Noise Level of Two Types of Tractor and Health Effect on Drivers

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Abstract: "Noise" or "unwanted sound" is one of the major sources of discomfort to the workers which affects human both psychologically and physically. The present investigation was conducted in Iran during the period from September to November 2010. The noise pollution caused by tractor and load were measured in open field with no obstruction and at the driver ear and by stander in accordance with NIOSHA standards. A ITM 399 (without cab) and Valtra T170 (with cab closed and open) and mold board plow and disk plow were used. Unloaded tractor noise was also measured. The data analyzed for different engine speed and gears. Results showed that the Sound Pressure Level (SPL) in the driver ear for the tractor without cab in all cases were more than NIOSH allowable 85 dB(A) criteria for eight hour of operation. The SPL of the tractor with open windows cab was also higher than the standards but lower than the tractor without cab. It was concluded that the driver should either stay on driving for less than 2 hours with tractors without cabin or open window cabin or the only best way, tractors should be equipped with factory made cabins. Even with the latter type of tractors, drivers should avoid opening the window very often for say checking the operation of the machinery behind the tractor or in case the air conditioner malfunctions.
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Keyword: sound level, noise measurements, tractors, cabin, driver's ear

1. Introduction

Noise or unwanted sound is one of the major sources of discomfort to the workers which affects human both psychologically and physically. It has caused hearing problems to many drivers in the world. Noise is measured in two ways for OECD tests (Anonymous, 2010): at the operator's ear and from a bystander position, and is measured in decibels [db(A)]. But to the human ear, a noise that sounds twice (or half) as loud is actually measured at 10 dB(A). So when comparing noise figures, remember that it takes a reduction of 10 dB(A) before the human ear will perceive the noise as being half as loud. Sound measurement is made on the test track in two locations- at the driver's ear and in a location representing "bystander noise." The tests at the driver's ear are performed in several gears and under a number of conditions; but only the maximum level is reported. The "bystander sound" test is performed with the microphone located at 7.5 m from the centerline of the tractor which is accelerating from a lower speed to full speed in its top gear. The OECD procedure differs. The SAE/ASABE procedure measures sound in only one gear under different load conditions, whereas the OECD procedure measures sound in different gears between High Idle and Rated Engine speed (Larsen, 2002). Sound levels are recorded using the "A" scale in the sound-level meter and are expressed in terms of decibels (A) or dB(A). The A scale is a filter that responds like a human ear. A 3-dB(A) increase in sound level doubles the sound-pressure level. Therefore, for every 5-dB(A) increase in sound level, the permissible exposure time is cut in half. In other words, at 95 dB(A), the allowable exposure time is only four hours. It is not uncommon to have tractor sound-level reaching 95 dB(A) (Grisso et al., 2007). Tractor driver farmer had more often high frequency hearing loss when compared to non tractor driver farmer. The noise levels observed on tractors in different operations were in the range of 90–110 dB (A) (Kumar et al., 2005). Sound levels that cause hearing loss begin at about 85 dB(A). Hearing loss occurs more quickly with louder noise. OSHA standards consider sound measured at 85 decibels or higher as damaging to the eardrum and therefore a risk to hearing (Anonymous, 2004). It is stated (Anonymous, 2010) that 30 percent of Sweden's farmers suffer from hearing loss. Similar results to those from Sweden were found in a study conducted by University of Iowa in the United States, indicating that

American farm workers are faced with the same noise problems in their daily work. An investigation by Dewangan et al (2005) for determination of SPL on 18.7 and 26.1 kW tractors and 4.6 and 6.7 kW hand tractors during field operations with various implements, revealed that both tractors produced the noise of 92 dB(A) in the working zone of operator. The SPL of the hand tractor was about 2 dB(A) higher than that of the tractor. The SPL during field operations at operator ear level increased with increase in engine speed and forward speed. Celen and Arm (2003) found that the maximum SLP of 97.1 dB(A) was in exhaust pipe and the minimum of 79.7 dB(A) at the bystander ear. An increase of 3 dBA was measured for engine speed changes from 1000 to 2000 rpm. Durgut and Celen (2004) measured an 96.6 db(A) at the drivers ear but a minimum of 67.7 dB(A) for the surrounding. They also found a 6 dB(A) difference when engine speed changed from 1000 to 2000 rpm. According to Aybek et al (2010), statistical analysis showed that type of operation, type of cabins, and operation x cabin interactions were statistically significant at ($P < 0.01$). The use of original cabins had a greater effect in decreasing average sound pressures and resulted in more efficient noise insulation, especially at higher center frequencies compared to field installed cabins. Sound pressure levels at 4000 Hz center frequency was reduced 2-13 dB and 4-18 dB by using a field-installed cabin and an original cabin, respectively. It was concluded that depending on the cabin types used, the operators could usually work from 4 to 6 h a day without suffering from noise induced inconveniences while 2–3 h is permissible for plowing and forage harvesting on tractors without cabins. In reference Anonymous (2009) it is stated that No Member State may refuse to grant EC (European Council) type-approval or national type-approval of any type of tractor on grounds relating to the driver-perceived noise level if that level is within the following limits: 90 dB(A) in accordance with Annex I, or 86 dB(A) in accordance with Annex II. Individual tasks which exceeded 85 dB(A) TWA-8 (NIOSH) identified by researchers were Tilling/plowing, Planting, or other farm activities (Milz, 2006). Equation (1) is given for safe exposure time to noise, $t = \frac{8}{2^{\frac{SPL-85}{3}}}$ (1) (Anonymous, 1996) where t= hours of exposure per day.

An experiment in Croatia by Goglia et al (2005) showed that by ISO 4872, 6393 and 362 standards, the noise level did not exceed the limit values. However, the noise level at the operator's position at full load and at nominal load exceeded the limits. Noise levels of 155 tractors on 36 farms were studied (Holt et al., 2006). The range of noise levels at the driver's ear level with radios off and windows closed (if so equipped) was from 78 to 103 dB. Seventy-five percent of tractors without cabs had noise levels in excess of 90 dB, compared to only 18% of tractors with cabs. The use of a radio adds an average of 3.1 dB of noise. When some cab windows are open and the radio is on, an average of 4.2 dB is added to the cab noise. A specially selected group of 45 farm tractor drivers were examined in order to estimate the degree of occupational hearing loss (Solecki, 2010). The drivers, aged 21-50 years, were employed on multi production farms. The study showed that the operators under study had statistically worse hearing within the range of high frequencies (3-6 kHz), especially those aged over 30 years. A study was carried out when a fabricated cab was added to an agricultural tractor (Abd-el-Tawwab et al., 2000). The fabricated cab was selected after a comprehensive series of experimental tests carried out on a variety of cab constructions. The results were discussed from the view point of obtaining the influence of the tractor driving parameters (road speed, gear-shift, engine speed and tractive effort) on the noise measured inside the tractor cab and over the frequency range up to 2000 Hz. In April, however, the occurrence of high total exposure values was due to intensive field activities (plowing, harrowing, sowing), and prolonged exposure to this factor (Aybek et al., 2010). In the seasons of the year analyzed, high equivalent exposure values were observed within the range: 5.53-6.61 Pa^2 h (some Polished standards). Mean value for this parameter for the whole year reached the value of 4.27 Pa^2 h (standard exceeded 4.3 times). This value is equivalent to a mean exposure level equal to 91.3 dB.

3. Material and Methods

Two types of tractor a 2-wheel drive MF399 with 62 kW PTO power without cabin and a Valtra T170, 184 kW power with closed window and open window cabin were tested. No load and loaded with moldboard plow and disk were tested for noise level at different gears and engine speed. The gears were 1 low, 2 low and 3 low and the speeds were set at 1500, 1750, 2000 and 2200 rpm. The measurements were taken at the driver ear and at a distance 7.5m from centre axis of tractor. A sound meter of type Lutron SL4013 equipped with capacitance microphone was used. The OECD testing standards were observed. The test course was a plot of 100 m long by 40m wide in open field. Each experiment data was recorded with 9 replicates. Data was analyzed based on factorial experiment with MSTAT-C software.

4. Results

Data was collected between the high idle and the rated speed according to OECD standards (Kumar et al., 2010) and in two ways as recommended by OECD (Abd-el-Tawwab et al., 2000). Statistical analysis of the results are show in tables 1-4 and the corresponding graphs in figures 1-6. A summary of results for the range of noise level is given in table 5. The maximum SPL reached 94.5 dB(A) in accordance with Grisso et al (2007) but less than the 96.6 dB(A) in Durgut and Celen (2004) and much lower than the maximum 110 dB(A) as measured in (Kumar et al., 2010). The SPL as shown in the figures does increase with engine and forward speed as mentioned in Dwangan et al (2005) with the exceptions in figures 2 and 4 for the second low gear. Holt et al (2006) gives a range of 78-103 dB(A) for closed window cabin while the experimental results showed a much smaller range of 74.3-77.9 dB(A). Durgut and Celen (2004) indicates a range of 76.5-91.9 at 2000 rpm engine speed without mentioning the type of tractor (with or without cab), the driving gear or loading in comparison with experimental 75.5-93.4 dB(A) for the same engine speed. The 93.4 dB(A) is for loaded and without cabin tractor. Goglia et al (2007) also indicates that the sound level exceeded the limits at full load but without mentioning the gear, engine speed, cabin and weather loaded or not. Neither it mentions how much the exceeded value was. In this experiment the maximum loaded SPL was 93.5 dB(A) for disking at gear 3 low. The graphs of Fig. 2, 4 and 6 show an ascending trend of noise level with increasing engine speed. Noise level for closed window cabin is way much below the 85 dB(A) permissible level for 8 hours of work. For tractors without cabin and the open window cabin both; the level surpassed the 85 dB(A) but in all cases the noise level on tractor without cabin is higher than the one with open window cabin. Loaded tractors had higher noise level than unloaded one. The disk loaded tractors at all cases had higher noise level than the plough loaded. This could be because of the higher speed of disking. The graphs of Fig. 1, 3 and 5 shows the noise level in 3 low gears. It is apparent that noise level with some exception at gear 2 low, raises with increasing speed. The loaded tractors with one exception have higher noise level.

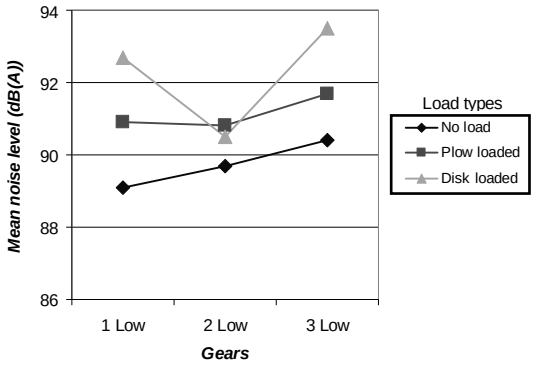


Figure 1. Mean noise level in different gears for tractor without cabin.

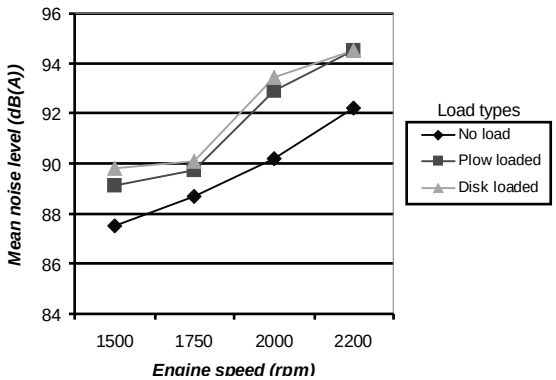
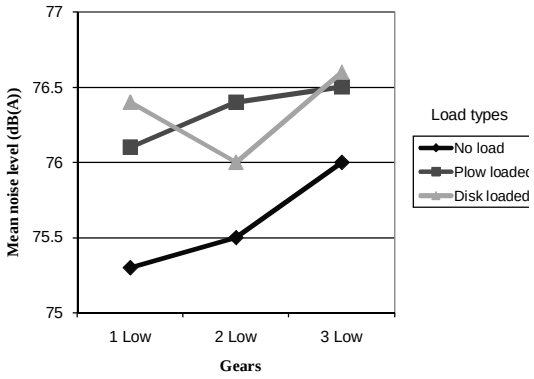


Figure 2. Mean noise level for different engine speeds for tractor without cabin.



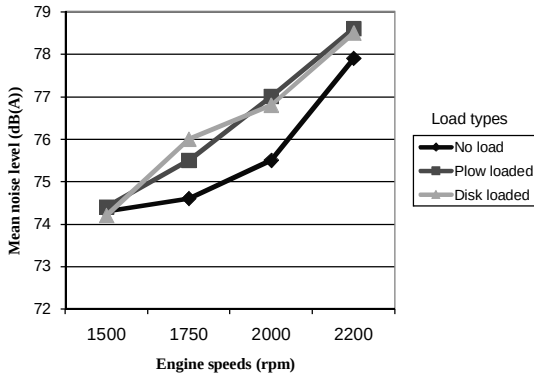


Figure 3. Mean noise level in different gears for tractor with closed window cabin.

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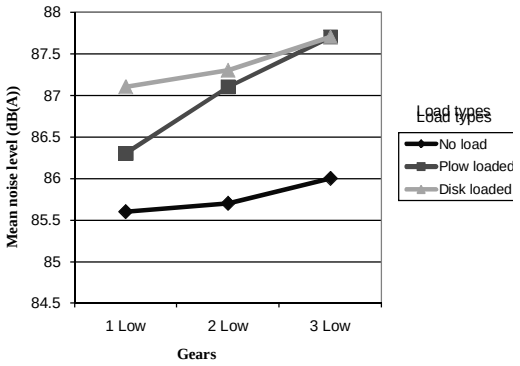
for tractor with closed window cabin.



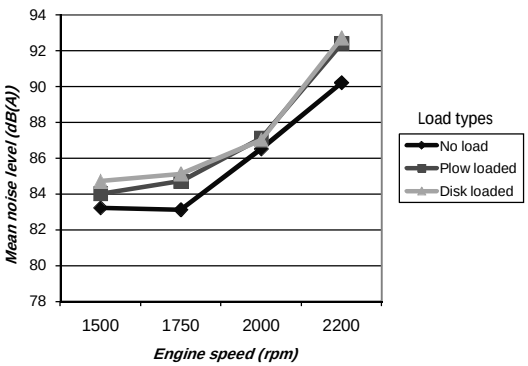


Figure 5. Mean noise level in different gears for tracto with open window cabin.

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for tractor with open window cabin.

Table 1. Mean noise level at driver ear in different gears*.

	Without cabin			Closed cabin			Open cabin		
Gears	1 Low	2 Low	3 Low	1 Low	2 Low	3 Low	1 Low	2 Low	3 Low
No load	89.1^{b}	89.7^{ab}	90.4^{a}	75.3^{a}	75.5^{a}	76.0^{a}	85.6^{a}	85.7^{a}	86.0^{b}
Plow loaded	90.9^{b}	90.8^{b}	91.7^{a}	76.1^{a}	76.4^{a}	76.5^{a}	86.3^{a}	87.1^{a}	87.7^{a}
Disk loaded	92.7^{b}	90.5^{b}	93.5^{a}	76.4^{a}	76^{a}	76.6^{a}	87.1^{a}	87.3^{a}	87.7^{a}

* Means with different letter in columns are significant at 1% level.

Table 2. Mean noise level at driver ear in different engine speeds*.

	Without cabin	Closed cabin	Open cabin

Engine rpm	1500	1750	2000	2200	1500	1750	2000	2200	1500	1750	2000	2200
No load	87.5 [b]	88.7 [a]	90.2[b]	92.2[b]	74.3[a]	74.6[a]	75.5[a]	77.9[a]	83.2[a]	83.1[a]	86.5[a]	90.2[b]
Plow loaded	89.1 [a]	89.7[a]	92.9[a]	94.5[a]	74.4[a]	75.5[a]	77.0[a]	78.6[a]	84.0[a]	84.7[a]	87.1[a]	92.4[a]
Disk loaded	89.8 [a]	90.1[a]	93.4[a]	94.5[a]	74.2[a]	76.0[a]	76.8[a]	78.5[a]	84.7[a]	85.1[a]	87.0[a]	92.7[a]

* Means with different letter in columns are significant at 1% level.

Table 3. Mean noise level at driver ear in different gears*.

	Without cabin			Closed cabin			Open cabin		
Gears	1 Low	2 Low	3 Low	1 Low	2 Low	3 Low	1 Low	2 Low	3 Low
No load	89.1 [c]	89. 7 [a]	90.4 [b]	75.3[a]	75.5[a]	76.0[a]	85.6[a]	85.7[a]	86.0[a]
Plow loaded	90.9 [b]	90.8 [a]	91.7 [b]	76.1[a]	76.4[a]	76.5[a]	86.3[a]	87.1[a]	87.7[a]
Disk loaded	92.7 [a]	90.5 [a]	93.5 [a]	76.4[a]	76.0[a]	76.6[a]	87.1[a]	87.3[a]	87.7[a]

* Means with different letters in rows, are significant at 1% level.

Table 4. Mean noise level at driver ear in different engine speeds*.

	Without cabin				Closed cabin				Open cabin			
Engine rpm	1500	1750	2000	2200	1500	1750	2000	2200	1500	1750	2000	2200
No load	87.5 [c]	88.7 [bc]	90.2[b]	92.2[a]	74.3[b]	74.6[b]	75.5[b]	77.9[a]	83.2[c]	83.1[c]	86.5[bc]	90.2[a]
Plow loaded	89.1 [c]	89.7[c]	92.9[b]	94.5[a]	74.4[c]	75.5[bc]	77.0[b]	78.6[a]	84.0[c]	84.7[c]	87.1[b]	92.4[a]
Disk loaded	89.8 [b]	90.1[b]	93.4[a]	94.5[a]	74.2[c]	76.0[b]	76.8[b]	78.5[a]	84.7[c]	85.1[c]	87.0[b]	92.7[a]

* Means with different letters in rows, are significant at 1% level.

Table 5. Summary of experimental results for range of noise level, dB(A).

		No cabin	Closed window	Open window
Gears:1-3 Low	No load	89.1-90.4	75.3-76.0	85.6-86.0
	Permissible Exposure time (h)	3-2	73.5-64	7-6
	loaded	90.7-92.5	76.0-76.6	86.3-87.7
	Permissible Exposure time (h)	2-1.4	64-56	6-4.3
Engine speed 1500-2200(rpm)	No load	87.5-92.2	74.3-77.9	83.1-90.2
	Permissible Exposure time (h)	4.5-1.5	97-41	12.4-3.2
	loaded	89.1-94.5	74.2-78.6	84-92.7
	Permissible Exposure time (h)	3-0.9	97-35	10-1.4

4. Discussion

It may be concluded that drivers should always work with lowest engine speed and the lowest gear but; this is contradictory because tractors in this case, would not produce enough power to do the job. The alternatives are either stay on driving for less than 2 hours with tractors without cabin or open window cabin, the driver wears some kind of ear protection or the only best, is that tractors should be equipped with factory made cabins. Even with the latter type of tractors, drivers should avoid opening the window very often for say checking the operation of the machinery behind the tractor or in case the air conditioner malfunctions. Calculated permissible time in hours using equation (1) is also shown in table 5.

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