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Noise exposure assessment for operator in agricultural tractor cabs

Ocena narażenia operatora na hałas w kabinach ciągników rolniczych

Abstract. The aim of the study was to assess the sound level inside the cabins of agricultural tractors. The research covered a group of tractors differing in engine power, mileage, and year of manufacture. The results were compared in terms of engine power, minimum and maximum sound levels, the newest and oldest tractor, as well as the sound level inside and outside the cabin. The measurements were made in accordance with the Polish norm PN-EN ISO 9612:2011. Additionally, selected tractors were tested while towing equipment such as a sprayer or a trailer. Based on the conducted tests, it was found that tractors manufactured after the year 2000 provide better sound insulation and greater operator comfort. In contrast, the oldest tractors, due to long-term use and lack of maintenance, no longer meet cabin tightness requirements, which increases the operator's exposure to noise.

Abbreviations: dB – decibel; HP – horsepower; mth – machine operating hours; rpm – revolutions per minute; PPE – personal protective equipment; L_{Aeq} – A-weighted equivalent continuous sound level; L_{ASmax} – maximum A-weighted sound level with slow time weighting; L_{Cpeak} – peak C-weighted sound level; $L_{EX,8h}$ – daily noise exposure level normalized to an 8-hour working day; $L_{Aeq,Te}$ – A-weighted equivalent continuous sound level during the effective exposure period; L_{peak} – peak sound level; L_{max} – maximum sound level; L_{min} – minimum sound level; IMPULSE – impulse time weighting; FAST – fast time weighting; SLOW – slow time weighting

Key words: noise, environmental pollution, environmental protection, agriculture, machinery

INTRODUCTION

Occupational work can pose a variety of hazards that negatively affect human health. One such hazard is noise, whose detrimental impact has been documented on several physiological systems, including the digestive and cardiovascular systems [Bortkiewicz et al. 2018]. Excessive noise levels may

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lead to hearing impairment and are also associated with tension, irritability, and decreased concentration [Kirpluk 2003, 2024, Bortkiewicz et al. 2018]. Noise is inherent in nearly all sectors of a developing economy, including agriculture, where one of the primary sources of noise is agricultural machinery. Recent studies emphasize that long-term exposure to noise generated by agricultural machinery remains a significant occupational risk, and that ergonomic improvements in machinery design can help reduce, but not completely eliminate, this hazard [Di Stefano et al. 2025, Mushtaq et al. 2025]. The intensity of noise exposure depends largely on the technical condition of the equipment, particularly the engine quality and operating lifespan. Poorly maintained or low-quality machinery not only contributes to excessive noise but also increases the likelihood of occupational accidents, including falls, fractures, electric shocks, entanglement in machinery, and fatalities. Such incidents are frequently attributed to insufficient awareness among farmers regarding occupational risks, a lack of occupational health and safety (OHS) training, inadequate education, and noncompliance with manufacturers' operational guidelines.

In the agricultural sector, health and safety risks remain pervasive due to the diverse range of tasks performed by individual farmers during a typical workday. Workplace safety practices, hygiene protocols, and preventive medical examinations are often neglected by agricultural workers, which reflects a general lack of awareness regarding occupational hazards [Jaśkowiec and Stopa 2016]. According to data from the Agricultural Social Insurance Fund (KRUS), the number of reported agricultural accidents has shown a downward trend. In 2023, a total of 10,709 occupational accidents were reported – 940 cases (8.1%) fewer than in 2022 – accompanied by a 4.6% decrease in the number of insured persons (49,640 fewer). Since 2014, the number of reported accidents has declined by over 50% (11,230 cases, 51.2%), while the number of insured persons has fallen by 400,335 (27.9%) [KRUS 2024]. Under the provisions of the Farmers' Social Insurance Act, 10,111 incidents were classified as occupational accidents in agriculture, representing a 5.2% decrease (556 cases) compared to the previous year. The number of fatal accidents in the three-year period from 2021 to 2023 totaled 45, compared with 77 cases in 2014 [KRUS 2024]. The most frequent causes of fatal accidents included being run over, struck, or caught by a moving vehicle, with the following specific cases reported: tractor rollovers (8 cases), combine harvester rollover (1 case), run-over incidents involving agricultural tractors (3 cases), and road traffic accidents (3 cases) [KRUS 2024]. It should be noted that the average nominal power of tractors, expressed in kilowatts (kW), increased from 37.9 kW in 2010 to 46.9 kW in 2020, representing a rise of more than 20% [GUS 2024]. The objective of this study was to compare the operator's exposure to noise inside the cabins of agricultural tractors across various tractor models. The evaluated machines differed in engine power, operational mileage, and service life.

MATERIAL AND METHODS

The noise level measurements in agricultural tractors were conducted on a farm located in the Tomaszów County. The farm specializes in crop production, primarily cultivating winter and spring wheat, sugar beet, and winter rapeseed.

A total of fourteen agricultural tractors used on the farm were included in the study. The comparison of the tested tractors was organized according to the engine power criterion (Table 1). To ensure that the measurements reflected real operating conditions, the tractors were tested under typical load scenarios commonly used by the farmers on the site. For this purpose, an Autosan trailer with a payload capacity of 8 tonnes and a Pilmet trailed sprayer with a tank capacity of 2000 liters were employed during the measurements.

The measurements were conducted in the first half of May 2023 under the following meteorological conditions:

– relative air humidity: 30–34%

– air temperature: 24–26°C
– wind speed: approximately 5 m/s.

The study employed a digital sound level meter SVAN 955 (Class 1) manufactured by Svantek (Figure 1). This instrument is designed for acoustic measurements, including environmental and occupational noise assessments. The device enables the measurement of various sound parameters (e.g., L_{peak}, L_{max}, L_{min}, etc.) within a frequency range of 20 Hz to 20 kHz, with a sampling rate of 48 kHz, and allows the use of time weightings (IMPULSE, FAST, SLOW) as well as frequency weighting filters A, C, and Z [Svantek 2009].

Table 1. List of agricultural tractors used for noise level assessment

No.	Model	Power (HP)	Year of manufacture	Operating hours (mth)	Remarks/Load
1	Ursus C3603P	47	1988	5 000	no cabin
2	Ursus C360	52	1978	10 000	no cabin
3	Ursus C385	76	1971	20 000	–
4	Case 844XL	84	1996	9 000	sprayer
5	Case 956XL	95	1989	12 000	–
6	John Deere 6230	95	2013	1 100	sprayer
7	Case 1056XL	105	1989	11 350	–
8	Fendt Favorit 711	115	2001	7 500	–
9	Case 5140	120	1991	14 000	–
10	Ursus 1634	120	1995	9 000	–
11	John Deere 6520	120	2003	4 000	–
12	John Deere 6930	155	2011	2 720	trailer
13	Case MX170	170	1999	9 150	–
14	John Deere 6170M	170	2015	1 580	trailer

Two independent measurement series were carried out to confirm the accuracy and repeatability of the results. Prior to each measurement session, the instrument was calibrated according to the manufacturer's instructions.

Noise level measurements were performed inside and outside each tractor (at a distance of 7 m in front of the machine). Inside the cabin, measurements were taken at the operator's head height, under the following operating conditions: idle speed, engine speed of 2000 rpm, during driving on a 100 m flat section of road at a speed of 5 km/h, both with and without load.

In four cases, measurements were conducted under additional load conditions, with the tractor connected to either a trailer or a sprayer. Detailed information regarding the tested tractors and loading conditions is presented in Table 1.

The noise exposure level inside the tractor cabin, normalized to an 8-hour workday $L_{EX,8h}$ is presented in Table 5. It was assumed that the tractor operator's actual working time amounted to 6 hours. Two of the tractors tested were not equipped with cabins, and these were treated as exceptions in the analysis. To determine the daily noise exposure level $L_{EX,8h}$, the following equation was applied:

$$L_{EX,8\,h} = L_{Aeq,T_e} + 10 \cdot log\left(\frac{T_e}{T_o}\right), [\mathrm{dB}]$$

where:
$L_{EX,\,8h}$ – noise exposure level normalized to an 8-hour working day,
$L_{Aeq,\,T_e}$ – A-weighted equivalent continuous sound level for the effective working period (dB),
T_e – duration of noise exposure (6 hours),
T_o – reference time period (8 hours).

Figure 1. SVAN 955 Class 1 sound level meter [photo: P. Maksym]

In addition to arithmetic mean values, the standard deviation (SD) was calculated for each measurement series in order to assess the variability and repeatability of the recorded noise levels.

RESULTS AND DISCUSSION

In the tables presented below (Tables 2–4), the following additional symbols and abbreviations are used:

* – tractor not equipped with a cabin,
N – measurement taken outside the tractor,
W – measurement taken inside the tractor cabin,
O – tractor loaded with a sprayer during operation,
P – tractor loaded with a trailer during operation.

Table 2. Measured sound levels of tractors at a frequency of 1000 Hz, based on L_{Aeq} — equivalent continuous sound level with SLOW time weighting

No.	Model	Measurement location	Idle speed	Engine speed 2000 (rpm)	During driving
			(dB ±SD)	(dB)	(dB)
1.	Ursus C3603P*	N	68.0 ±0.141	79.2 ±0.212	78.2
		W	74.6 ±0.071	87.0 ±0.141	92.2
2.	Ursus C360*	N	74.7 ±0.071	80.0 ±0.354	73.6
		W	72.4 ±0.354	89.4 ±0.141	86.3
3.	Ursus C385	N	74.9 ±0.425	88.0 ±0.495	80.3
		W	71.6 ±0.283	81.7 ±0.141	80.7
4.	Case 844XL	N	66.2 ±0.141	81.4 ±0.354	79.8 O
		W	61.9 ±0.071	76.0 ±0.141	74.6 O
5.	Case 956XL	N	69.0 ±0.779	82.4 ±0.708	78.6
		W	60.7 ±0.071	72.0 ±0.141	73.5
6.	John Deere 6230	N	62.0 ±0.212	74.5 ±0.495	69.2 O
		W	58.1 ±0.212	62.4 ±0.495	61.9 O
7.	Case 1056XL	N	70.1 ±0.071	80.5 ±0.0	77.8
		W	67.2 ±3.587	70.2 ±0.354	73.1
8.	Fendt Favorit711	N	63.4 ±0.141	72.0 ±0.071	69.1
		W	52.6 ±0.071	60.0 ±0.212	59.6
9.	Case 5140	N	77.7 ±0.283	89.1 ±0.851	79.6
		W	69.1 ±0.495	78.7 ±0.0	76.8
10.	Ursus 1634	N	69.8 ±0.141	81.3 ±0.071	74.2
		W	67.2 ±0.354	77.9 ±0.212	77.0
11.	John Deere 6520	N	73.1 ±0.212	83.7 ±0.354	79.0
		W	53.3 ±0.0	66.4 ±0.071	65.0
12.	John Deere 6930	N	68.0 ±0.354	74.8 ±0.283	70.8 P
		W	61.2 ±0.071	65.7 ±0.141	65.1 P
13.	Case MX170	N	80.2 ±0.0	86.8 ±0.141	76.2
		W	60.1 ±0.708	64.5 ±0.354	63.9
14.	John Deere 6170M	N	64.2 ±0.283	74.0 ±0.495	72.1 P
		W	54.5 ±0.283	63.7 ±1.208	60.6 P

The lowest measured value was 54.5 dB at idle speed, while the highest recorded value reached 92.2 dB, which exceeds the permissible exposure limit of 85 dB.

Table 3. Measured sound levels of tractors. L_{ASmax} – maximum A-weighted sound level with SLOW time weighting

No.	Model	Measurement location	Idle speed	Engine speed 2000 (rpm)	During driving
			(dB ±SD)	(dB)	(dB)
1.	Ursus C3603P*	N	73.1 ±0.354	85.1 ±0.141	92.0
		W	78.0 ±0.283	92.0 ±0.212	96.0
2.	Ursus C360*	N	66.9 ±0.071	84.8 ±0.141	85.0
		W	77.3 ±0.071	94.2 ±0.071	95.0
3.	Ursus C385	N	81.6 ±0.637	92.4 ±0.0	93,0
		W	77.9 ±0.071	90.1 ±0.637	87.0
4.	Case 844XL	N	70.7 ±0.283	87.2 ±0.071	92.4 O
		W	67.6 ±0.993	81.7 ±0.283	91.4 O
5.	Case 956XL	N	72.2 ±0.212	86.5 ±0.071	90.0
		W	67.2 ±1.136	76.8 ±0.495	79.0
6.	John Deere 6230	N	68.8 ±0.708	81.3 ±0.141	79.9 O
		W	81.1 ±0.283	69.0 ±0.708	69,2 O
7.	Case 1056XL	N	74.9 ±0.637	86.7 ±0.141	88,0
		W	80.4 ±12.082	77.1 ±1.858	79.0
8.	Fendt Favorit711	N	71.1 ±1.065	78.6 ±0.071	79.0
		W	66.9 ±4.058	69.3 ±1.858	67.0
9.	Case 5140	N	82.7 ±1.640	95.1 ±1.065	91.0
		W	74.3 ±0.212	85.4 ±0.922	83.0
10.	Ursus 1634	N	73.7 ±0.0	86.4 ±0.0	87.0
		W	72.0 ±0.212	83.5 ±0.071	83.0
11.	John Deere 6520	N	79.4 ±0.071	89.8 ±1.136	91.0
		W	62.2 ±0.922	71.6 ±0.212	71.0
12.	John Deere 6930	N	79.4 ±0.212	81.0 ±0.071	83.5 P
		W	71.0 ±1.496	71.0 ±0.0	72.5 P
13.	Case MX170	N	91.1 ±0.0	88.0 ±0.0	88.0
		W	76.4 ±3.743	72.0 ±0.425	72.0
14.	John Deere 6170M	N	79,9 ±0.708	83.0 ±0.637	83.6 P
		W	68.1 ±0.354	67.0 ±0,354	67.5 P

The maximum permissible sound level is 115 dB. Analysis of the results indicates that none of the measurements exceeded this threshold.

The peak sound levels ranged from 86.5 dB to 115.4 dB. These represent the highest recorded values compared with the previous measurements; however, they do not pose a health risk, as they remain below the permissible limit of 135 dB.

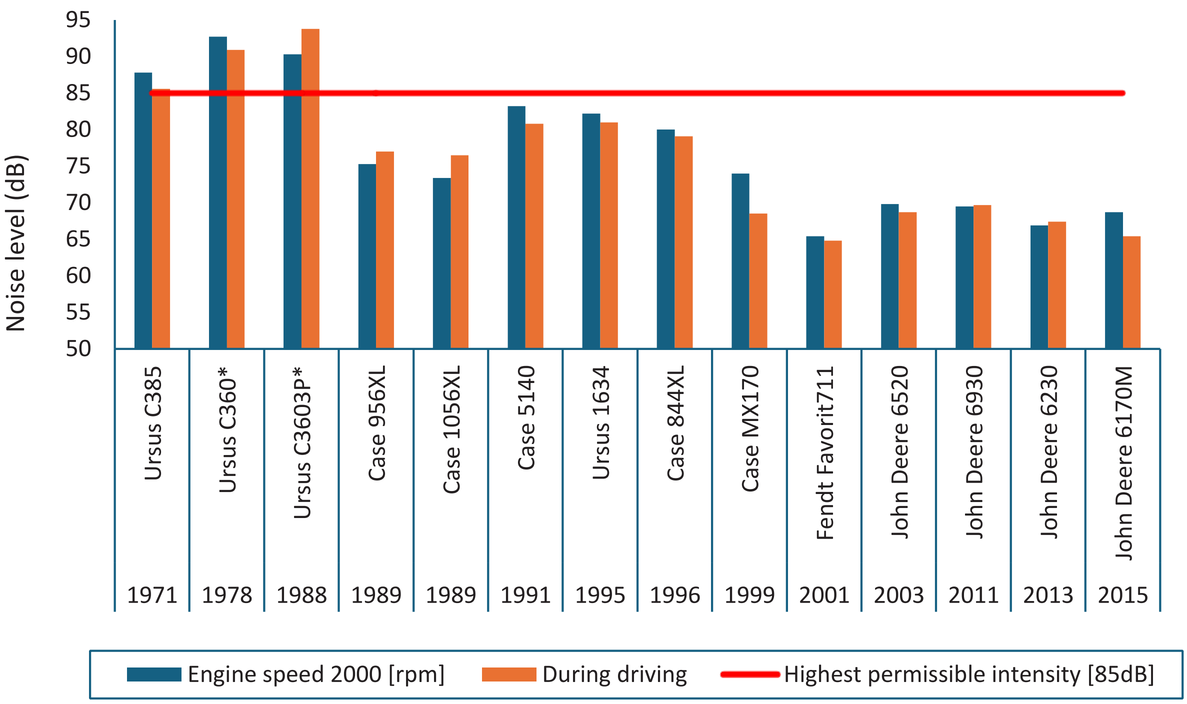
Table 4. Measured sound levels of tractors. L_{Cpeak} — peak C-weighted sound level

No.	Model	Measurement location	Idle speed	Engine speed 2000 (rpm)	During driving
			(dB ±SD)	(dB)	(dB)
1.	Ursus C3603P*	N	95.7 ±0.354	105.3 ±0.354	112.1
		W	101.1 ±0.212	115.0 ±0.283	115.4
2.	Ursus C360*	N	89.5 ±0.141	104.4 ±0.425	102.7
		W	100.7 ±0.425	113.4 ±0.071	117.1
3.	Ursus C385	N	99.1 ±0.566	109.7 ±0.566	111,0
		W	102.4 ±0.212	112.8 ±0.566	105.9
4.	Case 844XL	N	91.2 ±0.354	104.4 ±0.141	107.7 O
		W	95.6 ±0.141	102.0 ±0.851	112.9 O
5.	Case 956XL	N	92.4 ±0.495	102.1 ±0.071	105.4
		W	92.8 ±0.708	96.4 ±0.212	107.4
6.	John Deere 6230	N	97.3 ±0.851	99.3 ±0.283	98.3 O
		W	98.9 ±0.071	94.2 ±1.785	101.4 O
7.	Case 1056XL	N	92.9 ±1.065	102.6 ±0.354	103.2
		W	115.5 ±17.192	93.2 ±0.283	104.2
8.	Fendt Favorit711	N	94.0 ±0.495	96.3 ±0.212	100.0
		W	93.5 ±1.858	93.0 ±0.283	96.9
9.	Case 5140	N	101.5 ±2.672	111.5 ±1.568	107.5
		W	98.3 ±0.283	108.4 ±0.851	106.5
10.	Ursus 1634	N	96.3 ±2.373	102.8 ±0.637	103.1
		W	97.7 ±0.141	101.8 ±0.071	105.1
11.	John Deere 6520	N	95.1 ±0.708	102.2 ±0.283	106.0
		W	90.0 ±0.566	93.5 ±0.141	102.7
12.	John Deere 6930	N	89.7 ±0.708	96.9 ±0.566	100.1 P
		W	91.2 ±0.071	101.4 ±1.208	108.4 P
13.	Case MX170	N	101.5 ±0.851	106.9 ±0.425	102.7
		W	100.2 ±8.292	96.6 ±0.141	99.5
14.	John Deere 6170M	N	92.4 ±2.299	96.5 ±0.922	99.2 P
		W	86.5 ±0.354	94.6 ±0.495	100.8 P

Table 5. Noise exposure levels measured inside selected tractor cabins, normalized to an 8-hour working day, determined on the basis of the equivalent continuous sound level $L_{Aeq,6h}$

No.	Model	$L_{EX,8h}$	
		Engine speed 2000 (rpm)	During driving
		(dB ±SD)	(dB)
1.	Ursus C3603P*	90.3 ±0.071	93.8
2.	Ursus C360*	92.7 ±0.212	90.9
3.	Ursus C385	87.8 ±0.071	85.6
4.	Case 844XL	80.0 ±0.141	79.1
5.	Case 956XL	75.3 ±0.071	77.0
6.	John Deere 6230	66.9 ±0.354	67.4
7.	Case 1056XL	73.4 ±0.283	76.5
8.	Fendt Favorit711	65.4 ±0.141	64.8
9.	Case 5140	83.2 ±0.495	80.8
10.	Ursus 1634	82.2 ±0.141	81.0
11.	John Deere 6520	69.8 ±0.212	68.7
12.	John Deere 6930	69.5 ±0.425	69.7
13.	Case MX170	74.0 ±0.566	68.5
14.	John Deere 6170M	68.7 ±0.141	65.4

Figure 2. Comparison chart of noise levels depending on the year of tractor production



The obtained results may be interpreted in relation to the requirements of Directive 2009/76/EC, which defines the maximum permissible sound pressure level at the operator's position in tractor cabins as 85 dB(A) during operation.

When the measured values are normalized to an 8-hour working day, it can be observed that more than half of the tractors fall within safe operating limits. However, for three machines, the measured noise levels exceeded the permissible value of 85 dB. The remaining tractors exhibited noise levels between 80 and 85 dB, placing them at the threshold of acceptability. The issue of noise in agricultural machinery has frequently been addressed in scientific research, particularly in the works of Professor Solecki [Solecki 1995]. In his habilitation thesis, the author examined the exposure of farmers to harmful noise generated by mechanical devices. In subsequent studies, he conducted an ergonomic evaluation of tractor operator work conditions, along with optimization strategies to improve them [Solecki 2002]. Studies by Adamczyk [2004, 2005] entitled "Noise of tractors under field conditions" demonstrated that the engine is the primary source of noise. The propagation of sound was analyzed across different tractor types and distances from the source. Spectral analysis in octave bands revealed that high-frequency noise (4000–16000 Hz) decreases most rapidly with distance, whereas low-frequency noise (63–125 Hz) diminishes much more slowly. Similar observations were made in the present study, particularly when comparing results in the octave band centered at 1000 Hz – a frequency close to that of human speech–used to assess interior noise levels of tractors idling at rest. The quietest tractors exhibited measured sound levels of 52.6 dB, 53.3 dB, and 54.5 dB, which were significantly lower than those recorded at the 31.5 Hz center frequency band (80.4 dB, 78.7 dB, and 74.2 dB, respectively). Recent studies indicate that although modern tractor cabins reduce noise levels, they do not fully eliminate operator exposure, especially under real working conditions [Durczak and Rybacki 2023, Marques and Lanças 2022]. In the study by Olszewski and Lachowska [2020], the authors identified several factors contributing to hearing loss following occupational noise exposure, with particular emphasis on farmers as a high-risk group. The problem becomes especially pronounced during intensive fieldwork periods, when weather-dependent scheduling limits the possibility of taking breaks due to time pressure. The nature of agricultural work, conducted in direct proximity to tractors and machin-ery, makes the elimination or isolation of noise sources largely impractical. Furthermore, personal pro-tective equipment (PPE) often proves ineffective or inconvenient, as farmers need to receive auditory signals from different machines and environmental cues during operation.

SUMMARY

Noise is present in virtually every work environment, but machine operators and technical personnel are particularly exposed to its harmful effects. Agricultural machinery is an outcome of technological progress aimed at improving farmers' productivity and comfort. However, in less-developed farms, maintenance neglect and the failure to use hearing protection remain common issues during field operations.

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