Noise test of two manufactured power tillers during transport on different local road conditions

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Abstract: Hearing injury due to exposure to excessive noise during general farming activities is a significant problem for farmers. The present investigation was carried out for better understanding of the noise propagation trends, as well as noise attenuation characteristics of the two different developed power tillers on different surfaces in transportation under Egyptian conditions. In Egypt, the agricultural roads are one of the main problems that limited the usage of farm machinery. In the last few years, it is noticed that the manufacturers and farmers in Egypt applied the diesel engine of command irrigation pump as the source of power for the manufactured power tillers. Besides their on-farm application in Egypt, they are also engaged in transportation of agricultural products and human beings on the asphalt, and dirt rural roads. In spite of their adverse effects due to noise on operators and bystanders, limited information is available concerning the noise investigation of these manufactured machines. The aim of this research was to evaluate the noise propagation trends as well as noise attenuation characteristics of the manufactured power tillers on different surfaces in transportation conditions. The developed power tillers that used in this study were fitted with approximately 6 kW (8 hp) and 7.5 kW (10 hp) diesel engines for two different tillers transport machines. During measurement and recording the sound pressure signals of the power tillers, the variables of engine speeds and gear ratios were varied to cover the most normal range of the power tillers operation in transportation conditions for the asphalt and dirt rural roads. The test sites were prepared according to SAE noise measurement test procedures. The maximum overall noise measured at driver ear's position at different gear ratios in asphalt, and dirt rural roads were about 98.2 and 92 dB(A) for 1,350 r/min engine speed which is higher than allowable noise exposure prescribed by National Institute for Occupational Safety and Health[1] .

Keywords: noise test, power tiller, diesel engines, transportation, manufacture

DOI: 10.3965/j.issn.1934-6344.2010.04.019-027

Citation: E E Sehsah, M A Helmy, H M Sorour. Noise test of two manufactured power tillers during transport on different local road conditions. Int J Agric & Biol Eng, 2010; 3(4): 19－27.

1 Introduction

Noise environments of the type and severity associated with combustion engines and other noises arising from mechanisms or animals-may have the following principal effects on the person exposed:

a) The noise may be annoying to varying degrees, from being just objectionable to being unbearable.

b) Performance may be affected due to a lowering of concentration. Fatigue caused by longer exposure, rhythm disturbance, interference with sound cues associated with the work or interference with worker-to-worker communication in a team.

c) Damage to hearing may be caused by the noise; the character and, to a lesser extent, the mechanism of this damage is now being understood. Both temporary and permanent components of hearing threshold shift are possible.

Matthews[2] cited that the general effect of noise on

Received date: 2009-10-28 **Accepted date:** 2010-11-8

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agricultural worker performance can only be determined after extensive researches, but only a few preliminary experiments have been reported. There appeared to be relatively little objection to the noise by the workers although most men would have preferred a quieter environment. No scientific analysis was made of the worker's opinions, however, which would in any case have been biased by any hearing loss. The main purpose of the noise measurements was to provide data to help assess the likely hearing damage effect of the noise environments and, in particular, to define the noise environments for comparison with the audiologist data from measurements of hearing thresholds made by Southborough College of Technology in Bedfordshire in 1966 and 1967, the period during which the environmental noise measurements were made. If they produce noise more than 85 dB (A) for eight hours exposure (based on NIOSH noise exposure recommendations), it will be harmful to both drivers and by standers[1]. Although the tractors and other agricultural equipments are beneficial in many ways, there are some occupational health and safety problems due to their farm operation.

The example of an excessive noise level is present in Maring[3] and Brown[4]. Previous investigations concluded that human beings are affected mentally, physically and socially by excessive noise levels[5,6]. Although the tractors and other agricultural equipment and machinery have also been investigated regarding their emitted noise level and noise production sources[7, 8], Kang et al[9] limited information that is available concerning the noise investigation of power tillers. In an investigation regarding the ergonomic conditions of the power tillers, 200 farmers and 100 extension workers were studied. The study revealed that noise and vibration of power tillers played an important role in damages experienced by them. On the other hand, the limited space of the small engines fitted on the power tillers and other limitations do not allow equipping them with sound absorbing materials or provide them with the driver's cab[4], though the noise received by bystanders is still another dilemma. Some researchers believe that not only the noise and vibration of the power tillers, but also all machineries and equipments fitted with small engines suffer from the drawback of their higher noise productions[10]. This was the reason for the suggestion of replacing the diesel engines of the power tillers by electric power sources[11]. Franklin et al.[12] cited that the age of machinery is positively associated with increased noise level, and is most likely related to improved technology and general wear and tear. This highlights the importance of regular maintenance regimes, especially for older machinery, in order to minimize noise levels. Recommended exposure limits when engaged in an activity without the use of hearing protection were calculated based on the average noise level for each activity received at the ear position. For each 3 dB increase in noise level, the sound energy received at the ear position is doubled, so that for every 3 dB above the recommended daily limit of 85 dB (A), the time exposed to the noise needs to be halved to remain within recommended exposure limits. Exposure to noise levels of more than 85 dB (A) for more than eight hours a day (or its sound energy equivalent) on a regular basis can cause permanent hearing damage[13].

2 Materials and methods

The experiment was carried out in Kafr El-Sheikh University, Egypt to test the two manufactured small power tillers. The instruments that used in the current study consisted of a Multi-Function Environment instrument with electric condenser microphone inside, the digital tachometer (Voltkraft), ground speed instrument with infrared sensor, WS2300 weather station and Toshiba notebook computer. The Function Environment instrument was connected with notebook computer and the sound software (V 222). The ground speed instrument with infrared sensor with pointed beside the tillers to measure the forward speed. The measuring equipment Hand digital Tachometer (Voltkraft TD-01) is an optical revaluation counter with a precise measuring laser. The measurement is carried out via reflection. Self-adhesive reflective markers are provided and can be fixed to revolving objects. The measured range is 1–9999.9 r/min with accuracy ± (0.01% + 1 Digit). The digital Tachometer (Voltkraft TD-01) Laser is used to measure the rotational speed for two different power tillers. The selected variables under the current research were three gear ratios, the ages of the two different manufactured power tillers and type of roads. The engine rotational speeds for two tillers were of 980, 1,220 and 1,380 r/min. The rotational engine speed was obtained by calibrating the fuel paddle under all treatment conditions. The two tillers operated on full load condition by the 450 kg carried load in each tiller under different tests. The carrying load of 450 kg used as the simulated of the hand workers who translated by the power tillers.

The range of variables considered to perform the test could cover the normal and safe operating range of the power tillers during operation. Table 1 shows the test matrix of the power tillers under test conditions and Table 2 shows the specifications of the power tillers. The hand start engines of 6 kW and 7.5 kW were direct coupled to tillers as the transport machine usage. It is possible also to direct coupled to centrifugal water pump as the second usage on the farm. In the current investigation we used only the power tillers as the transport machine for the hand workers to the farm. The noise which produced from the tillers could affected the driver and hand workers. The local reference noise test was measured before the starting of the all tests. Figure 4 indicates the reference noise test for the local area conditions that was used to apply the bystander and the others tests. The weather conditions were air temperature 22℃, atmospheric pressure 0.998 kPa, relative humidity 54%, wind speed 2.4 km/h and wind direction 130 grad north-west.

It was hypothesized that the age of the machinery will have an impact on the wear and tear of the engine parts, seals, mufflers, and noise-insulating material. In addition, as machinery design and engine efficiency continue to improve, newer machines tend to run more quietly than their predecessors did when they were new[13]. Testing of individual machines over time was not possible and was not controlled for in this study. We used the two different ages power tillers one year old of 6 kW and eight years old for 7.5 kW to know the noise propagation trends and their effect on the driver and bystander.

Table 1 Treatments for test noise of two manufactured power tillers

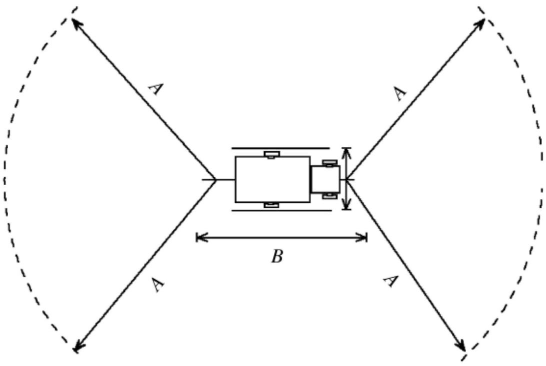
Gear ratio	Engine speed/r · min^{-1}		Forward speed/km · h^{-1}	
	Dirt road	Asphalt road	Dirt road	Asphalt road
Gear 1	980	980	6.2	8.3
Gear 2	1,220	1,220	11.9	14.2
Gear 3	1,380	1,380	17.2	21.2

Table 2 Specifications of the two manufactured power tillers and engine characteristics

Specifications	Power tillers ≈ 6 kW (8 hp)	Power tillers ≈ 7.5 kW (10 hp)
Engine		
Model	ROTEX diesel engine, RAJKOT, India	ROTEX diesel engine, RAJKOT, India
Age/a	1	8
Max./r · min^{-1}	1,400	1,500
Power/kW (hp)	≈ 6 (8)	≈ 7.5 (10)
Fuel	diesel	diesel
Cooling	Air	Air
Dimension		
L×W×H/m	3×1.4×1.8	3.2×1.4×1.8
Total weight/kg	900	1,100

2.1 Procedures

The test area was free from obstacles and consisted of a flat open space free from the effect of signboards, buildings and hillsides for at least 15 m from the measurement zone. The suggested wind speed and other climate limitations were measured online with computerized weather station WS2300 that connected to recording and saved the climate data in a file directly. The Multi-Function Environment Meter with PC interface was mounted at 1.7 m above the ground surface and 150 mm away from the drivers' left rear in a horizontal position and pointed in the direction of travel. Experiments were conducted according to SAE noise measurement procedures[14,15]. Figure 1 shows the dimensions of the area in which the power tillers noise measurement was made. The distance from the obstacles to the measurement zone, B and C are the length and width of measurement zone, respectively. The values of *A*, *B* and *C* were of 15, 200 and 2 m, respectively. Figure 2 shows the instrumentation set up for measurement of noise.



Note: A = 15 m, B = 200 m, C = 2 m

Figure 1 Dimensions of the area for the power tillers noise measurement

a. Power tiller with 10 hp

b. Power tiller with 8 hp

c. Weather station WS-2300

d. PC Notebook with Sound 222 software

e. Multi-Function Environment instrument with microphone

Figure 2 Instruments for the test of two different power tillers under Egyptian conditions

The bystander test site was managed based on the SAE J1175[15] recommended practice. The test area was consisted of flat open space free from the effect of signboards, buildings, or hillsides for at least 30 m from the measurement zone. Other test site specifications were chosen similar to the specifications mentioned earlier for the operator's position, with the exception that the Multi-Function Environment instrument was mounted at 7.5 m from the centerline path of the power tillers and 1.2 m above the ground surface. In addition, it was oriented perpendicular to the centerline path of the power tillers. Figure 3 shows the dimensions of the test area. The values of R and L were of 30 and 14.5 m, respectively.

The human ear is a sound pressure sensitive detector. It does not have a flat spectral response, so the sound pressure is often frequency weighted such that the measured level will match the perceived level. When weighted in this way the measurement is referred to as a sound level (Lw). Sound power and sound pressure are two distinct and commonly confused characteristics of sound. Both sharing the same unit of measurement, the decibel (dB), and the term "sound level" is commonly substituted for each.

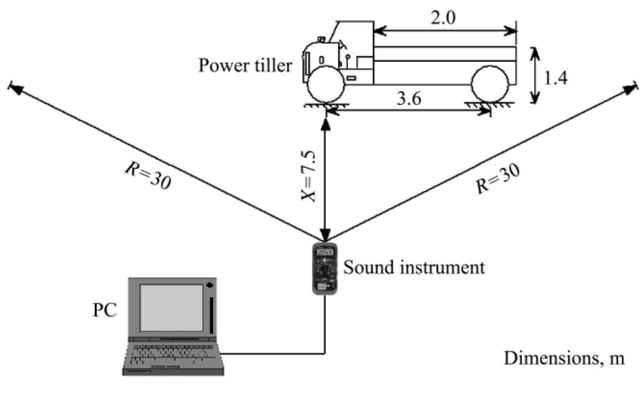


Figure 3 Dimensions of the test area in the bystander test

2.2 Estimating the increment values of the dB

The increment values of the dB (a) defined as the remained values between the measured values and the recommended values. The recommended value was 85 dB (A), it is also calculated by the following equation:

$$dB\ (A)_{Inc}=dB\ (A)_{me}-dB\ (A)_{rec}$$

Whereas, $dB(A)_{inc}$ Increment values of sound level pressure, dB; $dB(A)_{me}$ Measured values of the sound level pressure, dB; $dB(A)_{rec}$ Recommended sound level pressure value, dB.

The equations 6 and 7 used to calculate the sound power ratings and sound pressure after measuring.

Noise level data were analyzed using Origin programme version 7G (Origin 7G, 2004).

3 Results and discussion

3.1 Effect of the engine age on the noise pollution

Figures 4 and 5 indicate the typical set of sound pressure signals in time domain for the two different power tillers under two different test conditions operator and Bystander on asphalt and dirt surfaces. It is obvious that the time domain signals show information about the noise pollution for both power tillers. The effects of age of the engines' power tiller give the indicator for the noise pollution whereas the older power tiller eight years old (7.5 kW) produced the high noise pollution compared to the power tiller of one year old (6 kW). As well as the operator's ears affected more than the Bystander's for the older power tiller of 7.5 kW compared to the power tiller 6 kW Engine power. It noticed that there is a low effect for the operator compared to the Bystander on the dirt surfaces for both power tillers. The reference curve for the test location area indicates in Figures 4 and 5.

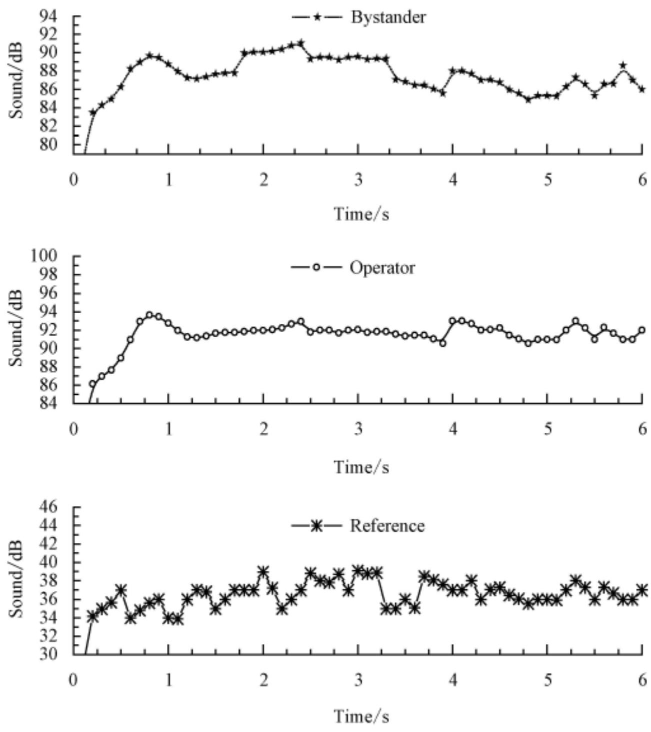


Figure 4 Noise for power tiller 6 kW on Asphalt surface

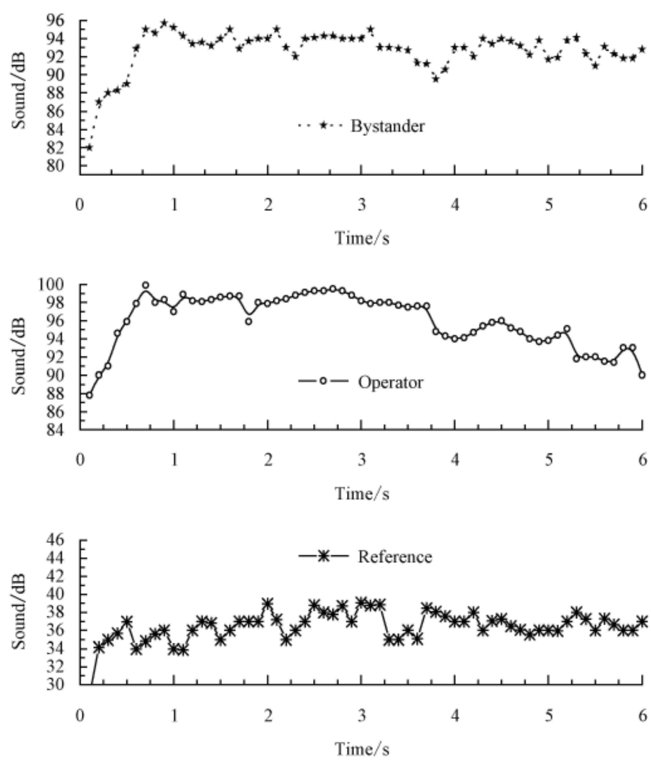


Figure 5 Noise for power tiller of 7.5 kW on Asphalt surface

Figure 6 shows the effect of the ages of the power tillers engine on the operator's ears at different gear ratios. Figure 6 illustrated that the age of power tiller engines highly affected the operator's ears due to noise pollution.

The older power tiller (7.5 kW) engine give the high values of sound level pressure compared to the power tiller one year old on asphalt surfaces. The increment of the dB (A) values between the two ages of power tillers for both operator and bystander tests for different roads are shown in Table 3. The maximum A-weighted overall sound pressure level of the power tillers at driver ear position for different surface types and gear ratios is of 8.4 dB(A). On the other hand, the low effect of the engine age on the noise pollution was revealed for both tests, the operator's ear and bystander on the dirt surface as shown in Table 3. This means that exhaust is a main contributor to the power tillers noise that needs to be investigated separately. This matter may be attributed to lack of distance between power tillers noise sources and microphone of the environmental instrument location.

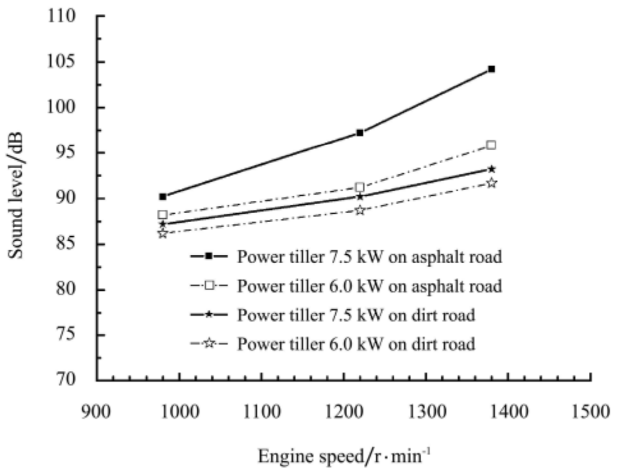


Figure 6 Effects of two different manufactured power tillers, engine speed and different roads on the noise pollution at operator test

Table 3 Increment of the dB (A) values between the two ages of power tillers for both operator and bystander tests on different roads

Speed /r·min^{-1}	Operator		Bystander	
	Asphalt road	Dirt road	Asphalt road	Dirt road
980	2.0	1.0	2.7	1.1
1,220	6.0	1.5	2.9	1.3
1,380	8.4	1.5	3.6	1.5

3.2 Effect of roads on the noise pollution

Figure 6 indicates the effect of the roads on the noise pollution at the operator's ear test. It is clear that the asphalt surface gives the high effect compared to the dirt road under all conditions. The maximum A-weighted overall sound pressure level of the power tillers at driver ear's position was of 11 dB(A) at higher engine speed for older power tiller. On the other hand, the dirt road makes the low effect on the noise pollution for both operator and bystander tests. The low values of the A-weighted overall sound pressure level was of 0.4 dB(A) at bystander test and low engine speed for power tiller one year old as shown in Table 4.

Table 4 Increment values of the dB (A) values between the two different roads at different engine speeds for both tests of operator and bystander

Speed /r·min^{-1}	Operator		Bystander	
	Power tiller eight years old	Power tiller one year old	Power tiller eight years old	Power tiller one year old
980	3	2	2	0.4
1,220	7	2.5	2.8	1.2
1,380	11	4.1	4.4	2.3

Figure 7 shows the effect of surface types of the power tillers at different gear ratios for bystander position. The noise attenuation potential of the dirt surface is obvious and this is due to the damping effect of soil cover surface that is distinguished from the reflecting surface of asphalt. It can be easily seen from Figure 7 that a diminishing trend in 1/3 octave band sound pressure signals exist and is visible when changing the surfaces from asphalt to dirt road for the same power tillers condition. This phenomenon could be related to the noise attenuation characteristics of different sound absorbing materials and surfaces known as "ground effect"[16].

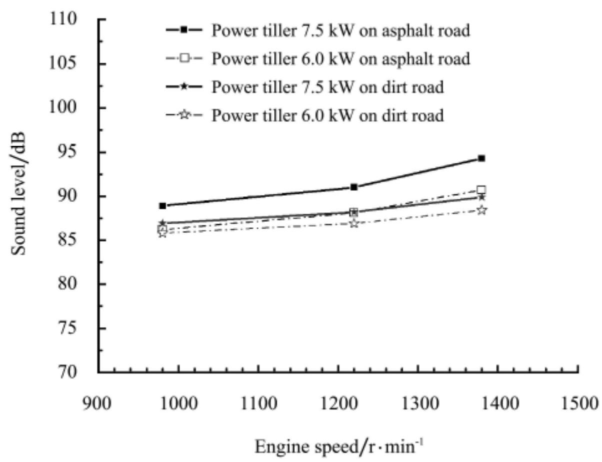


Figure 7 Effects of two different manufactured power tillers, engine speed and different roads on the noise pollution at bystander test

The comparison between the noise received by the operator Figure 6 and that of a bystander Figure 7 in corresponding conditions revealed that the noise level experienced by the power tillers operator is much higher than that received by a bystander, 7.5 m away from the power tillers centerline path in whole range of frequency bands.

Table 5 indicates the increment of the dB (A) values between the operator and bystander tests on different roads, engine speed and age of the two power tillers. The older power tiller gives the high different increment values of dB(A) at higher engine speed on asphalt road. As well as the low inclement values were found on the dirt road for power tiller of one year old as shown in Table 5. The reduction in noise level is an average of about 14 dB when sound waves reach the bystander. This is due to the combined effect of the surface absorption and distance.

Table 5 Increment of the dB (A) values between the high and low engine speeds for both operator and bystander tests and two ages of power tillers on different roads

Test conditions	Asphalt road		Dirt road	
	Power tiller eight years old	Power tiller one year old	Power tiller eight years old	Power tiller one year old
Operator	14	7.6	6	5.5
Bystander	5.4	4.5	3	2.6

3.3 Effect of engine speed on the sound pressure level

Figure 6 shows the effect of engine speed on the A-weighted overall sound pressure level of the power tillers at driver ear's position for different surface types and gear ratios. It is illustrated that the increase of the engine speed tends to increase the noise pollution in dB for both surface conditions of asphalt and dirt surfaces. Figure 6 indicates the increase of engine speed from 960 r/min to 1,380 r/min at different gear ratios and surface types. It is clear that the increase of engine speed from 980 r/min to 1,350 r/min tends to increase the noise pollution at different gear ratios. It could be observed that the maximum sound pressure level is of 104.3 dB (A) for older power tiller (7.5 kW) at 1,350 r/min engine speed on asphalt surface under the operator's ear test; but considerable ground effect for dirt covered road and power tiller of 6 kW could not be seen. Table 6 presents the increment of the dB (A) values between the high and low engine speeds for operator test on different roads and the two ages of power tillers. The maximum increment values for the overall sound pressure level for older power tiller (7.5 kW) under the operator's ear test at high and low engine speeds were from about 19.2 dB(A) to 5.2 dB(A) and 8.2 dB(A) to 2.2 dB(A) on asphalt and the dirt road respectively. On the other hand, the maximum increment values for the overall sound pressure level for power tiller (6 kW) and operator's ear test at high and low engine speeds were from about 10.2 dB(A) to 3.2 dB(A) and 6.7 dB(A) to 1.2 dB(A) on asphalt and the dirt roads respectively. It can be seen that the maximum noises produced under the operator's ear position were of 104.3 dB(A) and 91.4 dB (A) for asphalt and dirt road respectively, which agrees with the findings by Meyer et al.[8] and Hassan-Beygi and Ghobadian[17].

Table 6 Increment values of the dB(A) under all treatment conditions for operator's ear test

Engine speed /r·min^{-1}	Sound level pressure for ears' operator test, dB			
	Asphalt surface		Dirt rural surface	
	Age of engine		Age of engine	
	eight years old	one year old	eight years old	one year old
980	5.2	3.2	2.2	1.2
1,220	12.2	6.2	5.2	3.7
1,380	19.2	10.8	8.2	6.7

Figure 7 shows the effect of engine speed on the A-weighted overall sound pressure level at bystander for different power tillers on different types of road surfaces. It is clear that, the increase of engine speed from 980 r/min to 1,350 r/min tends to increase the noise pollution. It could be observed that the sound pressure level for power tiller (7.5 kW) were of 94 dB (A) and 87 dB (A) at 980 r/min and 1,350 r/min respectively. On the other hand, there are no significant effects of high and low engine speed on the sound pressure level for power tiller (6 kW) on dirt-covered road.

The increment of the dB (A) values between the high and low engine speeds for bystander test and two ages of power tillers on different roads are indicated in Table 7.

The maximum increment values for the overall sound pressure level for older power tiller (7.5 kW) and the operator's ear test for high and low engine speed were from about 9.3 dB (A) to 3.9 dB (A) and from about 5.7 dB (A) to 1.2 dB (A) on asphalt and the dirt road respectively. The maximum increment values at the overall sound pressure level and power tiller (6 kW) and bystander test at high and low engine speeds were from about 4.9 dB (A) to 1.9 dB (A) and 3.4 dB (A) to 0.8 dB (A), on the asphalt and dirt road. The increase of engine speed tends to increase the sound pollution.

Table 7 Increment values of the dB (A) under all treatment conditions for bystander test

Engine speed /r · min^{-1}	Sound level pressure for bystander test, dB			
	Asphalt surface		Dirt rural surface	
	Age of engine		Age of engine	
	eight years old	one year old	eight years old	one year old
980	3.9	1.2	1.9	0.8
1,220	6.0	3.1	3.2	1.9
1,380	9.3	5.7	4.9	3.4

4 Conclusions

It can be concluded that the noise attenuation of dirt road under Egyptian conditions, at both tests of the operator's ear and bystander positions was not considerable, but at driver' ear position, it was the maximum of 14 dB (A) on asphalt road and for older power tiller. The maximum overall noise produced by the power tillers, in operator's position at different gear ratios on asphalt road up to 104.3 dB (A) which is higher than the allowable noise exposure prescribed by NIOSH[1]. As well as on dirt rural roads, it reaches, the maximum overall noise produced by the power tillers up to 94 dB (A). It is also more than the allowable noise exposure prescribed by NIOSH [1].

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