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Full Length Research Paper

Driver exposure and environmental noise emission of Massey Ferguson 285 tractor during operations with different engine speeds and gears

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Agricultural tractor has led to development of agriculture industry, however, same as other new technologies it produces noise pollution on fields and makes some problems for drivers and farmers as well. This is aimed to investigate the driver's exposure and noise emitted from Massey Ferguson tractor; model 285 during operation by various engine speeds and gears. For field measurements, the Massey Fergusson 285 tractor of agriculture college field was used. The noise levels at the right ear of driver and surroundings were measured in both idle and mobile conditions. Frequency analysis in both idle and mobile conditions has shown that the noise levels at low frequencies were higher compared with high frequencies. Based on the measurements at selected engine speed, noise levels at surrounding conditions were lower than ACGIH standard. Similar results were also observed at driver's right ear by engine speed of 1000 rpm, while the noise levels for 2000 rpm was higher than standard limit of 85 dB A. The results indicate the high influence of engine speed and low impact of gear ratio on both driver's exposure and environmental noise pollution.

Key words: Noise levels, engine speed, gears, surroundings, idle condition, mobile condition.

INTRODUCTION

Application of new technologies during last decades has increased the growth of farm productions. Tractor and other farm machineries are some examples of the new technology in agriculture industry (Xinan et al., 2005). Agriculture is among the risky industries accompanied with different process and tasks where each tasks have the capability for any kind of risks and harmful effects on farmers. Extreme temperature, noise, vibration, mechanical injuries, dust, ultraviolet and pesticides are among the harmful effects that farmers are faced with (Kumar et al., 2005). Agriculture after construction was known as the second factor of hearing loss in Japan (Miyakita and Ueda, 1997). Tractors are the considerable power sources in agriculture in which have impressive effect (Singh, 2006). Engine, transmission and hydraulic system are the main sources of noise for tractors in which the engine is the main source of noise (Kechayov and Trifonov, 2003). Based on tractor type, engine speed and type of work in farm, the noise levels are varied in tractors. Matthews has found that there was insignificant correlation between the noise and engine power (hp)

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while engine speed was more correlated with tractor's noise (Matthews, 1968). Beckett and Chamberlain (2000) has determined the main sources of hearing loss in farmers and found that the mean noise levels from noise sources were as follows: Tractors 90.7dBA, milk area 76.4 dBA, vacuum pumps 91.9 dBA and cooling compressors 83.8 dBA. Miyakita et al. (2004) has compared the risk for noise induced hearing loss between farmers and office works in Japan. It was shown that 9.6% of office workers and 16.4% of farmers ranged between 40 and 49 year, 16.1% of office workers and 30.3% of farmers ranged between 50 and 59 year, 29.9% of office workers and 50.3% of farmers ranged between 60 and 69 years were induced to hearing loss at frequency 4000 Hz. Noise exposure levels of 157 tractor drivers in rural areas revealed that the mean exposure level was ranged between 78 and 103 dBA. Seventy-five percent of tractors without cabs and 18% of tractors with cabs had noise levels of more than 90 dB (Holt and Broste, 1993). The researches have shown that the use of cab is useful in noise insulation at high frequencies in which can also protect the driver from dusty environment and heat as well (Sümer et al., 2006). The aim of this study is to investigate the noise exposure of drivers and their surroundings during agricultural operations at different gears and engine speed by Massey Fergusson (MF) 285 tractor and also to compare the results with international standards.

MATERIALS AND METHODS

Tractor's characteristics

As MF 285 tractor, nowadays, has the highest production level among the other tractors in Iran and as this tractor was adopted with different type of weathers in Iran, after halting the Romania tractor production most of farm operations were performed by this model. In this study**,** MF 285 tractor of Agriculture College of Bahonar University (Department of agricultural machinery) was used in which its maximum engine speed was 2160 rpm. This tractor has four forward gears and one reserve gear equipping control system for providing eight front and two reserve speeds. The detailed characteristics are shown in Table 1**.** When the location of field measurements was defined, before the beginning of measurement process the pressure of tractor tires was checked according to manufacture instructions and the tractor was running around 20 min to warms up the engine and gearbox oil temperature achieves the operational temperature, which is monitored by thermocouple (Kechayov and Trifonov, 2003; Dewangan et al., 2005).

Characteristics of measurement field

Location of noise measurement was selected at the silent environment in agricultural college in which was far from trees and houses (radius of 100 m). To measure the sound levels, the length and width of field was defined as 20 and 3 m. Different conditions were selected for consecutive noise measurement including:

1. When the tractor was not operating (to measure the background noise)
2. At all gears of tractor (a) right ear of driver (b) tractor's surroundings (Figure 1).
3. When the tractor was running but not working (a) right ear of driver (b) tractor's surroundings (right and left side of tractor) (c) rear of tractor (d) in front of tractor (e) at the exhaust out of tractor. Engine speed was changed from 1000 to 2000 rpm (Celen and Arin, 2003; Durgut and Celen, 2004). Based on standard method of ISO 362 (1998), the microphone was installed at 10 m from the start point (CC), 7.5 m from the central line (at the mid of tractor wheel axis), at the height of 1.2 m from the ground and at the left side of driver (Figure 1).

Measurement with selected gears and engine speed were taken during movement of tractor from starting point till the back wheels were passed the BB line. For each gear and engine speed, the measurement was repeated four times and then the averaged of measurements was reported as the total sound level at tractor surrounding (Celen and Arin, 2003). To measure the noise levels at the right ear of driver, the sound level meter was hold 25 cm away from driver head and similar to the surrounding condition, measurement were carried out four times per gear and engine speed when the tractor was running. The averaged data was presented as the equivalent noise exposure level of driver. Noise levels were also measured at engine speed of 700, 1000 and 2000 rpm around tractor.

The device were hold 50 cm away from the wheel axis and 50 cm high in the front, rear, left and right side of tractor where it was parallel to the ground. Measurement was also performed at 20 cm distance from the exhaust outlet where the angle of microphone and vertical axis of exhaust was 45°. Frequency analysis with the selected gears and engine speed were performed at the right ear of driver and also at the right, left, front, rear side and exhaust out of tractor in one octave band when the tractor was either running or idling (ISO, 1997). Before each measurement, the sound level meter Casella CEL450 was calibrated by Casella CEL450 calibrator CELL 450. The meter is a single 140 dB measurement range, no need for range selection. Following the standard method, the A-frequency-weighting and slow time weighting were used for driver noise exposure measurement. The wind speed level in the field was determined using Anemometer (ISA-6-3D, Sibata). Measurements were carried out in a flat field without any slope difference where the wind was in the same direction of tractor movement. As the data was not normally distributed using Kolmogorov–Smirnov, non-parametric tests were applied. To identify the relation between sound level and different engine speeds and gears ratios Wilcoxon and Mann-Whitney tests were applied respectively. Also, Kruskal–Wallis analysis was used to investigate the relation between sound levels and high and low gears with different engine speed using SPSS v18.

RESULTS

Noise exposure of driver and surrounding when the tractor is idle

As was mentioned, the route of movement in tractor was same as the wind direction. In the time before measurements, the wind speed, temperature, environmental sound level were 2.1±.2 (m/s), 20±2°C, 51.2 to 49 dBA, respectively.

The results of noise measurement for the idle tractor with engine speed of 700 rpm were shown in Figure 2. The measurements were performed in the front, rear, left

Table 1. Characteristics of MF 285 tractor.

Model	MF 285,Tabriz, Iran
Engine type	Perkins, four cycle diesel or injection direct system, type A4/248
Built year	2010
Number of cylinders	Four
Combustion system	Injection of fuel directly
Max engine speed (without load)	2160 rpm
power	75 HP
Max allowable load	2223 kg
Steering wheel	hydraulic
Fuel	diesel fuel
Brake	Disk smeared with oil
Cooler system	Water with centrifugal pump and cooler impeller
Engine emission design	Tier 2
Tractor traction	4x4
Total weight (kg) + water, oil and fuel	2812 kg
Distance between front wheels	Min. 1651 mm
Distance between back wheels	Min. 1829 mm
Tractor dimension	Length: 3893 mm Width: 1829 mm Height: 2528 mm

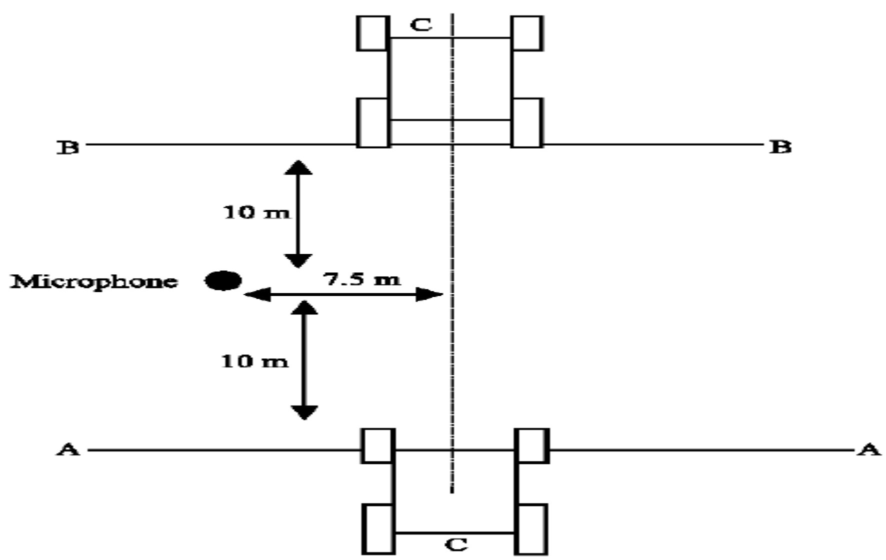

Figure 1. Noise level measurements at MF 285 tractor surrounding, derived from Celen and Arin (2003).

and right side with the distance of 0.5 m away from the tractor, right ear of driver and also at the exhaust out. Moreover, the noise level with the distance of 7.5 from the central axis wheels was 66.7 dBA.

Sound pressure level (SPL) at engine speed of 1000 and 2000 rpm in the front, rear, left side, right side, exhaust out of tractor and right ear of driver while tractor is idle were measured and summarized in Table 2. Based on Table 2, the highest and lowest SPL were found at the right side and in the rear of tractor by engine speed of 1000 rpm and for engine speed of 2000 rpm, the highest and lowest SPL were seen at the exhaust out and rear the tractor, respectively. Also, to understand the noise characteristics around tractor in the idle condition at octave band were performed in which the results are shown in Figures 3 and 4.

Table 2. Sound pressure level (dBA) around idle tractor at engine speed of 1000 and 2000 rpm.

Engine speed (rpm)	Rear side	Right ear of driver	Front side	Left side	Right side	Exhaust out
1000	76.5	78.8	85.8	84.4	85.9	83
2000	88.37	94.37	96.77	97.47	97.27	100.67

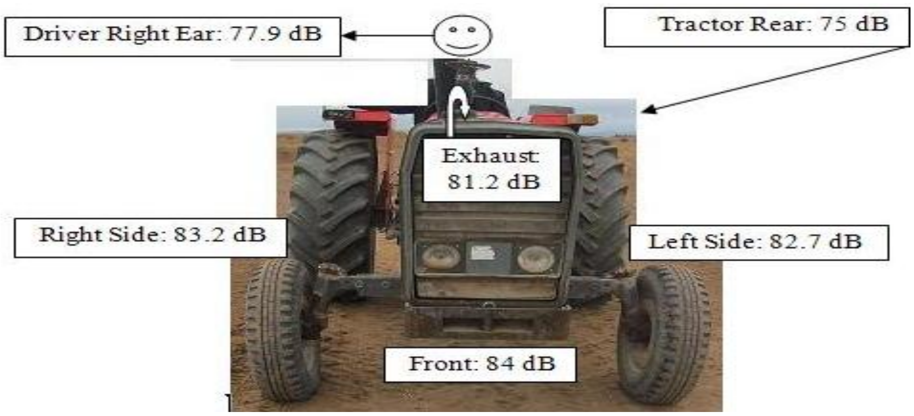

Figure 2. The sound pressure level measurements in idle tractor at the surrounding (engine speed was at 700 rpm).

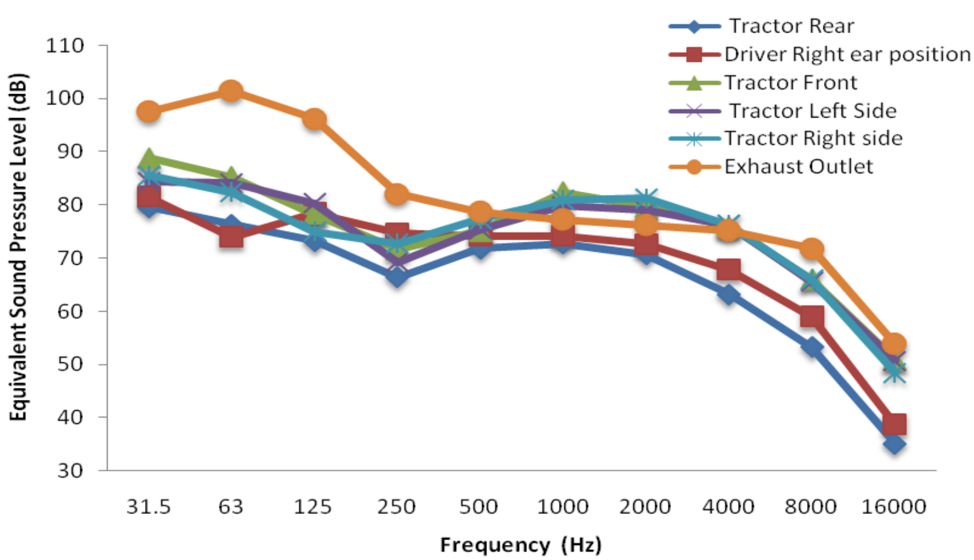

Figure 3. Frequency analysis around the MF 285 tractor with idle condition at 1000 rpm.

It was anticipated that the noise levels from exhaust out were higher at higher frequencies however as it can be seen from Figures 3 and 4, noise levels were higher at low frequencies. It can be explained by the special structure of MF 285 Tractor exhaust. The direct tube of exhaust with its metal cap operates as a barrier during gas and smoke emission. Also as the surface section was the same along its length and as the exhaust out was larger than other agricultural tractors, noise levels were higher at low frequencies.

Noise exposure of driver and surrounding when the tractor is moving

In this study, all of the gears of MF tractor were measured including low gears (first, second, third, fourth and reverse) and high gears (first, second, third, fourth

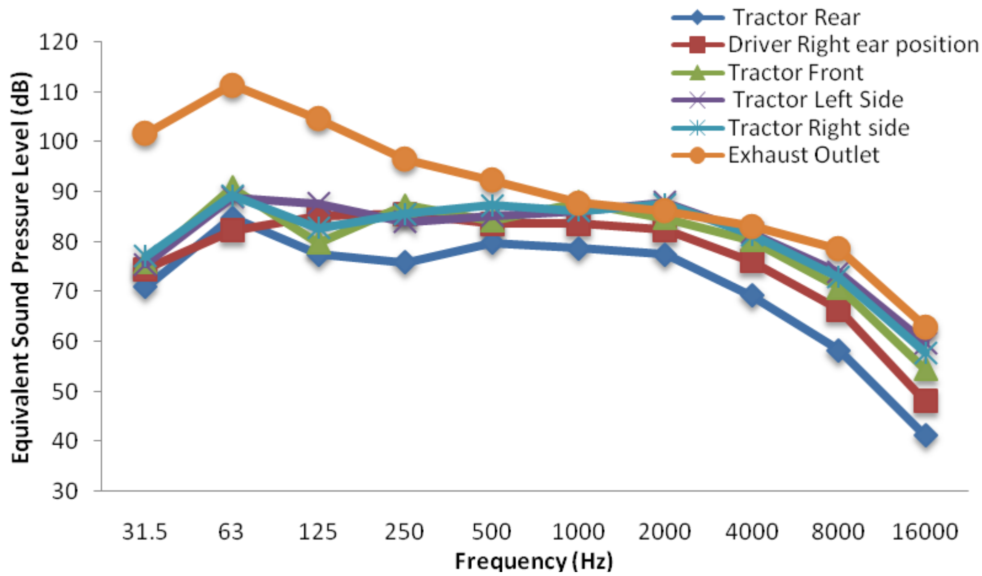

Figure 4. Frequency analysis around the MF 285 tractor with idle condition at 2000 rpm.

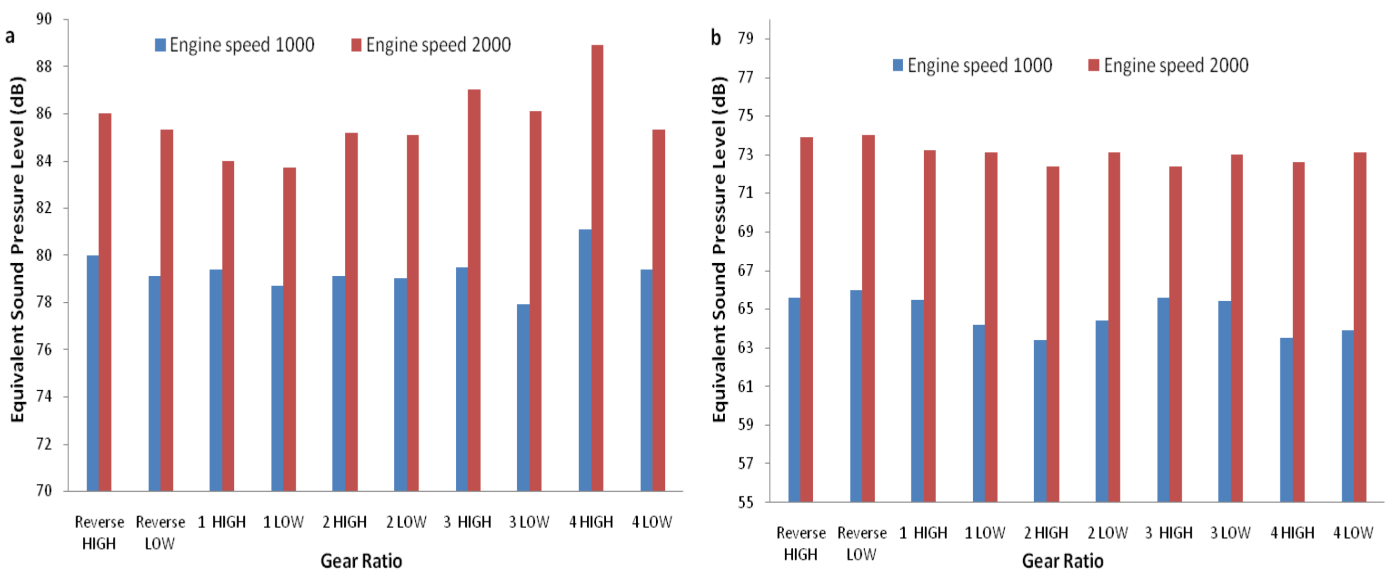

Figure 5. Sound pressure level values at MF tractor while it was moving by different gears and engine speed (1000 and 2000 rpm) (a) at right ear of driver, and (b) at surroundings (L and H stand for low and high gears).

and reverse). Figure 5 presents the SPL difference in various gears and engine speeds (1000 and 2000 rpm) at surrounding and right ear of driver while the tractor was moving.

As it can be concluded from Figure 5b, the lowest and highest sound levels were at third high gear and fourth low gear in surrounding areas by 6.8 and 9.8 dBA as a result of an increase in engine speed from 1000 to 2000 rpm. However, according to Figure 5a, the lowest and highest sound level in the right ear of driver were at first low gear and third high gear by 5 and 8.2 dBA respectively. At surroundings area and right ear of driver, there was significant difference between sound level and engine speed of 1000 and 2000 rpm using Wilcoxon test (P-value<0. 05). No considerable relation was found between sound level at different gears and engine speeds by Kruskal–Wallis analysis (P value=0.437). Based on Mann-Whitney test, no relation was found between sound levels and high and low gears at engine speed of 1000 and 2000 rpm. Moreover, to define the noise characteristics

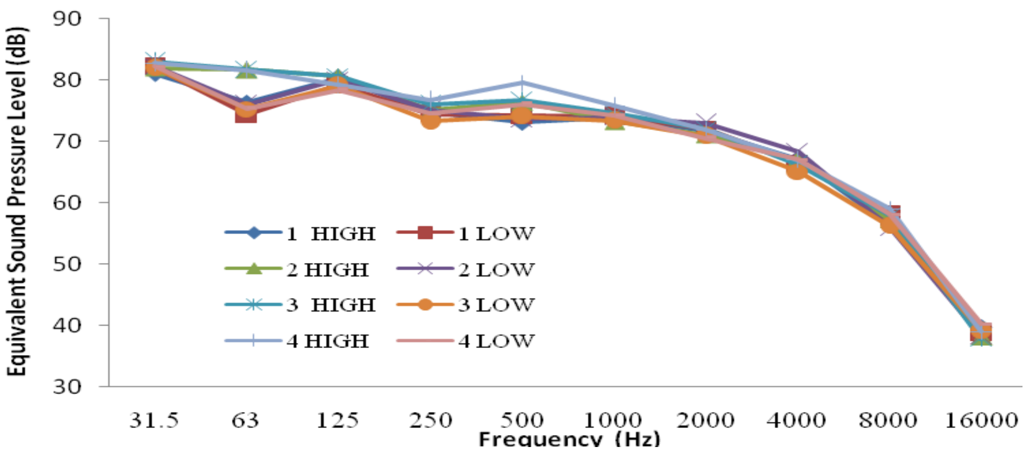

Figure 6. Sound level of MF 285 tractor with different gears of gear box and engine speed of 1000 rpm at right ear of driver (L and H stand for low and high gears).

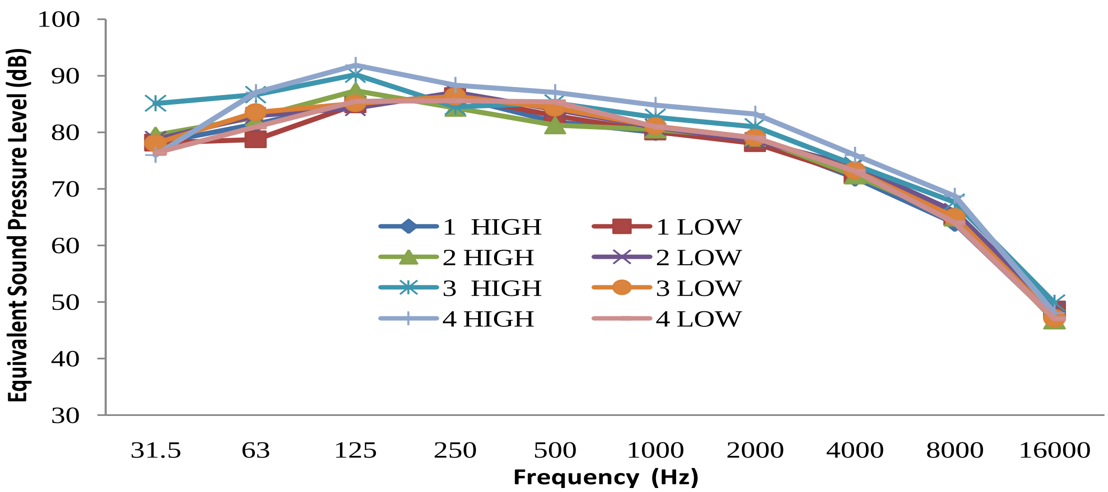

Figure 7. Sound level of MF 285 tractor with different gears of gear box and engine speed of 2000 rpm at right ear of driver (L and H stand for low and high gears).

characteristics of MF tractor, frequency analysis were performed in one octave band at different gears and engine speeds when the tractor was moving in the considered field. The results are shown in Figures 6 and 7. Note that as the reverse gears consists of low and high gears is used less both 1000 and 2000 rpm, frequency analysis in one than other gears in agricultural tasks, frequency analysis in these gears was not implemented. Figures 6 and 7 similar to frequency analysis around the idle tractor indicate that sound levels are higher at low frequencies.

DISCUSSION AND CONCLUSION

Figure 8 describes the method of noise production in farms, the effect of noise on tractor drivers and farmers (surrounding people) and the noise control methods, briefly (Winters et al., 2005).

In the study of Beygi et al. (2005) on power tiller / two-wheel tractor, it was found that noise levels at right ear of driver was higher compared to surrounding people by between 7.74 and 10.75 dBA and engine speed plays a considerable role in determining the sound level productions. Similarly, in the present study, the sound level of engine speed of 1000 rpm in right ear of driver was high in comparison with surrounding condition by between 10.1 and 15.2 dBA. According to statistical tests there was a significant correlation between sound levels and engine speeds at driver’s ear and surroundings (P-value<0. 05) (Beygi et al., 2009). The sound levels in condition of the engine speed of 2000 rpm was from 8 to

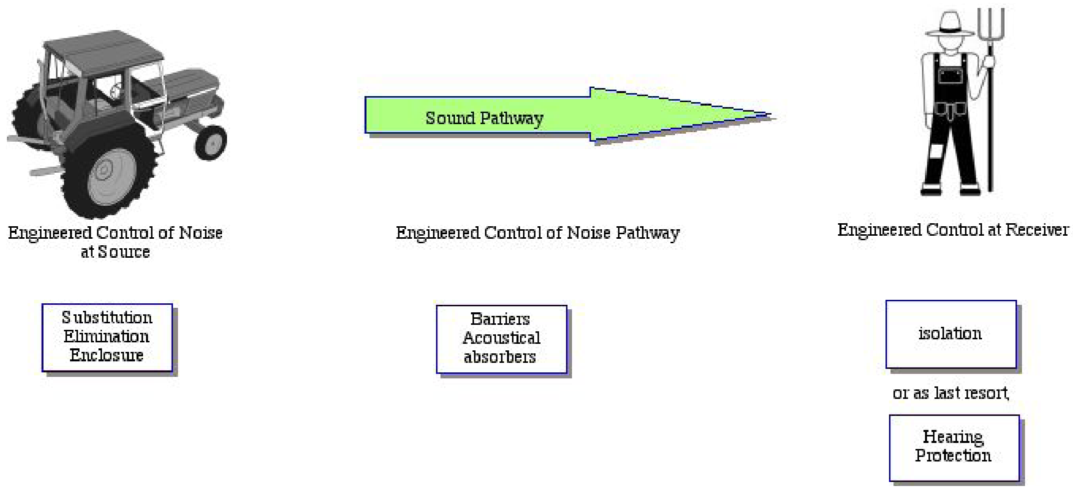

Figure 8. Impact of noise on tractor drivers and farmers along with appropriate control policies, derived from (Winters et al., 2005).

14.1 dBA in which the higher levels of noise in four-wheel tractor compared to two-wheel tractor was because of higher power in four wheel tractor. Sümer et al. (2006) reported that the sound levels at right ear of driver were 85 to 90, 81 to 83, and 76 to 81 dBA for the combines without cab, with cab attached after manufacturing, and with original cab, respectively. Sound level at low frequencies were higher than at high frequencies in which the level of noise for combine without cabin were higher than combine with cab attached after manufacturing and combines with original cab. But, the measurement results of this study showed that sound pressure level at the right ear of driver with different gears for engine speed of 1000 and 2000 rpm were 77.9 to 81.1 and 83.7 to 88.9 dBA, respectively. As the considered tractor has no cabin and as the distance between engine of tractor and driver was less than that of in combine, higher noise levels was produced. Findings in another study on urban bus drivers in Brazil stated that motor configurations has the main role for noise levels in buses in which front - engine design buses produce higher noise levels than those with rear engine design (Portela and Zannin, 2010).

A survey on tractors without cabins, field-installed cabins, and original cabins with twelve different operations has shown that sound pressure level were between 65 and 110 dBA during various agricultural operations in which sound level for low frequencies was higher than in high frequencies (Aybek et al., 2010). According to Figures 3 and 4 in idle tractor and Figures 6 and 7 during movement of tractor, it can be seen that sound pressure level were higher at low frequencies in both engine speeds (1000 and 2000 rpm) in which such increased trend was enhanced by the engine speed of 1000 to 2000 rpm. As it was observed from Figures 3 to 4 and 6 to 7 the SPL difference for various gears was considerable at frequencies lower than 250 Hz. However, such condition was not observed for frequencies higher than 250 Hz and the frequency analysis graphs were almost coincide together where the mentioned results are in agreement with the above study. Another survey has shown that that engine speed was effective on sound pressure level at tractor surrounding and ear of driver; when the engine speed changes from 1000 to 2000 rpm, SPL can increased by 6 dBA (Durgut and Celen, 2004). However, in this study, when the engine speed increased from 1000 to 2000 rpm, the sound pressure level at ear of driver and surrounding were 5 to 8.2 and 6.8 to 9.2 dBA in which has confirmed the results of previous study. Such difference for the increase in SPL between the studies can be explained by different technologies used in structure of tractors or acoustic absorption characteristics of test field. Meyer et al. (1993) found that when the engine speed changes from 1200 to 1500 and also 1500 to 2000 rpm, an increase of 3 dBA was observed. Also, it was shown that the gear ratio variable was not an important factor for total sound pressure level at tractors and other agricultural machineries and also there was no significant difference between sound pressure values at different gears. This finding was also confirmed by study of Beygi et al. (2005). Same as these studies, we found that there was no significant relation between gear variable and sound pressure level in both right ear of driver and surroundings. The obtained statistical results have shown no significant relation between gear ratio and type (high and low) and sound level at surrounding area. Similar finding was observed for gear ratio and sound level at right ear of driver's position. Although, no significant relation was found for engine speed of 2000 rpm and sound level, reserve condition was observed for engine speed of 1000 rpm.

When tractor is moving with low gear, sound level is increased while with a change from low to high gears, sound level is declined. This has its own economic benefits as it can save the energy. Thus, it is better to use high gear during driving period. Decrease in sound level for high gears could be attributed to higher speed in this gear (Behroozi Lar et al., 2012). This study have also confirmed the relation between gear type and sound level at engine speed of 1000 rpm at driver's right ear.

Among effective factors for high sound levels in tractors are age and mechanization activities such as ploughing and harrowing. With an increase in age of tractor and lack of maintenance higher sound levels are expected. Type of activity is also directly related to the soil type. Although Mijinyawa and Akinyemi (2012) could not find any significant relation between these parameters due to new machines, further investigation is necessary for old tractors and soil texture. In surrounding condition and in engine speed of 1000 rpm the maximum and minimum SPL were 63.4 and 66 dBA whereas in engine speed of 1000 rpm were 72.4 and 73.9 dBA in which for two conditions the sound levels were lower than ACGIH standard (ACGIH, 1994). Considering the right ear of driver, the sound levels were lower than ACGIH standard at engine speed of 1000 rpm while for engine speed of 2000 rpm except from first both low and high gears was more than standard limits. Thus control treatments, as it was shown in Figure 8, such as installing cabin on tractor or using hearing protection devices (HPD) should be considered. The sound pressure level were 2 to 5 dB lower at driver's ear for the combines with the cabs attached after manufacturing and 9 dB lower for those without cab (Sümer et al., 2006).

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