h with the distribution of data equivalent to normal distribution (Kołmogorow-Smirnow test: p = 0.73).

A more objective indicator of exposure, equivalent to the actual exposure to noise, is the value of mean equivalent daily exposure referred to as legally established workdays in each month (40-hour working week; holidays and Saturdays off work). As a result of calculations performed, statistical data were obtained concerning this parameter, included in Table 2. This Table shows that the variation in mean equivalent value of exposure to noise is considerably smaller than in the case of the total exposure to noise discussed (the arithmetic mean remains within the range 2.39 4.86 Pa^2· h). The greatest data dispersion was noted, as previously, in 4 months - March, January, June and

Table 2. Statistical values concerning mean equivalent daily exposure to noise in Pa^2· h.

Months	Mean ± SD	PU	α	k	Range	p
January	3.92 ± 5.19	1.15–6.68	2.11	4.48	0.15–19.13	0.18
February	2.49 ± 2.99	0.90–4.09	1.59	1.29	0.17–9.39	0.2109
March	4.86 ± 6.77	1.11–8.61	2.75	8.53	0.21–26.81	0.22
April	3.56 ± 2.93	1.93–5.18	1.50	1.70	0.12–10.74	0.29
May	4.20 ± 3.18	2.44–5.96	1.76	3.90	0.64–13.22	0.56
June	4.43 ± 5.33	1.48–7.38	2.03	3.94	0.73–19.56	0.04
July	2.45 ± 2.43	1.10–3.79	2.87	9.37	0.73–10.46	0.22
August	4.77 ± 3.07	3.07–6.47	0.83	0.94	0.89–12.16	0.99
September	3.27 ± 2.45	1.86–4.68	0.92	-0.10	0.40–8.53	0.41
October	4.22 ± 2.56	2.80–5.63	0.78	0.72	0.71–10.16	0.83
November	2.74 ± 1.64	1.83–3.64	0.45	-0.82	0.58–5.83	0.99
December	2.39 ± 3.61	0.31–4.48	3.01	9.74	0.47–14.09	0.09
For whole year	3.61 ± 0.92	3.05–4.17	-0.13	-1.61	2.39–4.86	0.92

Mean - mean arithmetic value; SD - standard deviation; PU - confidence interval; α - skewness coefficient; k - kurtosis; Range - (min-max) range; p - probability normal distribution.

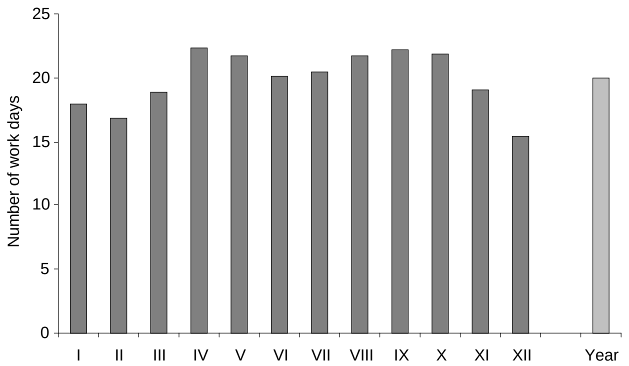

Figure 5. Mean number of workdays during a month for exposure to noise.

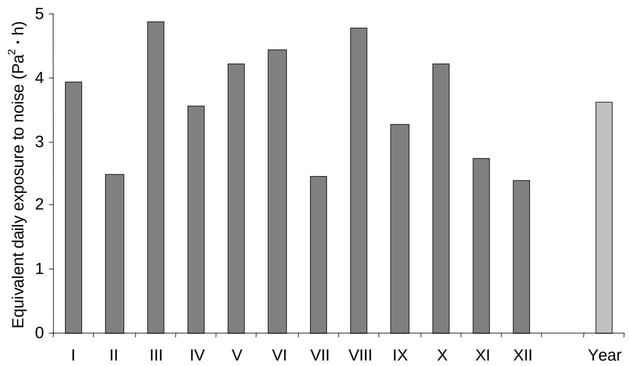

Figure 8. Mean values of equivalent daily exposure to noise (with relation to legally accepted workdays) in individual months.

December, as a result of a wide range of the values measured (range: min.–max.) and relatively high values of standard deviations exceeding mean values.

The distributions of data in these months, due to high values of kurtosis coefficients k (3.94–9.74, leptokurtic distributions) and skewness coefficients α (2.03–3.01; positive skewed), differ slightly from normal distributions; according to Kołmogow-Smirnow test, however, they remain within the lower limits of normal distribution (p = 0.04–0.22). Similar to the equivalent actual exposure to noise, data distributions which best fulfil the requirements of normal distribution, refer to 3 months: August, October and November (p = 0.83–0.99), associated with low values of kurtosis and skewness coefficients and not very high values of standard deviations.

The calculated values of confidence intervals for this acoustic parameter maintain a distribution similar to that for total exposure. The smallest width of confidence intervals is observed in 5 months - May, August, September, October and November ([1.33–1.43] x_{mean}; 1.3–1.5 dB). The results obtained in these months should be classified as relatively accurate. In the remaining months the width of confidence intervals was greater ([1.46–1.87] x_{mean}; 1.6–2.7 dB), equivalent to the moderate accuracy value.

The analysis of variance performed for equivalent daily exposure shows that there is a small degree of variation in test results (F test = 0.880; p = 0.561); whereas Leven test indicates a slight heterogeneity of variance (S = 1.982; p = 0.033). Also, Duncan test shows that the mean values for this parameter do not differ statistically from each other in individual months (p > 0.05).

Analysis of the data obtained shows that the highest value of mean equivalent daily exposure (arithmetic mean) (Fig.8) are noted in March (4.86 $Pa^2 \cdot h$), followed by August (4.77), June (4.43), May and October (4.20–4.22 $Pa^2 \cdot h$) with the lowest values observed in December, July and February (2.39–2.49 $Pa^2 \cdot h$). The occurrence of high equivalent value of daily exposure in the 5 above-mentioned months was due to the performance of very noisy agricultural-transport activities, activities associated with firewood logging (circular saws), repair activities, as well as the application of noisy machines for fodder production.

With relation to the standard values (standard = 1.01 $Pa^2 \cdot h$ for 8 hours), the registered data concerning mean equivalent exposure to noise exceed the standard by 2–5 times during the whole year, with the highest standard-exceeding values noted in March (4.9 times) and August (4.8 times).

The mean value calculated for the whole year for the mean equivalent daily exposure to noise reached a value equal to 3.61 $Pa^2 \cdot h$ (standard exceeded 3.6 times). This value is equivalent to mean level of exposure to noise and

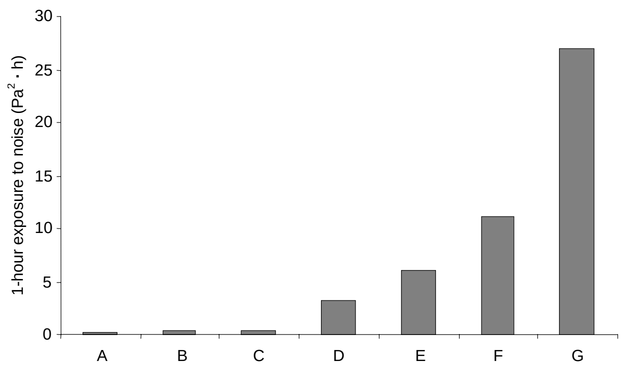

Figure 6. Mean values of 1-hour exposure to noise emitted while operation of various workshop machines (A – concrete mixer; B – bench-grinder; C – compressor; D – chain saw; E – metal cutting saw; F – angular grinder; G – circular saw).

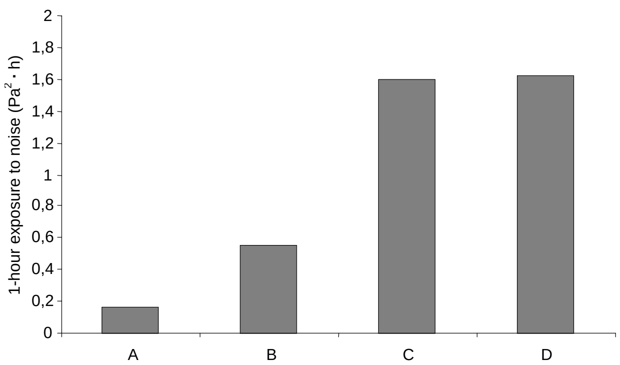

Figure 7. Mean values of 1-hour exposure to noise emitted by machines for fodder production (A – radial plate grinding mill; B – grinding mill of the “Bąk” type; C – grain crusher; D – fodder mixer).

referred to an 8-hour workday ($L_{EX,8h}$), equal to 90.5 dB (standard: 85 dB-A).

DISCUSSION

The study of annual exposure to noise among private farmers specializing in animal production showed the great complexity and changeability of results in the time interval covering the whole year. This is due to the type of agricultural work activities performed within individual time periods, types of agricultural tractors and machines coupled with them, excessively noisy machines used for logging (saws), as well as workshop machinery, characterised by high level of noise (angular and bench grinders, drills, etc.), and machines for fodder production.

The degree of noise load among private farmers, on the one hand, is conditioned by the level of noise emitted by these machines, and on the other, by the duration of exposure to this factor within an individual time interval.

The results of the study showed that the highest values of the total monthly exposure to noise ($E_{A,T}$) occur both in summer and autumn (August, October) and winter and spring (January, March, May and June). During the summer-autumn season, the degree of noise load is directly associated with the intensity of field and transport activities, while during the winter-spring season the degree of this load depends on the frequency of application of machines used for logging, repair activities and fodder production. The results of the study obtained clearly confirm the principle that in order to achieve a reliable and representative evaluation of the degree of risk caused by noise among private farmers, the complete production cycle covering the whole year and all types of noise sources should be examined.

The calculated mean equivalent daily exposure to noise shows the highest values in 5 months - March (4.86 $Pa^2 \cdot h$), August (4.77 $Pa^2 \cdot h$), June (4.43) and May and October (4.20–4.22). The mean value of this parameter for the whole year reached the level of 3.61 $Pa^2 \cdot h$ (exceeding the standard 3.6 times).

There are few literature reports concerning the evaluation of exposure to noise among agricultural workers which cover the whole year. One of the precursors in this field was Mieńszow [2] who determined noise doses absorbed by operators of agricultural tractors employed on multi-production farms in the former Soviet Union. The mean equivalent daily noise doses obtained by Mieńszow ranged within 3.3 in February and March (not very noisy workshop activities with small number of workdays) to 11.6 in July and August (harvesting time with a large number of work days).

Similar studies of noise load among operators of agricultural tractors employed on State-owned farms in Poland were conducted by the author of the presented study [5]. The results of these studies showed that the greatest load for the organ of hearing is caused by medium-power tractors (equivalent daily noise doses from 7.9 in December to 13.6–14.7 in August–October), while the smallest - by high-power tractors (doses from 1.36–1.54 in December and January to 4.1 in August).

The studies of annual exposure to noise conducted by Franzinelli [1] and Miettinen [3] concern farmers working in Italy and Finland, are closer to the work conditions of Polish private farmers. The results obtained by Franzinelli showed that at grapes production, farmers are exposed to noise on a medium level of exposure, slightly exceeding 90 dB-A, whereas at the production of cereals this level reached the value of 95 dB-A. The studies carried out by Miettinen confirmed that farmers engaged in animal production are exposed to noise of a level considerably exceeding the value 85 dB-A.

The author of the present study also conducted the evaluation of the annual exposure to noise among private farmers on farms of plant-production profile [9]. The results of these studies showed that the mean noise load (during the whole year) among farmers engaged in plant production remains on the level equal to 91.3 dB-A. This allows us to presume that a greater noise risk occurs on farms which specialise in plant production, compared to those engaged in animal production. The results obtained by the author of the presented study are close to the data obtained by other researchers.

The statistical calculations indicated that the mean values obtained for 2 analysed acoustic parameters (total monthly exposure and equivalent daily exposure) have normal distributions, are characterised by moderate accuracy, show a small degree of variation of results, and do not significantly differ statistically between individual months.

CONCLUSIONS

1. The studies of annual exposure to noise among private farmers specializing in animal production showed that there is a relatively great load on the organ of hearing caused by this factor (mean level of exposure to noise for the whole year = 90.5 dB-A), considerably exceeding allowable values.

2. Especially great noise risk occurs in March, August, June, and in May and October (maximum allowable value of exposure to noise - $E_{A,8h}$ is exceeded 4 - 5 times).

3. The results of the presented study are close to the data obtained by other authors and confirm that the degree of noise risk among private farmers depends on the type of agricultural production and the type of machinery applied.

4. Due to the fact that the mean values of selected acoustic parameters obtained are characterised by moderate accuracy and small level of variation of results, these values may be used by the proper State services (Sanitary Inspectorate, Labour Inspectorate, agencies of the Agricultural Social Insurance Fund and Regional Centres of Occupational Medicine) for the evaluation of noise risk among private farmers (engaged in animal production).

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