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Tractor drivers and bystanders noise exposure in different engine speeds and gears

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Abstract

Aims: Tractors are one of the most important sources of noise exposure in agriculture. This study aimed to investigate noise exposure in Romanian tractor drivers and bystanders' when it's operating at different engine speeds and gears.

Methods: This cross-sectional study was carried out on Romanian tractor (M-650) available in agriculture college field of Shahid Bahonar University of Kerman in 2011. According to international standards a 20m×3m field was chosen and then the noise levels for two positions, the driver's ear and bystanders, were measured in two conditions, fixed (neutral) and moving (at different gears and engine speeds). To define the characteristics of the tractor's noise, frequency analysis was also performed. Data analysis was done by descriptive statistical methods using Excel software.

Results: While working in place, bystanders near the exhaust had the highest noise exposure and an increase in engine speed from 850 to 1700 rounds per minute led to an increase in noise for the driver's ear from an average of 5.8 to 9.3dB and for the bystanders from an average of 2.3 to 10.3dB. The mean sound level at lower frequencies was higher than middle and high frequencies.

Conclusion: When the tractor is moving, at 850 rounds per minute the driver's exposure to noise in all gears is less than standard, but at 1700 rounds per minute the noise level is higher than the Iranian and ACGIH standard and controlling measures seems to be necessary.

Keywords: Romanian Tractor, Noise Level, Engine Speed, Gear

Introduction

Noise is generally created unintentionally. This noise could be derived from the airplane's engine, strokes of pressing machine and stereo sound systems, etc. [1]. Among all pollutions related to jobs, noise is the most prevalence one and exists virtually in every environment and industry and is considered as one of general stress-inducing factors for cardiac-artery patients [2]. The high level of noise has been known as the threat to human health for consecutive centuries. In the past, the sources of noise were little and therefore, their by-product effects were lower and only a small group of people were exposed to it. But after the Second World War, ordinary people were exposed to the harmful effects of the noise, due to the rapid growth of industry and the development in the sources creating noise in the world [3]. In the US, around 11 million workers are exposed to the levels of potentially dangerous noises in workplaces and in 1990 compensation amounting to 200 million dollars was paid due to the decline in hearing stemmed from noise [4]. Decline in hearing stemmed from is among the most prevalent and preventable job diseases in most Asian countries. The sources of noise in these countries include industries, agriculture industry, exploitation of natural resources and city traffics [5]. Agriculture is among the industries in which the workers (farmers) face a wide range of harmful factors. The physical dangers derived from agricultural machineries and animals lead to the injuries in farmers but most agricultural works is accompanied by noise and will lead to the decline in hearing [6]. Agriculture is known as one of the three jobs which encounter the highest noise levels in the world. The use of hearing protection tools is not common among agricultures. It is still unknown in which age the decline in hearing related to noise starts in the farmers. But its prevalence is high among men working in the farm [7]. In *Troster*'s study which was done to determine the extent of decline in hearing related to facing noise among 60 tractor drivers, it became clear that the noise level in all tractor drivers has been higher than 85 decibels and their decline in

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hearing increase with the rise in the years they have been using tractors [8]. *Breste* et al.'s study showed that the level of noise pressure in the ear positions of drivers of tractors with and without cabin with open windows is much higher than standard levels and in cases, the noise levels have been higher than 95 decibels [9]. In a study done under the name of "the features of tractor noise and its effects on the drivers' health", it became clear that the level of noise pressure in the positions of driver and his assistance has exceeded the proposed standards (NIOSH & OSHA) for 8 working hours and this will lead to problems in the long-run [10]. Tractor's engine speed is recognized as one of factors affecting the noise level produced by tractors [10, 11, 12, 13]. Romanian tractors (M-650) are among tractors with the power of between 45 and 80 horsepower and in Iran, at present, despite the existence of some problems such as the farmers' low purchase power, the smallness of cultivation lands, etc., it is not possible to use big tractors with high power. This study was done to investigate the noise level produced by M-650 Romanian tractor in both fix and mobile states in two positions of the driver's ear and the bystanders.

Methods

In this cross-sectional study that done in 2011, a Romanian tractor (M-650) was used which was still in good shape and manufactured by Iran-Tabriz tractor manufacturing factory existing in agricultural faculty of Shahid Bahonar university. It possessed a gearbox consisted of 5 forward gears and 1 reverse gear, equipped with tractor splitting system to provide 10 speed forward and 2 speed backward. Its complete details are provided in Table 1. With respect to the fact that to do agricultural works normally the above tractor's main gears (without the splitting gears) are used, thus, in this study, 5 speeds of the forward of the tractor were used, without the splitting gears. Also, because the use of backward gear seldom happens during farming, it was eliminated and the study embarked on investigating gears without splitting ones in the selected engine speeds. Before measuring, the air pressure of tractor's tires was set according to the brochure of the manufacturer to do agricultural works. As such, the air pressure of front and rear of the tractor's tires was 2.2 and 1 atmosphere respectively. Before measuring, the tractor was ignited 20 minutes before so as to warm its engine [14].

Measuring noise was done in a calm environment and remote from residential areas and trees (in a diameter of 100 meters), inside the agricultural faculty of Kerman's Shahid Bahonar university. To do so, a stage was defined inside the farmland of the above faculty whose length and width were 20 and 3 meters respectively, and when measuring noise level, the tractor was moving on it (Figure 1).

Table 1- The features of Romanian tractor (M-650) used for this study

Engine Model	Four-cycle diesel-Injection system Direct D-110
Power	65 horse power
Maximum engine speed	1800 rotations per minute
Fuel consumption	Gasoline
Cooler system	Water with centrifugal pump and cooling fan
The overall weight of the tractor	Together with oil and gasoline 2980kg

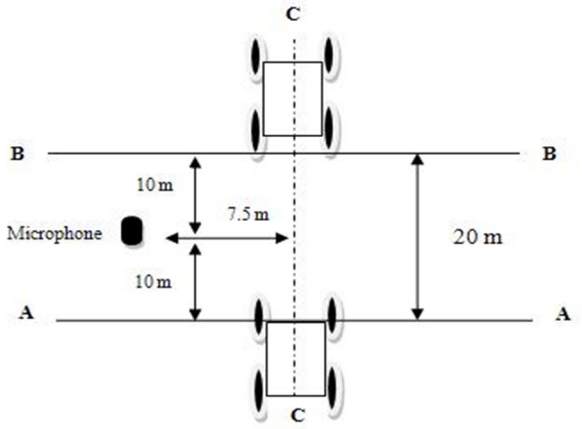

Figure 1- Measuring noise level in the position of bystanders of Romanian tractor (M-650)

In this study, engine speeds of 850 and 1700 rotations per minute was selected for Romanian tractor (M-650). In the previous researches, engine speeds of 1000 and 2000 rotations per minute were used to measure noise level in tractors [12, 13]. But because the maximum engine speed of Romanian tractor is 1800 rotations per minute, these engine speeds were selected (Table 1). Measuring noise level in both positions of the driver's right ear and bystanders was done. In the position of the driver's right ear, there was inserted a sound-measuring microphone within 25 centimeters from the driver's right ear. This was repeated for four times for each gear and two selected engine speeds and eventually, logarithmically average of these measures was reported as the balanced level of the driver encountering noise on the stage. To measure the noise level in the position of bystanders, a sound-measuring microphone was inserted in the driver's left side within 10 meters from Commencement Center (CC) and within 7.5 meters from central line (the center of the axes of the tractor's

tires) and at a height 1.2 meters from the ground from the CC, based on the standard method of ISO 362 (Table 1) [15]. The measuring with gear and the selected engine speed was done since the tractor's front tires started moving from AA point, lasting when the tractor's rear tires passed the BB point. This was done four times for each gear and two selected engine speeds and eventually, logarithmically average of these measurements was reported as overall level in the positions of bystanders. Then, noise level around the tractor (in engine speeds of 850 and 1700 rotations per minute) in fix state was measured. To do so, the sound-measuring device was inserted within 50 centimeters from the tires' axes, parallel to the ground, in front, rear, right and left sides of the driver and at a height of 50 centimeters. Measuring was also done in the position of exhaust emissions within 20 centimeters from the exhaust. To do so, the angle between sound-measuring microphone and the vertical axes of exhaust was selected 45 degrees. In fix state, noise level was measured in both engine speeds in the position of the driver's ear. Finally, to make ourselves aware of the features of the noise created in the position of the driver's right ear, frequency analysis was measured in one octave-band spectrum and in the two selected engine speeds while moving [16]. All environmental conditions were taken as similar while measuring, including temperature, wind speed, and steepness of the stage. Furthermore, the wind direction in the environment was taken similar to the movement direction of the tractor in the stage. Before starting each measurement, the environmental noise level (background noise) was also measured.

Before starting each measurement, the device measuring noise level (the model of CEL 450) was calibrated to insure of research's accuracy with the calibrator (the model of CEL 450) in 1000Hz frequency and to prevent the wind effect on measured noise level, a wind catcher spongy was inserted on level-measuring microphone. To measure noise level, the network A and the SLOW response speed of level-measuring device were used. The wind speed and temperature were determined in the environment and during measuring noise by the anemometer (the model of ISA-6-3D) and simple thermometer respectively. To analyze the data, the descriptive statistical methods and Excel software were employed.

Results

Before measuring, wind speed, temperature and level of environmental noise (background) were 2.1±0.2 (m/s), 20±2 centigrade and 49-51.2dB respectively. When the tractor was fixed and turned on, measuring of noise level was done in engine speeds of 850 and 1700 rotations per minute and the results are provided in Table 2.

Table 2-The results of the averages of noise level in the surroundings of Romanian tractor in fix state in different engine speeds (without the use of splitting gear)

The position of measuring	Engine speed 850	Engine speed 1700	Difference in noise levels (dB)
Bystanders (within 7.5 meters)	70.1	81.8	11.7
The tractor's rear	76	87.1*	11.1
The tractor's front	82.5	96.1*	13.6
The driver's right ear	79.4	91.2*	11.8
The tractor's left side	87.2*	97.6*	10.4
The tractor's right side	85.9*	98.6*	12.7
The tractor's Exhaust emissions	94.7*	107.9*	13.2

*The noise level exceeds national standard and ACGIH

According to Table 2, in measured positions in fixed state, in both selected engine speeds, the bystanders' position had the lowest noise level and there comes second the position of the tractor's rear. The most extent of noise level is related to the Exhaust emissions in which for the increase in engine speed from 850 to 1700 rotations per minute, there is an increase of 13.2dB in noise level. Based on this, the frequency analysis in Exhaust emissions position was done according to the mentioned method and its results are summarized in Diagram 1.

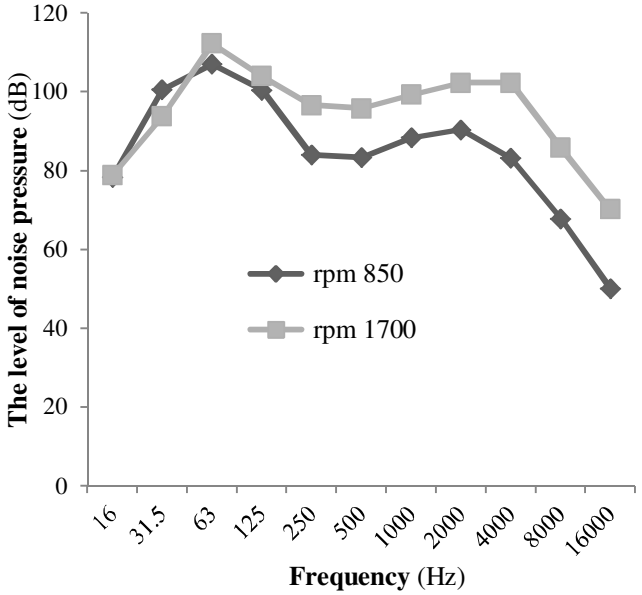

Diagram 1- Results of frequency analysis in the position of M-650 Romanian tractor's Exhaust emissions in fixed state in the selected engine speeds

The results, derived from measuring noise level in the position of the driver's ear and bystander, while Romanian tractor (M-650) was moving on the stage with different gears and engine speeds, are summarized in Tables 3 and 4.

Table 3- The results of averages of noise level in different gears and engine speeds in the position of the driver's right ear in moving Romanian tractor

The gear ratio	Engine speed 850	Engine speed 1700	Difference in noise levels (dB)
One	81.5	90.8*	9.3
Two	84.5	90.4*	5.9
Three	81.5	90.4*	8.9
Four	81.6	91.2*	9.6
Five	84.9	90.7*	5.8

*Noise level exceeded national standard and ACGIH

Table 4- Results of averages of noise level in different gear and engine speeds in Romanian tractor in the position of bystanders in moving tractor

Gear	Engine speed 850	Engine speed 1700	Difference in noise levels (dB)
One	67.8	77.3	9.5
Two	68.1	78.4	10.3
Three	68.2	78.3	10.1
Four	69.7	77.2	7.5
Five	71.3	73.6	2.3

To compare the extent of decrease in noise level due to the existence of distance between the position of the driver's ear and bystanders, the results of noise level in different engine speeds and gears are summarized in Table 5.

Table 5- Difference in averages of noise level in different gears and engine speeds in the position of the driver's ear and bystander in moving Romanian tractor

The gear ratio	Difference in noise level in the position of the driver's ear and bystander in the engine speed of 850 rotations per minute (dB)	Difference in noise level in the position of the driver's ear and bystander in the engine speed of 1700 rotations per minute (dB)
One	13.7	13.5
Two	16.4	12
Three	13.3	12.1
Four	11.9	14
Five	13.6	17.1

According to Table 5, in engine speed of 850, the difference in averages of noise level between the two positions of the driver's ear and bystander was 11.9-16.4dB and was 12-17.1dB in engine speed of 1700. Therefore, with the increase in the engine speed, there has been an increase in the levels of difference between the driver's ear and bystander.

In the following, the results of frequency analysis in octave-band spectrum in the position of moving Romanian tractor driver's ear in the two engine speeds of 850 and 1700 rotations per minute in different gears are represented in Diagrams 2 and 3.

The level of noise pressure in the frequency of 4000Hz, in which the human's ear is more sensitive to the noise level, is between 71-80.7dB and in the engine speed of 1700 the difference decrease and equates 82.4-84dB. This increase in engine speed leads the amounts of level noise to approximate the permitted standard level (85dB).

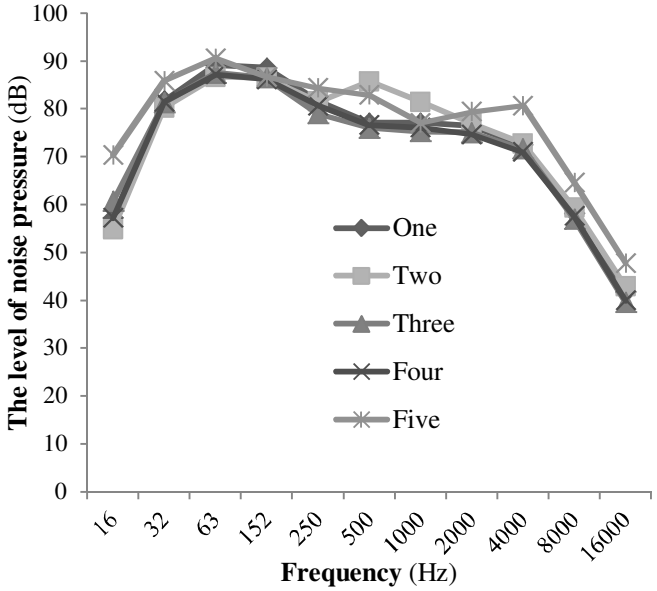

Diagram 2- Results of frequency analysis in the position of the driver's ear in different gears in the engine speed of 850 rotations per minute in moving Romanian tractors

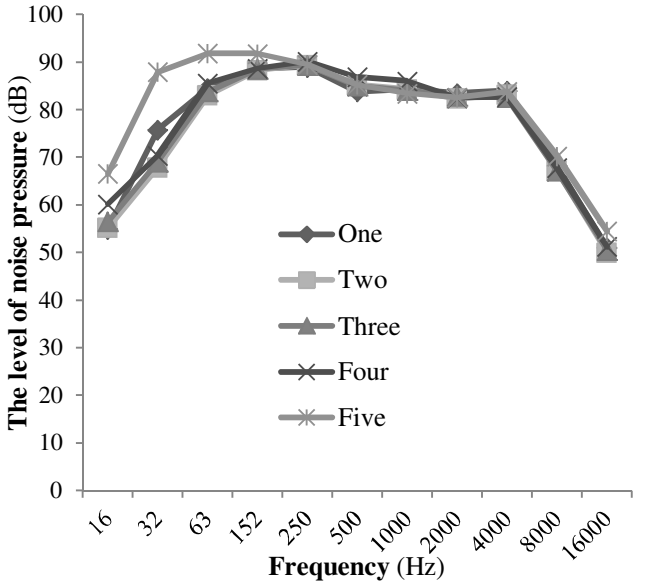

Diagram 3- Results from the frequency analysis in the position of the driver's ear in different gears in engine speeds of 1700 rotations per minute in moving Romanian tractor

Discussion

The aim of this research was to investigate the noise level created from Romanian tractor (M-650) in both fixed (without the use of gears) and moving states in the position of the driver's ears and bystander. In fixed state, with the increase in engine speed from 850 to 1700 rotations per second, the average of noise level increased as well in all situations. In engine speed of 850, the position of bystander (within 7.5 from the tractor) had the least average of noise level (70.1dB) and Exhaust emissions had the highest average of noise level (94.7dB). Also, the highest and the least levels of added noise, due to the increase in engine speed in the positions of the tractor's front and left side, have been 13.6 and 10.4dB respectively. In the position of the driver's ear, with the increase of engine speed from 850 to 1700 rotations per minute, the level of noise pressure also increased. The highest and the least difference in levels were 9.3 and 5.8dB in fourth and fifth gears respectively. By observing noise level in the position of the driver's right ear of the Romanian tractor in both fixed and moving states, it became clear that in the engine speed of 1700 rotations per minute, noise level in fixed state equals noise level of the fourth gear of the tractor in moving state. This means that the noise level created in this tractor has not much to do with the gear's ratio. In the position of the driver's ear in moving tractor, with the increase in engine speed from 850 to 1700 rotations per minute, the level of noise pressure also increased. The highest and least extent of the increase was 10.3 and 2.3dB in second and fifth gears respectively.

In *Dourgat* & *Klen*'s studies in Turkey in 2004, and also *Klen* & *Arin*'s study in Turkey in 2003, with the increase in engine speed from 1000 to 2000 rotations per minute, the noise level of the tractor increased 6dB averagely [12 and 13]. In the present study, in the position of the driver's ear in the engine speed of 850 rotations per minute, the highest and the least average of noise level were 81.5 and 84.9dB respectively, which amounts between 90.4 and 91.2dB in the engine speed of 1700. In a study in New Zealand, it became clear that the noise level in the tractors without cabin is higher than 100dB [6]. In a study done by *Lar* et al. in Shoushtar, it became clear that the average of noise level in the tractors without cabin, in the tractors with cabin with open windows, and in the tractors with cabin with closed windows were 89.1-90.4, 85.6-86, and 75.3-76dB respectively. At the same time, in the same tractors while plowing, the average of noise level in above cases is 90.8-91.7, 86.3-87.7, 76.1-76.5dB respectively [17]. According to Table 5, with the increase in distance from the source of noise (tractor), the average of noise level decreased which leads to the increase in distance and the noise attraction feature across the farm. In engine speed of 850, the highest and the least difference in the levels were related to the second and fourth gears. In the same manner, in engine speed of 1700, the highest and the least difference in noise levels were related to fifth and second gears respectively. As can be seen in the diagrams 3 and 4, in frequencies less than 250Hz, the level of noise pressure increases with the rise in frequencies but after the frequency of 250Hz, this upward trend changes a downward one and in overall, the level of noise pressure in low frequencies is higher than those in high frequencies and this will lead to problems in control cases. Since most control cases in low frequencies have lower functionality in comparison with higher frequencies. With the increase of engine speed from 850 to 1700, an increase is observed in the level of the frequencies of octave-band spectrum. The results of frequency analysis in this study are in harmony with those of *Iback* et al. and also those of *Summer* et al. [18, 19]. In the engine speed of 1700, the average of noise level in frequencies lower than 250Hz in different gears has more difference in comparison with those in frequencies higher than 250Hz. In the engine speed of 850 in the frequencies higher than 250Hz, the difference in the average of noise level is higher. As can be seen in diagram 2, the noise level in the position of Exhaust emissions increases with the rise of frequencies in each engine speed, up to the frequency of 63Hz and after that, this upward trend changes to downward one, up to the frequency of 500Hz, and from the frequency of 500 to around 2000Hz, the trend becomes upward and then after that, it becomes a downward trend up to the frequency of 16000Hz. In a study done by *Khavanin* et al., it was clear that in the frequency analysis of the motorcycle's exhaust emission, with the increase in engine speed, the noise level in high frequencies increases and the distribution of sound energy occurs more in low frequencies, and reaches its maximum in the frequency of 63Hz [20]. In this study, the variable of gear did not much affect the noise level created by the tractor and this is in harmony with the results derived from *Hassan Beygi* et al.'s research and those of *Myer* [21, 22]. In another study in which health problems of drivers of tillers and those of farmers were compared, it became obvious that the tiller's drivers had more health problems in comparison with the farmers and more than 80% of tiller's drivers suffer from decline in hearing, faint, the fingers' pain and backache. At the

same time, farmers suffered from the decline in hearing, amounting to 24% [23]. Agricultural machineries create synthesis noise, often in area of low frequencies. The inactive methods of controlling noise are unable to decrease effectively the noise inside the cabin [24]. Repressing the noise in the source of the tractor is problematic and costly; but insulating and using the cabin will provide the permitted noise level for the driver [25]. The results of this study shows that the average of noise level in the position of the driver's ear, in the engine speed of 850 is lower than the permitted level but in the engine speed of 1700 is higher than the permitted level (85dB) (ACGIH) [26].

Conclusion

By considering cases such as installing the cabin on the tractor and (installing) muffler inside the tractor's exhaust, and also the use of individualist protection tools, it is possible to protect the drivers, who constitute the majority of the society, from the harmful effects of the noise.

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