Noise levels of a Massey Fergusson 285 tractor during movement on dirt and paved roads

M.R. Ghotbi Ravandi[a)], M.R. Monazzam[b)], N. Khanjani[c)], S. Momen Bellah Fard[d)], H. Nadri[e)] and F. Nadri[f)]

(Received: 22 April 2016; Revised: 20 August 2016; Accepted: 21 August 2016)

This study aimed to determine the noise levels of a Massey Fergusson 285 tractor during movement on dirt and paved roads. The Massey Fergusson 285, 75 hp tractor accompanied by a trailer with one-ton load travelled on dirt and paved roads. The test field had 20 m length and 3 m width as defined according to international standards. The sound levels were measured with different gears and for engine speeds of 1000 and 2000 rpm at bystander position and right ear of operator. The difference between A-weighted sound levels for bystanders and right ear of operator, in engine speed of 1000 for dirt and paved roads, was 13.7–15.9 and 10.9–14.7 dB and, in engine speed of 2000, was 12.7–16.1 and 9.8–13.8 dB, respectively. In the bystander position, the sound levels for both engine speeds were lower on the dirt road compared to the paved road. The sound level at the right ear of the operator at engine speed of 1000 rpm was lower than ACGIH standards (85 dB whereas it was higher in engine speed of 2000 rpm for both roads, except in first low and first high gears on the dirt road. Based on similar distance for measurement points on both roads, the lower acoustic impedance of dirt compared with pavement surface provides less noise reflection which leads to lower noise levels in bystander position. The farmers who work near dirt roads are exposed to lower sound levels than those working near paved roads.

Primary subject classification: 13.7.1; Secondary subject classification: 72.1

1 INTRODUCTION

Noise is an unwanted sound that can affect our daily life. It is also defined as an environmental pollutant and can have negative impacts on mental and physical health[1]. It was anticipated that one out of every ten people in England has hearing loss which affects their hearing ability and common conservation. Two common risk factors for hearing loss in adults are age and excessive noise exposure[2]. Hearing loss is preventable, while mainly irreversible. The effect of noise on the auditory system depends on the noise level, duration of exposure, sound frequency (Hz), individual sensitivity and environmental and physiological factors. Frequencies between 500 to 4000 Hz are important for conservation and perception in which high sound levels can interfere with these frequencies[2]. High sound levels can increase blood pressure, pulse rate, enhance muscle reflexes and cause sleep disturbance[3]. Most industries such as steel manufacturing, artillery, machinery, dye making, agriculture, electronics, medicine, construction, cement production and transportation are accompanied by high noise levels[4]. Barbosa and Cardoso[5] studied hearing loss among workers exposed to road traffic noise in Brazil and found that hearing loss prevalence was equal to 28.5 %[5]. Exposure to continuous sound levels higher than 85 dBA may lead to hearing loss, while it can vary based on person and exposure time[6]. Studies have shown strong relations

a) Department of Occupational Hygiene, School of Public Health, Kerman University of Medical Sciences, Kerman, IRAN.
b) Department of Occupational Hygiene, School of Public Health, Tehran University of Medical Sciences, Tehran, IRAN.
c) Environmental Health Engineering Research Center, School of Public Health, Kerman University of Medical Sciences, Kerman, IRAN.
d) Department of Environmental Science, Graduate School of the Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, IRAN.
e) Department of Occupational Hygiene, School of Public Health, Ghazvin University of Medical Sciences, Ghazvin, IRAN.
f) Department of Occupational Hygiene, School of Public Health, Kerman University of Medical Sciences, Kerman, IRAN; email: nadrifarshad64@gmail.com (Corresponding author).

between sound levels and increase in Noradrenaline concentrations in urine, blood pressure and increased incidence of heart infarctions[7,8]. Hearing impairment from exposure to high sound levels during agricultural activities is considered as an important problem for farmers. Tractors are the main noise producing factor in the agricultural industry in England[9]. Although tractors and other agricultural machineries are useful in agriculture, they are accompanied with safety and occupational health problems as well[10]. A study from India showed that the degree of hearing loss in tractor operators was higher than the control group and the sound levels produced by the tractors were higher than OSHA standards (90 dBA) during different operations[11]. Solecki also showed that most noise exposure in farmers occurred in 5 months (August, September, October, November and April) and the highest total noise exposure was between summer and fall (August till November) which was a result of agricultural activities such as harvesting, threshing and seeding[12]. The results of another study showed that the sound levels in both the right ear of operator and the bystanders of power thriller on dirt roads were lower than paved roads[13]. The surface of paved roads increases the sound level at bystander positions[14]. Also, engine speed was related to sound levels at bystander position and right ear of the operator in New Holland L95 tractors, and when the engine speed changed from 1000 to 2000 rpm, sound levels increase by 6 dB[15].

However, the authors of the present article found no study investigating the effect of road surfaces on sound levels produced by the Massey Fergusson (MF) 285 tractor in Iran. In this study the noise levels produced by the MF 285 tractors during movement on dirt and paved roads with different engine speeds were evaluated, at both right ear of the operator and bystander position.

2 METHOD

2.1 Tractor Characteristics

In this study, the MF 285 tractor from the College of Agricultural at Shahid Bahonar University, Department of Agricultural machinery was used. The gear box of this tractor has four forward gears and one backward gear equipped with a control system that provides eight front and two back speeds. The characteristics of the MF 285 tractor are presented in Table 1. A two-ton trailer carrying a one-ton load (sandbags) was hocked to the MF 285 tractor. Before each measurement the air pressure of the front and rear tires were adjusted for carrying agricultural implements.

2.2 Measurement Location

Noise measurements were performed in a low background noise environment, in a radius of about 100 m away from residential areas and trees and on the College of Agriculture fields. Two locations with 20 m length and 3 m width on dirt and paved roads were used (Fig. 1). Before starting the measurements, the engine of the tractor was running for a few minutes until the tractor engine warmed up.

Table 1—Technical characteristics of the MF 285 tractor.

Engine type	Perkins, with four stroke cycle direct injection combustion system, type A4/248
Power	75 horse power(hp)
Attached trailer weight + load	1000 + 2000 = 3000 kg
Fuel	Diesel
Cooling system	Centrifugal water pump impeller
Total weight (kg) + water, oil and fuel	2812 kg
Max engine speed (without load)	2160 rpm

2.3 Measurement Method

According to the maximum engine speed of the MF 285 tractor (Table 1) and based on previous studies, the engine speed of 1000 and 2000 rpm was selected for sound level measurements[15,16]. Sound level measurements for both roads were performed at right ear of the operator and bystander position according to the standard method of ISO 362[17]. The sound level meter (SLM) microphone was fixed at 25 cm from the right

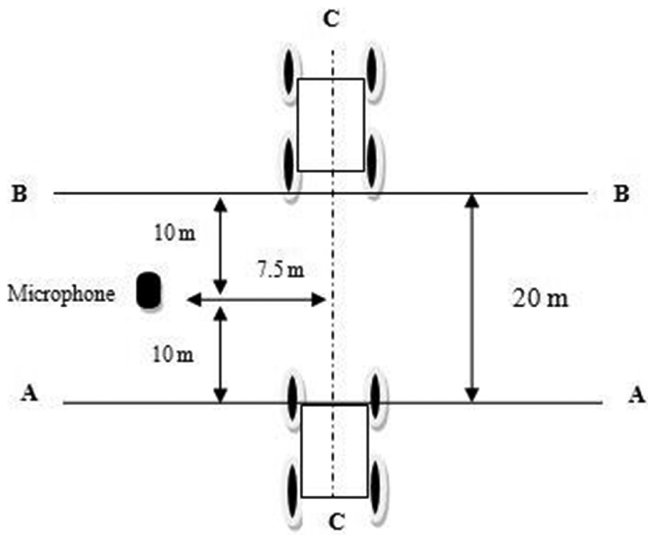

Fig. 1—The position of the microphone for bystander sound level measurements of the MF 285 tractor.

Table 2—The characteristics of the measurement tools.

Tool	Sensitivity	Range	Precision	Model and manufacture
Microphone	50 mV/Pa	–	–	CEL 450, England
Sound level meter	–	0–140 dB	0.1 dB	CEL 450, England
Anemometer	–	0.05–25 m/s	0.02 m/s	Sibata, ISA-6-3D, Japan
Thermometer	–	0–100 °C	0.1 °C	China

ear of the operator. On each road, the measurements were conducted four times for each gear and engine speed, then the logarithmic average was calculated and reported as the equivalent sound exposure level (Leq) for the operator. To measure the sound level at the bystander position (Fig. 1), the SLM microphone was mounted at a distance of 10 m from the starting point, 7.5 m from the central line (mid of wheel axis), at a height of 1.2 m above the ground and at the left side of the operator's starting point. Measurement started when the front wheels of the tractor started to move from the AA line and until the back wheels and the trailer passed the BB line. This was repeated four times for each gear and engine speed, and then, the logarithmic average values were reported as the noise levels at bystander position. All the other variables such as temperature, wind speed and slope of surfaces were similar on both roads and the wind was in the direction of the tractor's movement in the field. Before each measurement, background noise level was also measured. The characteristics of the measurement tools are briefly shown in Table 2.

Before each measurement, the SLM, model CEL 450, was calibrated by calibrator model CEL 450. Measurements were conducted at slow response speed and the A-weighted network. A sponge windscreen was used on the microphone to decrease the wind effect. The microphone sensitivity change was also considered according to the recommended correction chart of the manufacturer.

Wind speed was measured at different gears and engine speed for both road types. The anemometer was installed with a distance of 25 cm parallel to the right ear of the operator and it was in the same direction of the wind. The measurements were performed in the mid route of the tractor's path and when the tractor reached its specified speed.

3 RESULTS

Before noise measurements, the wind speed, air temperature and ambient noise level (background noise) were measured and they were respectively 2.1 ± .2 (m/s), 20 ± 2 °C and 49–51 dBA. When the tractor moved on the field with different gears and engine speeds, the wind speed was measured again at the right ear of the operator in which the results are presented in Table 3.

Table 3 indicates that the highest and lowest wind speeds for both roads in the engine speed of 1000 and 2000 rpm were at the fourth high gear and first low gear, which is easily explainable by the tractor speed. Using basic knowledge on dynamics one can say that driving on paved roads with less tire-road friction provides higher speed compared with dirt roads, with the same engine rotational speed and gear. The higher the tractor speed, the higher was wind speed at the right ear of the operator (Table 3). Meanwhile, the highest acceptable wind speed according to ISO 7216 was 19 km/h[18]. According to Table 3, none of the conditions violated the assumptions of the standard method. The results of sound level measurement at the right ear of the operator in both roads and different engine speeds are presented in Figs. 2 and 3, respectively. As it can be seen, the highest sound levels were measured in the fourth high gear where the tractor speed was maximum.

In most gears, the operator's noise exposure on dirt road was higher that on pavement road. The higher noise exposure at this engine speed shows that noise reflection is not dominant over tractor speed, although at

Table 3—The wind speed measurements (km/h) at the right ear of the operator at different engine speeds on both dirt and paved roads.

Gear	Road			
	Dirt		Pavement	
	1000 rpm	2000 rpm	1000 rpm	2000 rpm
1 High	10.1	11.5	15.1	13.7
1 Low	5.4	6.4	6.8	7.6
2 High	10.4	16.9	15.1	13.7
2 Low	7.2	6.8	9.4	8.7
3 High	13.3	12.6	23.4	11.2
3 Low	8.7	8.8	13.3	8.0
4 High	14.0	17.6	23.4	18.7
4 Low	9.7	10.4	11.1	9.2

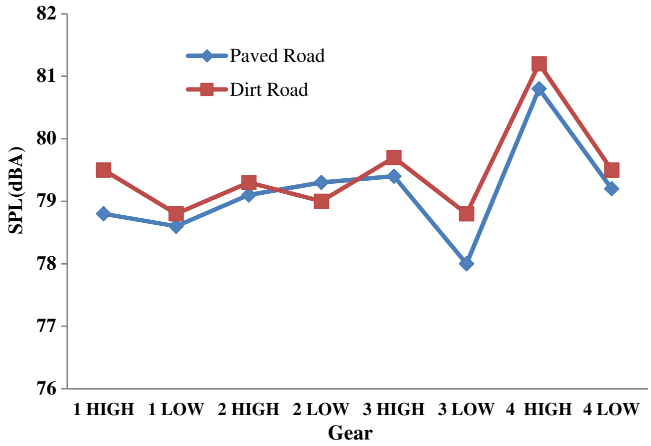

Fig. 2—Sound level measurements with engine speed of 1000 rpm at right ear of operator on dirt and paved roads.

similar gears, the tractor speed is higher on paved road than on the dirt road. However, by increasing engine speed from 1000 to 2000 rpm, ground reflection dominates over tractor speed particularly at gears lower than the third gear. This means as the engine noise level gets higher, the ground effects get stronger.

The result of sound level measurements at bystander positions for the MF 285 tractor on both dirt and paved roads with different gears and engine speeds is shown in Figs. 4 and 5.

As it can be seen from Figs. 4 and 5, the sound levels for the paved road were higher than for the dirt road in all gears and engine speeds at bystander positions. This indicates that on both roads for bystanders the ground effect is dominant over tractor engine speed, although still gears and engine speeds are related to noise levels. According to Table 3, on dirt roads gear changes noise levels from 1.4 dB in 1000 rpm to 3 dB in 2000 rpm

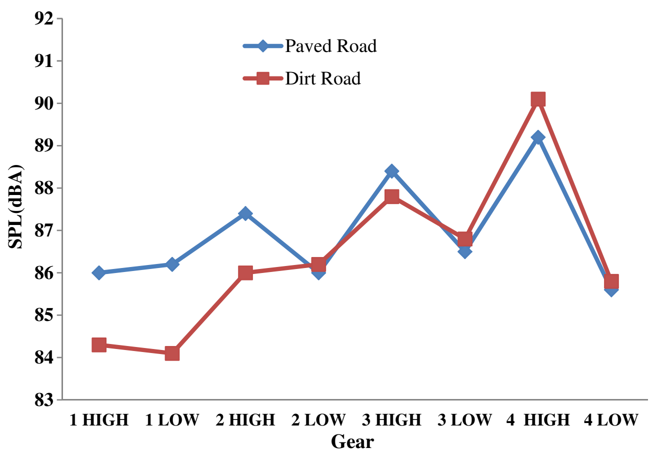

Fig. 3—Sound level measurements with engine speed of 2000 rpm at right ear of operator on dirt and paved roads.

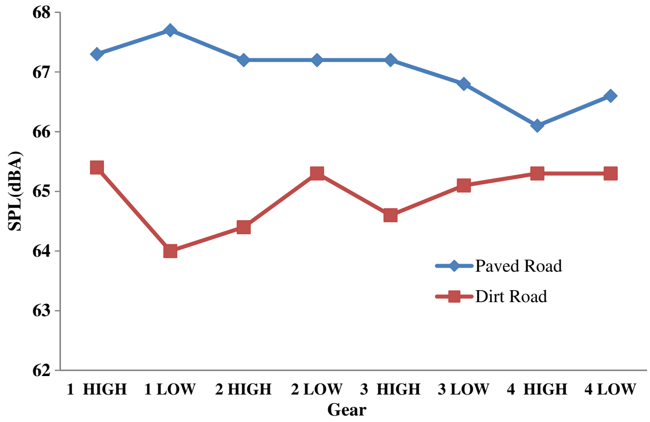

Fig. 4—Sound level measurements with engine speed of 1000 rpm at bystander position on dirt and paved roads.

which is statistically significant ($P < 0.001$). The same condition existed for paved roads and significant effects for engine speed were seen. On the other hand, although on paved roads the gear showed slight effects on noise exposure for the bystanders, it was not statistically significant ($P > 0.05$). It means that the amount of ground noise absorption for the bystander position was not high enough to show significant differences at different engine speeds.

Table 5 provides more information on absorption effects of different ground conditions in different tractor engine speeds. As it can be seen, at low engine speeds the difference is small, but by increasing the tractor engine speed, by increasing the gear from the first to fourth gear, the amount of ground effect on noise increased from -0.4 to 2.9 dB, which was statistically significant ($P < 0.01$). Findings in Tables 4 and 5 show that ground absorption has a significant effect on noise reduction at the bystander location in different gears and engine speeds.

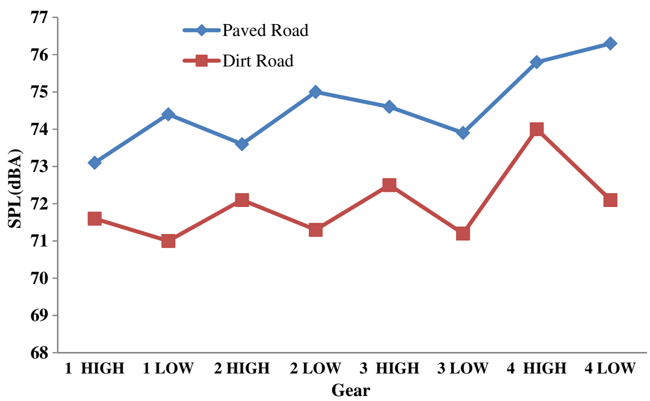

Fig. 5—Sound level measurements with engine speed of 2000 rpm at bystander position on dirt and paved roads.

Table 4—A-weighted sound level difference (dB) between different gears in two different engine speeds and different roads in bystander position.

Engine speed	Dirt	Pavement	Pavement–dirt
Engine speed 1000	1.4	1.6	0.2
Engine speed 2000	3	3.2	0.2

Table 6 is similar to Table 4, but it is for the operator's right ear position and shows significant effects of ground absorption in different engine speeds. This is because the operator's position is closer to both the engine and ground, so a higher ground effect is achieved.

Table 7 confirms that the noise associated with engine speed increase is dominant over noise reduction by ground absorption in operator's position; therefore no significant changes for different ground conditions were seen.

4 DISCUSSION

The aim of this study was to investigate the operator's and bystander's noise exposure from an MF 285 tractor during movement at two different road types (dirt and paved roads) in different gears and engine speeds. The main source of noise in vehicles is the engine in which other factors such as accessories, wind, vibration, tires, exhaust, the cooler fan, transfer system of gear box are the other but less important sources of noise[19].

With an increase in engine speed from 1000 to 2000 rpm, the difference in the highest and lowest noise levels were 5.8 dB for the first high gear and 9.7 dB for fourth high and fourth low gears at bystander position on the paved road and this value for the dirt road was 6 and 8.7 dB for second low gear and fourth high gear, respectively. The maximum sound level on the pavement road at the right ear of the operator position, with engine speed of 1000 and 2000 rpm, in the fourth high gears was 81 and 89 dBA while for engine speed of 1000 and 2000 rpm on the dirt road in the fourth high gears was 81 and 90 dBA. At bystander positions, the maximum sound levels on paved road for engine speed of 1000 and 2000 rpm were for the first low gear and fourth low gear were equal to 68 and 76 dBA. For the dirt road, the levels were 65 and 76 dBA in first high gear and fourth high gear, respectively.

The sound levels at the right ear of the operator were lower than the ACGIH standard (85 dB)[20] on both dirt and paved roads for an engine speed of 1000 rpm, but the values for the engine speed of 2000 rpm were higher than 85 dBA, except for the first high gear and first low gear on the dirt road. Moreover, at the bystander location the sound measurements were lower than standard values on both roads. The A-weighted SPL difference between bystander and right ear of operator position for dirt road at engine speeds of 1000 and 2000 rpm was between

Table 5—A-weighted sound level difference (dB) of different engine speeds on two road types and different gears in bystander position.

Gear	Dirt (2000–1000) rpm	Pavement (2000–1000) rpm	Pavement–dirt (2000–1000) rpm
1 High	6.2	5.8	–0.4
1 Low	7	6.7	–0.3
2 High	7.7	6.4	–1.3
2 Low	6	7.8	1.8
3 High	7.9	7.4	–0.5
3 Low	6.1	7.1	1
4 High	8.7	9.7	1
4 Low	6.8	9.7	2.9

Table 6—A-weighted sound level difference (dB) between different gears in two different engine speeds and on different roads in operator's right ear position.

Engine speed	Dirt	Pavement	Pavement–dirt
Engine speed 1000	2.4	2.8	0.4
Engine speed 2000	6	3.6	–2.4

Table 7—A-weighted sound level difference (dB) between different gears in two different engine speeds and different roads in the operator's right ear position.

Gear	Dirt (2000–1000) rpm	Pavement (2000–1000) rpm	Pavement–dirt (2000–1000) rpm
1 High	4.8	7.2	2.4
1 Low	5.3	7.6	2.3
2 High	6.7	8.3	1.6
2 Low	7.2	6.7	–0.5
3 High	8.1	9	0.9
3 Low	8	8.5	0.5
4 High	8.9	8.4	–0.5
4 Low	6.3	6.4	0.1

13.7–15.9 and 12.7–16.1 dB, whereas for paved road was 10.9–14.7 and 9.8–13.8 dB, respectively. The higher difference of the SPL on dirt road can be explained by the sound absorption effect of ground type. In other words, because the reflection effect of the paved road was more than its absorption effect, lower SPL difference was seen.

The sound levels of power tillers during transporting on dirt and paved roads were investigated in Egypt. They found that sound levels on asphalt roads in all gears and engine speeds at the right ear of the operator and bystander positions were higher for dirt roads[13]. The results of this study are in line with our environmental measurements (Figs. 4 and 5). The higher damping effect of dirt roads compared to paved roads was the likely reason for these results. However, in most gears the noise levels for dirt roads were higher than paved roads at the right ear of the operator position, but, according to Figs. 2 and 3, the second low gear for engine speed of 1000 and the first high and low gears and second and third high gears for engine speed of 2000 rpm were exceptions.

The experiments conducted in various gears and engine speed at operator and bystander position on both roads showed no significant relation between the gears and sound levels. However, engine speed was an effective variable on sound levels. This finding is in line with findings from Hassan-Beygi et al.[21]. The results of this study showed that noise level increased at the operator's ear position with an increase in engine speed from 1000 to 2000 rpm whereas, for the pavement road, the maximum and minimum difference were at the third high (9 dB) and fourth low (6.4 dB) gears, and for dirt road it was at the fourth high (8.9 dB) and first high (4.8 dB) gears. The same results were observed at the bystander positions with a maximum difference of 9.7 dB for the paved road at the fourth high and low gear ratios. According to the present and previous results, the received sound level at the bystander positions is lower than the operator as a result of the distance between the source and receiver[14]. The noise levels on paved roads are higher than dirt roads, probably because the paved road reflects the noise more, while the absorption effect is higher on dirt roads.

Farmers as well as operators are exposed undesirably to high noise levels from tractors during agricultural activities and it is necessary to protect both groups by applying control methods. In order to control noise three factors should be considered: noise source, noise transmission and the receiver in which the appropriate control method is to modify or damp the noise produced at the source location. In order to control the noise during transmission, several methods can be used including full and local enclosures for devices with high noise levels, barriers or reactive mufflers for low frequency noise and small exhausts and dissipative mufflers for high frequency noise. Large exhausts, vibration isolators for vibration structures, vibration absorbers and dampers can also be used for noise control. Suitable hearing protectors are the other control method used to prevent any excessive noise exposure at the receiver position[1].

Also cabbed agriculture equipment is preferable for increased noise isolation. Indeed, a cabin mounted after manufacturing can also reduce the noise at operator's ear in which the perceived sound level is lower than a tractor without the cabin. Along with these strategies, short term rest could be useful to prevent the negative effects of long term exposures to noise[22,23].

Also, to reach the international standard values on paved roads the received sound levels at the farmer's (by standers') positions can be reduced by control methods such as planting shrubs and trees or building earth mound near paved roads. This method of noise control has been proven to be efficient both in agriculture and in big cities with noise pollution.

5 CONCLUSION

According to the above results working on dirt roads led to lower noise exposure than working on paved roads with agricultural tractors. In this study no association was found between the gears and noise levels. It is suggested that, in future studies, the effect of activities such as plowing, on noise levels produced by tractors be evaluated.

6 ACKNOWLEDGMENT

The authors would like to thank Mohsen Shamsi, the Head of the Agricultural Machinery Department of Shahid Bahonar University of Kerman, and Eng. Fiezi for their helpful support.

7 REFERENCES

1. C. Hansen, *Noise Control from Concept to Application*, Taylor & Francis, (2005).
2. M. Maltby, *Occupational Audiometry Monitoring and Protecting Hearing at Work*, Elsevier Ltd., (2005).
3. C.K. Cheung, "Organizational influence on working people's occupational noise protection in Hong Kong", *Journal of Safety Research*, **35**, 465–475, (2004).
4. D. Henderson and S. Saunders, "Acquisition of noise-induced hearing loss by railway workers", *Ear Hear*, **19**(2), 120–130, (1998).
5. A.S.M. Barbosa and M.R.A. Cardoso, "Hearing loss among workers exposed to road traffic noise in the city of Saõ Paulo in Brazil", *Auris Nasus Larynx*, **32**, 17–21, (2005).
6. S. Melamed, Y. Fried and P. Froom, "The interactive effect of chronic exposure to noise and job complexity on changes in blood pressure and job satisfaction: A longitudinal study of industrial employees", *Journal of Occupational Health Psychology*, **6**, 182–195, (2001).
7. A. Fyhri and G.M. Aasvang, "Noise, sleep and poor health: Modeling the relationship between road traffic noise and cardiovascular problems", *Science of the Total Environment*, **408**, 4935–4942, (2010).

8. M.R. Ghotbi, N. Khanjani, A. Barkhordari, S. Rahim Moghadam, A. Mozaffari and M.H. Gozashti, “Changes in urinary catecholamines in response to noise exposure in workers at Sarcheshmeh Copper Complex, Kerman, Iran”, *Environmental Monitoring and Assessment*, **85**(11), 8809–8814, (2003).
9. C. Chisholm, D. Bottomsb, M. Dwyer, J. Lines and R. Whyte, “Safety, health and hygiene in agriculture”, *Safety Science*, **15**, 225–248, (1992).
10. M.R. Ghotbi, M.R. Monzzam, N. Khanjani, F. Nadri and S. Momen Bellah Fard, “Driver exposure and environmental noise emission of Massey Ferguson 285 tractor during operations with different engine speeds and gears”, *African Journal of Agricultural Research*, **8**(8), 652–659, (2013).
11. A. Kumar, N.N. Mathur, M. Varghese, D. Mohan, J. Singh and P. Mahajan, “Effect of tractor driving on hearing loss in farmers in India”, *American Journal of Industrial Medicine*, **47**, 341–348, (2005).
12. L. Solecki, “Characteristics of annual exposure to noise among private farmers on family farms of mixed-production profile”, *Annals of Agricultural and Environmental Medicine*, **13**(1), 113–118, (2006).
13. E.E. Sehsah, M.A. Helmy and H.M. Sorour, “Noise test of two manufactured power tillers during transport on different local road conditions”, *Int. J. Agric. Biol. Eng.*, **3**(4), 1–9, (2010).
14. S. Hassan-Beygi and B. Ghobadian, “Noise attenuation characteristics of different road surfaces during power tiller transport”, *Agricultural Engineering International: the CIGR EJournal*, **7**, Manuscript PM 04 009, (2005).
15. I.H. Celen and S. Arin, “Noise levels of agricultural tractors”, *Pakistan Journal of Biological Sciences*, **6**(19), 1706–1711, (2003).
16. M.R. Durgut and I.H. Celen, “Noise levels of various agricultural machineries”, *Pakistan Journal of Biological Sciences*, **7**(6), 895–901, (2007).
17. ISO 1998 Standard 362, “Acoustics—Measurement of noise emitted by accelerating road vehicles — Engineering method”, International Organization for Standardization, (1998).
18. ISO 1992 Standard 7216, “Acoustics: Agricultural and forestry wheeled tractors and self-propelled machines. Measurement of noise emitted when in motion”, International Organization for Standardization.
19. Sound Research Laboratory Ltd., *Noise Control in Industry.* Third Ed., Taylor & Francis, (2004).
20. “Threshold limit values for chemical substances and physical agents and biological exposure indices”, *American Conference of Governmental Industrial Hygienists: 1994–1995*, (1994).
21. S.R. Hassan-Beygi, B. Ghobadian, R.A. Chayjan and M.H. Kianmehr, “Prediction of power tiller noise levels using a back propagation algorithm”, *J. Agric. Sci.*, **11**, 147–160, (2009).
22. A. Aybek, H.A. Kamer and S. Arslan. “Personal noise exposures of operators of agricultural tractors”, *Applied Ergonomics*, **41**(2), 274–281, (2010).
23. S. Sümer, S. Say, F. Ege and A. Sabanci, “Noise exposed of the operators of combine harvesters with and without a cab”, *Appl. Ergon.*, **37**(6), 749–756, (2006).