Effect of tractor noise on operator and bystander's health and its attenuation using noise protection devices

Sheikh Aadil Mushtaq, Jagvir Dixit*, Mohd. Muzamil, Hilaas Ahmad Peerzada and Sherab Dolma

(Division of Farm Machinery and Power Engineering, Sher-e-Kashmir University of Agricultural Science and Technology, Srinagar-190025, India)

Abstract: The study focused on assessing the impact of agricultural tractor noise hitched with a disc plough, cultivator and rotavator on operator's health. The tractor-hitched-implement's noise level was measured at no load (0 cm tillage depth) and load (10 cm and 14 cm tillage depth) at the operator's ear level and bystander's position at an engine speed of 1000 rpm, 1500 rpm and 2000 rpm. The response parameters were measured in terms of physiological parameters like heart rate, blood pressure and sound pressure level (SPL). The experimentation and analysis revealed that the noise level at operator's ear level exceeds beyond the allowable 85 dB level. In order to reduce noise, the attenuation characteristics of ear muff, ear plug and moist cotton were also tested. The results revealed 24.26% noise attenuation with ear muff, 19.04% ear plug and 13.94% moist cotton, respectively. The drop of 37.38%, 26.26% and 24.50% in the heart rate and 7.8%, 1.07% and 1.05% in blood pressure with ear muff, ear plug and moist cotton was also recorded. The study leverages towards the interventions to reduce the intensity of noise, protect the operators from occupational health syndromes (OHS) and improve the working efficiency.

Key words: Tractor, noise, operator, noise protection, health

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1 Introduction

The agricultural farm tractor is a slow-moving vehicle with the ability to generate torque for pulling the implements (Awwad et al., 2023). It is widely perceived that the revolution in the agricultural sector was triggered by the emergence of tractors. The environment and the discomfort have a severe impact on the overall working efficiency of human and machine while using farm tools and machinery (Dixit and Namgial, 2012; Dixit et al., 2014). However, the tractor operator is significantly influenced by the noise generated in the engine, exhaust, intake fan, movement of gears, cams, bearings and pumps (Choi et al., 2023). The noise produced during tractor running is one of the key reasons of discomfort for workers (Karamousantas et al., 2016, Rabbani et al., 2012, Bilski, 2013; Vallone and Catania, 2014). The interior noise level of a cab is an important performance indicator of agricultural tractors. The interior noise has four components: structure-borne noise, air-borne noise, internal-sources-radiated noise, and reverberation noise (Han et al., 2019). The noise level at the driver's ear position is lower in a tractor with a cab than that in a cabinless (open-station)

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***Corresponding author: Jagvir Dixit.** Division of Farm Machinery and Power Engineering, Sher-e-Kashmir University of Agricultural Science and Technology, Srinagar-190025, India. Email: jagvirdixit@gmail.com.

tractor (Lar et al., 2012) due to reduction in radiation noise of the engine, intake, exhaust and transmission system in a cab by direct path blockage system (Han et al., 2022).

Human ear repetition spectrum ranges from 20 Hz to 20,000 Hz. Tractor employees in India are subjected to noise levels well above the acceptable threshold range identified by the Occupational Safety and Health Agency (OSHA), Bureau of Indian Standards (BIS) and International Labour Organisation (ILO) in 90% of the models of all types of tractors (Sharma and Mukesh, 2012). Thus, it is suggested that hearing conservation initiatives must be implemented for tractor operators for protection of health and improvement in working efficiency (Dewangan et al., 2023). The performance of sound insulation materials is affected by the surface density, stiffness and damping, and it is difficult to effectively isolate low-frequency noise. Therefore, sound insulation of low-frequency noise can only be improved by increasing the surface density of the materials (Wang et al., 2022). Noise disrupts communication, induces discomfort, and impairs both physical and mental performance, particularly in workshops where machinery noise is prevalent and workers are frequently exposed to high decibel levels (Celen and Arin, 2003).

A sound level or decibel monitor with a triple frequency weight scale, A, B and C, is used to measure it. It is described in terms of dB (A). The working conditions of the A, B, C scale could be chosen on the recorder. The minimum sensitivity is in the A-scale and the maximum is in the C-scale. The A-scale is often used to measure the frequencies that could be heard by the human ear (Sharma and Mukesh, 2012). Approved doses of 90 dB(A) for 8 hours per day and 5 dB(A) time-intensity trade-off as the permissible dosage time was slashed half for each 5 dB(A) noise increase (Murphy and Frank, 2002). For instance, 16 hours around 85 dB(A) poses the same hearing threat as 8 hours around 90 dB(A), 4 hours around 95 dB(A), 2 hours around 100 dB(A), and so forth. An 8-hour standard limit of 85 dB(A) per day and 3 dB(A) time-intensity trade-off as the allowable dosage time was cut by half with every 3 dB(A) noise increase (Murphy and Frank, 2002). The allowable dosage time is doubled with every 3 dB(A) decrease in the noise rate. It is thought that indeed time/intensity values displayed on the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits (REL) axis are equally dangerous as 8 hours around 85 dB(A) carries the same hearing threat as 4 hours around 88 dB(A), 2 hours around 91 dB(A) and so forth. The noise exposure index of the OSHA and NIOSH is given in Table 1.

Table 1 Allowable noise exposure scale

Duration (hr./ day)	Sound level (dB(A))	Sound level (dB(A))
8	85	90
4	88	95
2	91	100
1	94	105
1/2	97	110
1/4	100	115
	Based on NIOSH Noise Standard.	Based on OSHA Noise Standard.

2 Material and methods

Experimental site: The field experiments were conducted out at Pulse Research Station, SKUAST-K, Srinagar located at 34°07′30″ N latitude and 76°47′41″ E longitude with an altitude of 1590 meters above mean sea level. The test area was open, flat and without any obstruction like a house, solid fence, tree or another vehicle that would have disturbed trials within 20 m space**.**

Weather and climate: The average temperature and relative humidity during the experiment were in the range of 27.9ºC to 30.1ºC and 48 to 58 per cent. The field experiment was carried out when the background noise level, including wind noise, was below 10 dB (A). The average wind velocity during the experimental period ranged from 0.35 – 1.17 km

h^{-1} with an average of 0.84 km h^{-1}.

Soil characteristic: The moisture content of the soil was measured with Lutron Electronic Soil Moisture Meter. Larson Davis sound meter with the G4 LD utility program was used with the frequency range of 6.3 Hz to 20000 Hz. The Larson Davis Sound Expert L&T 831 sound meter was a full-featured meter with a graphic display and a fixed set of firmware options. It had 2GB internal memory including real-time octave band analysis and measurement history. It had a 3 and a half-inch digit LCD monitor, 22.4 cm × 7.1 cm × 4.1 cm size, dB (A and C weight) function, quick, slow and maximum hold response with preamplifier and microphone. The moisture content ranged from 6.70 to 8.10 per cent on dry basis.

Instruments used: During the study, noise levels during tillage operations were assessed using a Larson Davis Model LxT 831 digital sound level meter set to A-weighted mode for accurate measurements, with a slow response setting. This device, equipped with a condenser microphone capable of measuring noise levels from 30 to 140 dB, captured variations in tractor noise across different field conditions influenced by varying surface forces. Heart rate measurements were conducted using a Polar Watch RS 400sd following a 10-minute relaxation period for operators prior to task commencement. A Polar heart rate sensor was utilized, attached to the subject's wrist along with a chest-worn belt sensor as recommended by the manufacturer, to record heart rate data. Blood pressure readings were taken using an Automatic Blood Pressure Monitor HEM-75156-A, positioned on the subjects' bicep. The monitor, initiated by pressing a start button, inflated the cuff and automatically deflated to display systolic and diastolic values. The data collected was stored and analysed.

Subject selections: The weight of Indian male agricultural workers varies from 45 to 85 kg. Thus, subjects reflecting the average population were chosen to carry out field experiments to determine the impact of the noise level of the tractor on the physiological costs of the driver and the bystander (heart rate, systolic and diastolic blood pressure). Before evaluating the impact of tractor noise on the subject’s health and calculating their energy expenditure, medical examinations were conducted to calibrate their measurements, such as blood pressure, heart rate, and weight, as detailed in Table 2.

Table 2 Details of selected subjects

S.No.	Parameters	Subject A	Subject B	Subject C
1	Age (years)	45	37	25
2	Body Weight (kg)	82	64	57
3	Stature (cm)	176.78±2.41	173.73±1.83	181.44±2.98
4	Average resting heart rate (beats min^{-1})	81.25±3.21	79.25±3.92	73.7±4.01
5	Average resting blood pressure(mmHg)	128.4/69.5	124.4/66.8	115.9/64

Calculating energy expenditure: The metabolic cost for tractor drivers or any occupation was estimated using specific metabolic equivalents (METs) and these METs quantify the energy expenditure of various activities. One MET represents the energy cost of sitting quietly and is equivalent to a caloric consumption of 1 kcal kg^{-1} $hour^{-1}$ (Sallis et al., 1985). The Compendium of Physical Activities provides MET values for a wide range of activities. For tractor drivers, who are typically engaged in sitting and driving, the MET value is generally around 3.5. For specific activities like tillage, which can be more physically demanding than regular tractor driving, the energy rate (*ER*) or MET value might be higher, the *ER* for tractor driving during tillage is approximately 4.0 METs (Ainsworth et al., 2000). To calculate the maximum heart rate (*HRmax*) and heart rate reserve (*HRR*) using the resting heart rates provided, we can use the following formulas:

$$HRmax = 220 - Age \quad (1)$$

$$HRR = HRmax - \text{resting heart rate} \quad (2)$$

The metabolic cost for a tractor driver was calculated by the following formula:

$$\text{Energy expenditure (kcal hour}^{-1}\text{)} = \text{MET value} \times \text{weight (kg)} \times \text{duration (hours)} \quad (3)$$

Evaluation Procedure: The experimental design was designed to assess the impact of tractor-hitched-machinery on operator’s health (Table 3).

Table 3 Specifics of the experimental configuration for field work

Independent Parameters	Levels	Description	Responses
Implement (I)	03	I_1: Disc plough I_2: Rotavator I_3: Cultivator	Noise level at operator’s ear level.
Depth of operation (D)	03	D_1: No-load D_2: 5-10 cm D_3: 10-15 cm	Noise level at bystander’s position.
Number of Engine speed (S)	03	S_1: 1000 rpm S_2: 1500 rpm S_3: 2000 rpm	Heart rate Blood pressure

Experimental setup: The study involved a tractor of 55 hp with wheel base 2050 mm, weight 2110 kg and overall length of 3535 mm. The tractor was hitched with two bottom disc plough with disc diameter of 66 cm and a thickness of 6 mm with weight of 278 kg, L-type blade rotavator with a working width of 2490 mm, a height of 1040 mm, and a weight of 485 kg and 9-tyne cultivator with width 1830 mm, coil type tyne and weight of 220 kg. A field assessment was carried out to determine the level of noise produced tractor during various farm operations at operator’s ear level and bystanders’ position (7.5 m away from the tractor engine and 1.2 m above the ground level). The heart rate and blood pressure were monitored with polar RS 400sd heart rate monitor and Omron digital blood pressure apparatus (Figure 1).

Figure 1 Measurement of sound pressure level, heart rate and blood pressure during field operations

3 Results and discussion

3.1 Effect of tillage operation, engine speed and depth of operation on the noise level at the operator’s ear level and bystander’s position

The highest mean noise level during NL was 101.83 dB(A) at the engine speed of 2000 rpm in rotavator while the minimum mean noise level during NL was 80.70 dB(A) at the engine speed of 1000 rpm in cultivator. Rotavator produces more noise level than disc plough and cultivator due to its rotary motion (Abood et al., 2015). During tillage operation at constant tillage depth, it was observed that the noise level at the operator’s ear level increased with an increase in engine speed. The maximum mean noise level at bystander’s position during NL was 86.53 dB(A) at 2000 rpm engine speed for rotavator while the minimum mean noise level during NL was 66.61 dB(A) at 1000 rpm engine speed for cultivator (Table 4). During tillage operation at a constant engine speed, the mean noise level at the bystander’s position increased as the tillage depth increased. The findings align with research conducted by Khan et al. (2023), Abood et al. (2015), and Celen and Arin (2003). Also, it is clear that during tillage operation at constant tillage depth, the noise level at the bystander's position increased as engine speed increased.

Table 4 Tractor noise level (dB(A)) during field operation at the Operator's ear level and bystander's position

Implements (I)	Level of Engine Speed (S, rpm)	Mean noise level ± SD (dBA) Tillage depth (D, cm)					
		No-load (0)		10		14	
Cultivator	1000	**80.70±0.33**	66.61±0.46	**83.72±0.34**	71.59±0.34	**85.94±0.18**	73.63±0.16
	1500	**84.64±0.57**	71.37±0.55	**87.76±0.21**	73.25±0.25	**94.88±0.90**	76.12±0.55
	2000	**89.06±0.82**	76.46±0.35	**93.46±0.50**	79.78±0.20	**96.21±1.06**	81.58±0.21
	1000	**83.12±0.62**	66.83±0.12	**85.59±0.61**	74.44±0.45	**87.37±0.91**	78.62±0.44
Disc plough	1500	**88.60±0.40**	72.30±0.73	**92.21±0.51**	77.91±0.16	**98.37±1.07**	79.58±0.53
	2000	**91.28±0.42**	77.89±0.44	**96.28±0.43**	82.03±0.66	**99.04±0.15**	83.81±0.89
	1000	**84.85±0.32**	68.08±0.17	**89.04±0.13**	75.53±0.46	**91.67±0.78**	79.53±0.42
Rotavator	1500	**92.27±0.40**	72.96±0.38	**95.95±0.15**	78.80±0.21	**98.91±0.15**	81.11±0.87
	2000	**94.58±0.52**	80.48±0.42	**98.92±0.12**	84.92±0.34	**101.83±1.12**	86.53±0.21

3.2 Octave analysis of sound pressure level (SPL) at the operator's ear level bystander's position

The frequency analysis of SPL showed the main peaks at 63 Hz for the operation of all implements (Rotavator, disc plough and cultivator) by tractor, which was higher than that observed during the stationary condition. This indicated the shift in the frequency of noise to higher levels during the operation of tillage implements. The Octave analysis of sound pressure level (SPL) at bystander's position for the operation of a tractor with various implements is presented in Figure 2 and Figure 3. The highest value of L_{eq} was in the 1/3 octave band having a Centre frequency of 80 to 100 Hz for all the implements. The frequency analysis of SPL showed the main peaks at 63 Hz for the operation of all implements (Rotavator, disc plough and cultivator) by tractor, which was higher than that observed during the stationary condition. At the bystander's position, the values were usually below the threshold but exceeded in some cases (high rpm, more tillage depth and type of operation). Dewangan et al. (2023) have also reported the same trend while studying noise characteristics of tractors and health effect on farmers.

3.3 Variation in Heart rate during field operations

The results indicated that during tillage operation with different implement at a constant engine speed, the mean HR of the subjects increased as the tillage depth increased (Table 5). Also, it is clear that during tillage operation with different implement at constant tillage depth, the mean HR of the subjects increased as engine speed increased. It was observed that HR increased significantly both at the operator's seat and bystander level as the noise level and working time increased. The maximum mean HR of the subject was 144.33 beats min^{-1} at 14 cm tillage depth and 2000 rpm engine speed during Rotavator operation at operator's seat and 96 beats min^{-1} at bystander's position. Similar trends were reported by Abood et al. (2015).

3.4 Change in blood pressure during field operations

The results indicated that during tillage operation with the implements the increase in engine speed and tillage depth, the mean blood pressure viz, systolic blood pressure (SBP) and diastolic blood pressure (DBP) of the subjects increased and vice versa. The maximum mean SBP of the subjects was 151.31 mmHg at 14 cm tillage depth and 2000 rpm engine speed and the maximum mean DBP was 98.40 mmHg at operator's seat. At bystander's maximum SBP was 139.31 mmHg and DBP was 82.90 mm Hg (Table 6). The results of the current study are in wide agreement with the study of Kumar and Tewari (2022).

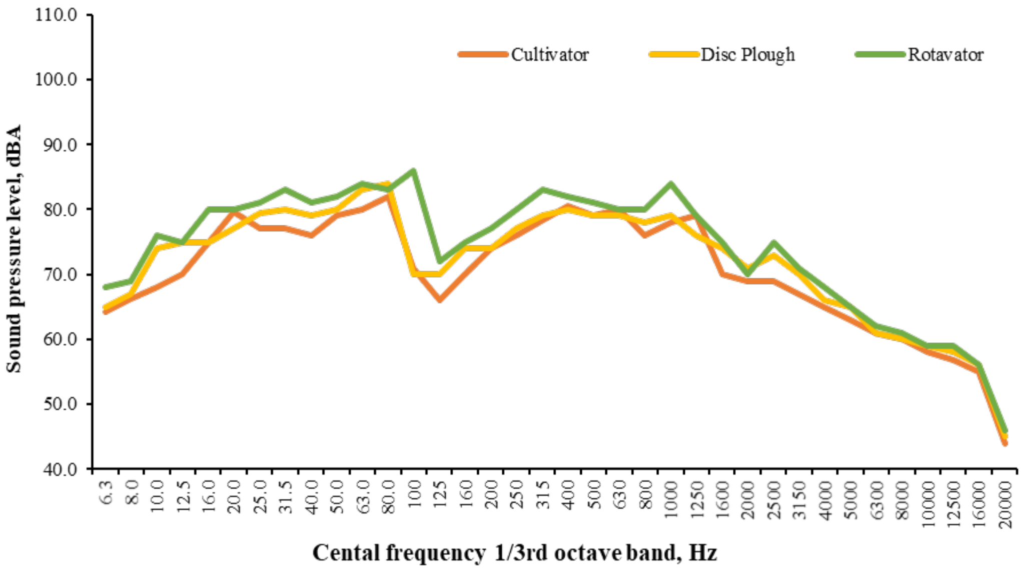

Figure 2 Frequency analysis at maximum SPL for tractor during field operation with various implements at the operator's ear level

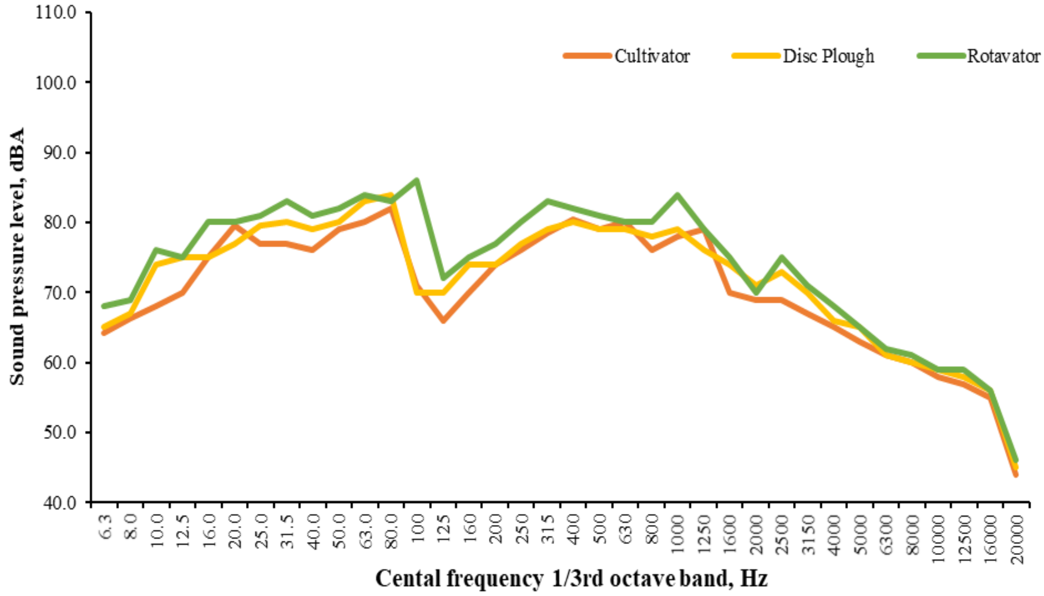

Figure 3 Frequency analysis at maximum SPL for tractor during field operation with various implements at the bystander's position

Table 5 Effect of Engine speed, Tillage depth and Implement type on operator's Heart rate level during field operation and bystander's position

Implements	Level of Engine Speed (S, rpm)	Mean H.R ± S. D Tillage Depth (D, cm)					
		No-load (0)		10		14	
Cultivator	1000	**87.00±4.00**	65.66±3.05	**97.66±3.55**	73.33±1.52	**109.33±3.51**	75.33±.57
	1500	**106.00±4.58**	72.66±2.08	**117.00±4.00**	75.00±1.00	**126.66±2.51**	82.00±2.64
	2000	**128.33±4.16**	83.66±2.5	**131.00±2.00**	86.66±1.15	**141.00±1.00**	86.33±1.52
Disc plough	1000	**88.00±1.00**	67.63±0.66	**98.66±2.08**	74.00±1.00	**110.00±2.00**	75.33±0.57
	1500	**108.66±1.52**	73.66±0.57	**119.33±3.055**	75.66±1.15	**127.66±6.11**	82.33±1.15
	2000	**129.00±4.16**	85.33±1.52	**134.33±3.05**	87.66±1.15	**142.00±2.00**	87.33±1.52
Rotavator	1000	**98.33±1.52**	68.66±2.30	**110.00±1.52**	75.33±1.52	**112..66±3.51**	77.00±0.57
	1500	**111.66±3.05**	74.66±1.52	**127.66±6.00**	82.33±0.57	**134.66±4.50**	84.00±2.64
	2000	**132.00±4.58**	87.00±1.00	**142.00±1.52**	89.33±1.52	**144.33±4.16**	96.00±1.00

Table 6 Effect of Engine speed, Tillage depth and Implement type on operator's Blood pressure level (mmHg) during field operation and bystander's position

Implements (I)	Level of Engine Speed (S, rpm)	Mean B.P ± S. D Tillage Depth (D, cm) No-load (0)		10		14	
		SYS. / DYS.	SYS. / DYS.	SYS. / DYS.	SYS. / DYS.	SYS. / DYS.	SYS. / DYS.
Cultivator	1000	**128.60±1.51**	110.41±2.51	**131.45±1.52**	115.45±2.53	**135.41±0.57**	121.61±2.87
		73.41±2.11	62.41±2.14	**80.45±0.79**	63.45±1.71	**85.41±0.79**	64.41±1.79
	1500	**132.66±1.52**	124.66±1.52	**138.41±0.57**	129.41±1.57	**140.78±2.64**	131.78±2.64
		79.14±0.99	71.16±2.19	**86.78±0.94**	73.78±0.93	**89.41±0.79**	72.41±2.97
	2000	**140.45±1.00**	134.75±1.00	**143.41±1.52**	136.41±3.52	**147.31±1.00**	135.31±3.41
		87.00 ±1.00	74.00±2.00	**89.33±1.52**	75.33±0.52	**96.00±1.00**	81.40±1.19
Disc plough	1000	**129.41±1.51**	115.41±2.51	**134.45±1.53**	117.45±2.53	**136.41±0.87**	125.61±2.87
		74.41±2.14	63.41±2.14	**82.45±0.71**	64.45±1.71	**86.41±0.79**	68.41±1.79
	1500	**134.66±1.52**	126.66±1.52	**139.77±0.57**	130.41±2.57	**141.78±2.64**	133.78±1.64
		80.13±0.19	72.16±2.19	**88.78±0.93**	74.78±0.93	**89.41±0.97**	75.41±2.97
	2000	**140.75±1.00**	135.75±1.00	**144.41±2.52**	138.41±3.52	**148.31±1.14**	137.31±3.41
		87.34±1.00	76.00±2.00	**89.01±0.52**	78.33±0.52	**97.00±1.19**	82.40±1.19
Rotavator	1000	**130.41±1.51**	121.41±2.51	**137.45±2.53**	125.45±2.53	**139.61±3.87**	127.61±2.87
		75.41±2.14	66.41±2.24	**84.45±1.71**	68.35±1.71	**86.55±1.79**	69.21±1.79
	1500	**134.66±1.52**	127.66±1.52	**140.41±2.57**	131.41±2.57	**143.78±2.64**	136.78±1.64
		82.13±2.19	72.16±2.19	**89.78±0.93**	75.78±0.93	**92.41±2.97**	77.41±2.97
	2000	**144.75±1.00**	136.75±1.00	**146.41±3.52**	139.21±3.52	**151.31±3.41**	139.31±3.41
		89.33±2.00	77.10±2.00	**95.33±0.52**	78.93±0.52	**98.40±1.19**	82.90±1.19

Note: Bold value defines operator's value.

Table 7 Noise level attenuation during the idle condition of power source at the operator's ear level and bystander's position after using noise protection devices

Power source (P)	Level of engine speed (S, rpm)	Mean noise level ± SD (dBA) Ear muff	Earplug	Moist cotton
		Operator's ear level		
Tractor	1000	59.30±0.0.72	63.29±0.0.56	71.44±0.49
	1500	64.48±0.0.62	68.52±0.16	74.53±0.56
	2000	68.66±0.66	72.77±0.11	75.04±0.75
		Bystander's position		
	1000	43.86±1.07	50.69±0.52	53.68±0.49
	1500	48.33±1.28	54.23±0.28	62.40±0.40
	2000	52.25±1.09	61.02±0.92	64.87±0.46

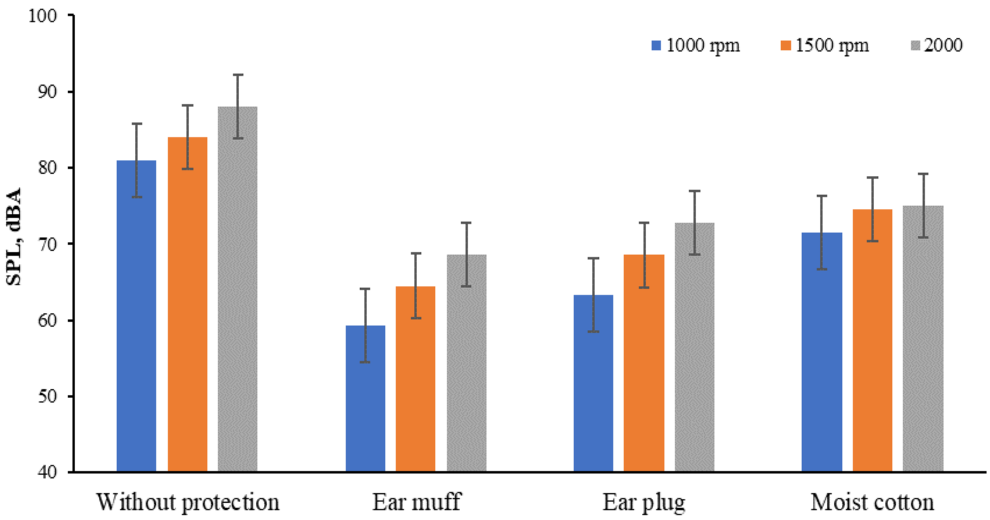

Figure 4 Comparison of SPL without & with noise protection devices in tractor

Table 8 Comparative evaluation of noise protection devices at operator's seat during idle condition

Ergonomic parameters	Without a noise protection device at 2000 rpm	Ear muff	Earplug	Moist cotton
HR (bpm)	132	82.66	97.33	99.66
BP: SBP/DBP mmHg	144.75/89.33	133.45/73.10	134.21/74.33	137.31/77.40

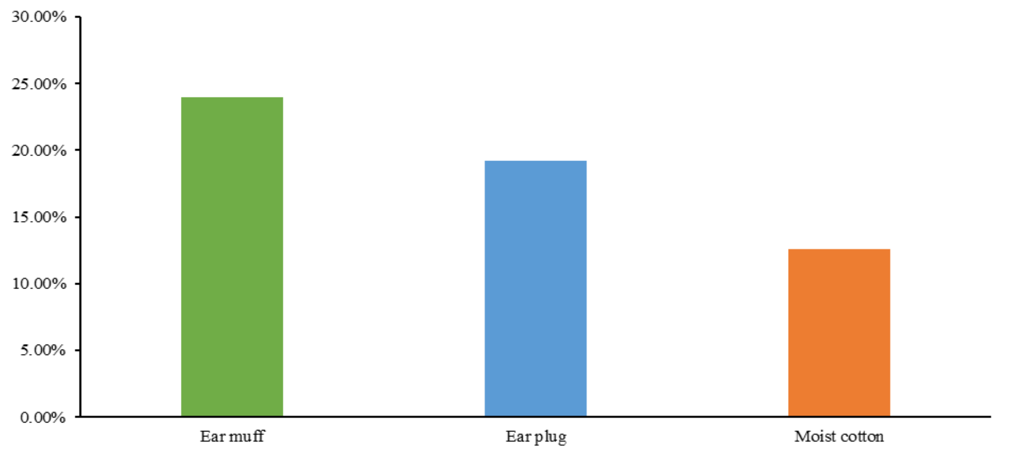

Figure 5 Overall noise reduction percentage in tractor while using different noise protection devices

3.5 Attenuation characteristics of selected noise protection devices

After experimentation, it was observed that the noise levels produced by tractor during idle condition and tillage operation were higher at the operator's ear level than the threshold as recommended by NOISH and OSHA. The industry has already recognized the noise hazard for its workers, and standards have been developed to guide the protection of hearing by either reducing the noise level, reducing exposure time, or supplying ear protection devices. A maximum reduction in noise was observed with ear muff followed by ear plug and moist cotton and same trend was observed at bystander's position (Table 7). Lar et al. (2012) conducted a study on comparison of the noise level of tractors with and without cab and reported that the SPL at the driver's ear level for the tractor without cab ranged from a low of 91 dB(A) to a high of 93 dB(A) and the SPL for a closed cabin in all cases stayed below 82 dB(A).

It was also observed that ear muff reduced maximum noise (up to 25- 30 dB(A)) followed by Earplug (up to 10- 17 dB(A)) and Moist cotton (up to 2- 5 dB(A)) (Figure 4). It was found that Ear muff reduced noise up to 24.26% followed by earplug 19.04% and then moist cotton 13.94% (Figure 5). The higher efficiency of Ear muff was due to the whole ear covering and high-quality vinyl foam pad fitted inside that filters out specific noise pitches. It was also observed that there was a significant drop of 37.38% in heart rate level by ear muff followed by ear plug (26.26%) and moist cotton (24.50%) and for the blood pressure, it was 7.8%, 1.07% and 1.05% respectively (Table 8).

3.6 Energy expenditure of subjects

Energy expenditure, expressed in kilocalories per hour (kcal hour^{-1}), refers to the amount of energy that an individual or a system expends or uses over the course of one hour. It represents the rate at which energy is consumed by the body or by a specific activity**.** The results indicated that during tillage operation with the implements the increase in engine speed, tillage depth, the mean energy expenditure kcal hr^{-1} of the subjects increased and vice versa. This rise in energy expenditure is primarily due to the heightened physical demands placed on the operators. As engine speeds increase, operators must exert more effort to manage and control the equipment effectively. They may need to maintain posture, handle steering, and adjust settings more frequently or with greater force, all of which contribute to increased muscular exertion. Similarly, deeper tillage requires operators to engage more intensely in manipulating the equipment through potentially tougher and more resistant soil conditions, further elevating their physical workload. These factors combined lead to a higher overall energy expenditure per hour as operators strive to maintain operational efficiency and productivity amidst varying operational challenges and conditions. The energy expenditure of tractor operators during tillage operations is significantly influenced by both their weight and age. Age and weight both impact energy expenditure. As people age, their basal metabolic rate typically decreases due to muscle loss and hormonal changes. Conversely, higher muscle mass increases metabolic rate, meaning weight and body composition affect energy needs. Physical activity remains crucial, as it boosts metabolism regardless of age or weight, highlighting its role in managing energy balance and overall health as depicted in the Table 9.

Table 9 Metabolic cost per hour for driving a tractor for each subject

Subject	Age	Weight (kg)	Maximum heart rate (HRmax)	Heart rate reserve (HRR)	Energy expenditure (kcal $hour^{-1}$)
A	45	82	175	93.75	328
B	37	64	183	103.75	256
C	25	57	195	121.30	228

3.7 Impact of machine parameters on heart rate and blood pressure

The parameters of tractor machinery, such as engine power, operational speed, and maintenance condition, significantly influence the heart rate and blood pressure of operators during use. High engine power and operational speed can increase noise and vibration levels, exacerbating the physiological stress experienced by operators. During tillage operations, the high noise levels produced by tractors can notably impact the heart rate and blood pressure of operators. Extended exposure to such noise triggers the body's stress response, resulting in the release of hormones such as adrenaline and cortisol. This physiological response elevates heart rate and blood pressure as part of the body's natural reaction to stress. While this mechanism is initially adaptive, chronic exposure can lead to detrimental effects, causing sustained hypertension and tachycardia. Over time, these conditions increase the risk of developing cardiovascular diseases. Moreover, prolonged noise exposure contributes to fatigue and impairs cognitive function, thereby compromising the overall health and safety of operators. To safeguard cardiovascular health, it is essential to implement noise-reducing strategies, including the use of noise-canceling devices and the regular maintenance of equipment to reduce noise emissions. Research conducted by Roscoe et al. (2023) and Egela and Hamed (2017) supports these findings, demonstrating the adverse effects of tractor noise on cardiovascular health and underscoring the need for effective noise mitigation measures.

4 Conclusion

The results revealed that the noise produced with tractor-hitched implements (disc plough, cultivator and rotavator) at operator’s ear level and bystander’s position was higher than the allowable level of 85 dB (A). The heart rate with the intervention of ear muff, ear plug and moist cotton was reduced to 82.66 bpm, 97.33 bpm and 99.66 bpm from 132 bpm without intervention. Similarly, the heart rate (SBP/DBP) was reduced to 133.45/73.10, 134.21/74.33 and 137.31/77.40 from 144.75/89.33 with intervention. The ear muff reduced the noise by 24.26% followed by Earplug 19.04% and moist cotton 13.94%. The study can be instrumental in involving the interventions to reduce the discomfort of the operator and improve the working efficiency.

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Conflict of interest

The contributing authors have worked in unison in preparing this manuscript and therefore, no conflict of interest exists.

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