NOISE LEVEL DETERMINATION IN FORESTRY MACHINES

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ABSTRACT

Until recently, the high noise level of many forestry machines presented an occupational risk of hearing loss for operators exposed over a long period of time. This is a serious health and occupational safety problem, with different. regulations in various countries concerning noise levels and exposure time allowed.

This study evaluated the noise level of sixteen relatively new forestry machines (forwarders, loaders, harvesters, processors, skidders and a slingshot), during normal operational activities. The percentage time of all activities of each machine was determined with respective noise levels obtained by a Metrosonics db-3080 noise monitor. The results showed that all machines had noise levels below the Brazilian legal limit of 85 dB(A) for an S-hour shift. The skidders were the only machines with a concern since their average noise level, 82 dB(A), was close to the limit. The next step will be to follow these machines during their operational life, to see if operational, noise levels will change over time due to normal machine wear.

Keywords: noise, wood harvesting, forestry machines.

1. INTRODUCTION

Occupational noise exposure can reduce or damage the hearing ability of operators who are exposed to high noise levels over a period of time. Many forestry machines have open cabs which may expose operators to noise levels above accepted limits. However, since noise exposure is a cumulative environmental factor which results in a gradual physical changes to the person, it is often overlooked or neglected by workers and supervisors. The process of hearing loss may take 5 to IO years at noise exposure levels typical of tractors before there is definitive'evidence of auditory damage, usually around frequencies of 4000 Hz (Gregg, 1972).

In Brazil, legislation specifies the exposure time allowed for several noise levels, with a maximum value of 85 dB(A) for an 8-hour shift without personal protective equipment (PPE) (Saad, 198 1). A recent survey conducted by an insurance company in the USA found that only 10 percent of forestry workers utilized auditory protection (Table 1). The low level of PPE use could be due to the difficulty of perceiving hearing loss, a lack of management concern about hearing loss, lack of training and education, or the perceived discomfort of personal protective equipment.

To determine if there is a legal requirement for hearing protection, the employer must calculate a representative noise exposure for each worker. Simply knowing the noise level of specific equipment is not enough. Noise exposure is a cumulative environmental stressor and must be assessed during a work shift. Two machines working side by side, for example, create a higher noise level than either machine by itself This can be a factor in yards or at landing areas where several machines may be working close together at same time.

Some studies have documented the high noise levels associated with typical wood harvesting operations. Reif & Howell (1973) evaluated the noise level of 57 forestry machines in Canada and concluded that 49 percent didn't meet accepted exposure limits to continuous or intermittent noise. Skidders had the. worst noise level with 70 percent of the machines above the action limits. Another Canadian study found that skidders operated' with an average noise level of 104 dB(A), varying between 90 and 112 dB(A) (Myles et al.,

1971).

Table 1. Utilization of personal protective equipment among forestry workers in the USA. (Robert Rummer, personal communication, 1995)

Personal Protective Equipment	Percent in Use
Hardhats	36
Safety Footwear	29
Chainsaw Chaps	24
Eye Protection	17
Hearing Protection	10
First Aid Kits at Job Site	50

Research conducted in the 70's by the Pulp and Paper Research Institute of Canada found some machines, like feller-bunchers, harvesters and processors, above the accepted noise limits (Powell, 1970; Heidersdorf, 1973; Powell, 1974a; Powell, 1974b). The Forest Engineering Research Institute of Canada (FERIC) continued noise measurements and found two feller-bunchers, one feller-forwarder and one delimber with noise level under 90 dB(A) (Folkema, 1977; Folkema, 1982; Levesque, 1983; Levesque, 1985; Hope, 1986). Other studies detected unacceptable noise level in some skidders (McDonald et al., 1978; Ryans, 1982; Heidersdorf, 1983).

In Brazil, Femandes (1991) analyzed 198 domestically manufactured agricultural tractors in real field operations and concluded that all of them were above the legal limit of 85 dB(A) for an 8-hour shift. Audiometric testing of a sample group of 111 operators indicated that 60 percent of them had hearing problems. Fiedler et al. (1995), working with forestry machines in eucalyptus plantations, also found noise levels above the limit of 85 dB(A) on a shear feller-buncher (106 dB(A)) and a wheeled skidder (101 dB(A)).

Several researchers have studied the relationship between machine design aspects and noise exposure. Fischer (1978) collected noise data from harvesting machines and concluded that some of the variation found in an "unloaded" condition could be due to climate (moisture, wind, precipitation), period (of year, day), machine life or obstacles (trees, leaves etc.). During the "loaded" condition other factors must be considered: the load weight, internal wear, operator control and travel speed. Several machines, including a loader, skidders, yarders, trucks and one chain saw, exceeded the USA limit of 90 dB(A), established by the Occupational Safety and Health Administration (OSHA). Hope (1986) reported that reducing the engine speed of a delimber from 2800 rpm to 2500 rpm, also reduced the noise level from 85-87 dB(A) to 83-85 dB(A). McDonald et al (1978) determined the operational noise level of a skidder was 98-100 dB(A) traveling unloaded and 99-101 dB(A) in a loaded condition. Liley (1985) evaluated a cable skidder and found a noise level of 78 dB(A) at the operator's station with the engine idling and transmission in neutral. At maximum travel speed, the same skidder produced 95 dB(A).

Forestry machine manufacturers can give some indication of noise level exposure for forestry conditions using a standard procedure outlined in Standard J1166 "Sound Measurement-Off-road Self-propelled Work Machines-Operator-Work Cycle" (SAE 1990). This U.S. document presents instrumentation and procedure specifications for the evaluation of time-weighted operational noise levels of various construction and industrial machines. The standard identifies work cycle times and representative conditions for each type of machine. Table 2 summarizes the standard conditions for forestry machines that are included. Some manufacturers provide noise levels for their products based on this test. Anotner standard noise test for forestry machines is outlined in International Standard 5 13 1 "Acoustics-Tractors and machinery for agriculture and forestry-Measurement of noise at the operator's position" (IS0 1996). The IS0 standard specifies measurement of noise under unloaded conditions at a constant speed of 4 km/h.

Many new machines are equipped with features such as climate control, which can reduce the noise level. Recent designs of cut-to-length technology like forwarders, harvesters and processors, operate with lower noise levels compared to conventional harvesting systems with chainsaws, skidders, and feller-bunchers. With these improvements, one question that arises is whether manufacturers have fully addressed the noise problem. Are the new models operating within legal limits or is hearing protection required? Do the new designs, like closed cabins, give adequate noise attenuation? Does the operational condition, like yard design and machines working close together, affect the operator noise level exposure?

The objective of this study was to determine the operational noise level of new models of forestry machines in real working conditions. New machines were observed, getting data that will be compared in the future with additional noise data from different periods of the same machines' life, looking for the effect of machine age on the noise level inside the cabins.

Table 2. Standard work cycle for florestry machines.

Machine	Work Cycle Elements	Work Conditions
Rubber-tired Cable Skidder	Hooking 41% Travel Loaded (182 m) 14% Unhook 21% Decking 7% Travel Empty 10% Position 7%	3-5 logs, 80% of capacity 15 min cycle time
Rubber-tired Grapple Skidder	Grapple 24% Travel Loaded 23% Decking 24% Travel Empty 17% Position 12%	3-5 logs 9 min cycle time
Tracked Feller-buncher	Travel and Swing 20% Position and Cut 45% Swing and Bunch 35%	Wooded or open area Trees may or may not be cut Cycling the cutting mechanism
Rubber-tired Feller-buncher	Travel to Trees 35% Cut and Accumulate 40% Travel to pile, Bunch 25%	is acceptable

2. METHOD

This study was conducted in eucalyptus plantations located on Duratex S.A. lands in São Paulo State, Brazil. A Metrosonics db-3080 noise monitor obtained the noise level inside the cabin. This instrument records noise level over specified intervals and had been programmed to measure sound with A-scale weighting, slow response and a 5-second interval. The microphone was located 200 mm to the right from the central axis of the operator's head, in line with the ear and pointing towards the engine.

Machine operational activities were observed in a time study, simultaneously with the noise level recording, by an external observer. Each operational activity was correlated with its respective noise level at every 5 seconds.

The life of the machine (engine-hour) was recorded to establish for future reference the relationship between machine age and the noise level inside the cabin. The following machines were observed in this study: (3) Valmet' 636 forwarders; (2) CAT 312 track loaders; (1) adapted loader on a Massey 290 wheeled tractor; (1) tracked feller-buncher on a CAT 3 12 base machine; (2) Valmet 601 harvesters ; (1) harvester on a CAT 312 base machine; (3) processors on CAT 3 12 base machines; (2) CAT 525 skidders; and (I) "slingshot" harvester on a CAT 320L base machine.

Each machine was observed for approximately 50 minutes, registering the necessary data each 5 seconds, with a total of 600 noise level data points and the respective activity.

Data analysis

The noise level data were aggregated to obtain an average sound level (Lav) for each operational activity and also a global average for the entire machine operation. The study time data were summarized to determine the average percent of total time utilized for each activity. The incremental noise levels of air conditioning and FM radio, when available, were also determined inside the closed cabin, with the engine working in neutral position. Finally, the noise level exposure was calculated for an 8-hour shift for every considered machine.

3. RESULT AND DISCUSSION

[1] The use of trade names is for the convenience of the reader and in no way implies an endorsement of the mentioned products by the authors to the exclusion of others.

Almost all machines had an operational noise level under the 85 dB(A) legal limit.

The only exception was the Massey 290 wheeled tractor adapted as a loader, which also had a damaged cabin. This tractor had noise values of 90.8 dB(A) for "loading", 91.3 dB(A) for "unloading", 77.9 dB(A) for *technical* pause *(engine* in neutral position) and an average of 89.6 dB(A) for the whole operation.

Forestry loader

Table 3. Noise level and operational activity of a forestry loader (CF) with a CAT 3 12 crawler base machine.

	CF 1	CF2	Time
Machine-hour	689 h	10 h	
Activities			
Loading	70.9 dB(A)	73.3 dB(Aj	41.4 %
Unloading	70.6 dB(A)	73.1 dB(A)	50.1 %
Moving	73.9 dB(A)	73.1 dB(A)	2.7 %
Technical Pause	68.7 dB(A)	73.3 dB(A)	5.7 %
Average	70.7 dB(A)	73.2 dB(A)	

Two tracked log loaders were observed during the study (Table 3). The higher values for the very new loader may be due to the natural break-in of the engine parts, but even these levels were not harmful to the operator. The noise level with the transmission in neutral reached 56.6 dB(A) and the increase with the air conditioning working was 10.2 dB(A), much higher than other air conditioning equipment observed during the study.

Feller-buncher

Only one disc feller-buncher on a crawler base machine (CAT 320) was observed, with no air conditioning during the test period. The noise level with the transmission in neutral was 63.1 dB(A) and working noise levels are listed in Table 4. The comparison with the literature results is not possible because the different models, but is possible to verify the development of this kind of machine getting a better noise isolation to the operator.

Table 4. Noise level and operational activity of a disk feller-buncher with a CAT 3 12 crawler base machine.

	FELLER	Time
Machine-hour	2913 h	
Activities		
Cut	78.4 dB(A)	13.3 %
Travel Loaded	78.7 dB(A)	32.7 %
Bunching Trees	80.3 dB(A)	13.5 %
Travel Unloaded	80.4 dB(A)	40.6 %
Average	79.6 dB(A)	

"Forwarder"

Two of the three forwarders (Valmet 636) had radios. The noise level with the transmission in neutral averaged 69.9 dB(A), with and additional 5.1 dB(A) with the air conditioning and 0.8 dB(A) due the FM radio. The radio was turned off during the operational data collection. One forwarder (Forw 2) had higher noise levels during the travel stage which may indicate that this machine was running faster than others did

Table 5. Noise level and operational activity of a forwarder Valmet 636 (Forw).

	Forw 1	Forw 2	Forw 3	TIME

Machine-hour	2071 h	1938 h	1675 h	

Activities				
Loading	76.4 dB(A)	76.0 dB(A)	76.1 dB(A)	49.8 %
Travel Unloaded	76.5 dB(A)	81.7 dB(A)	76.0 dB(A)	18.5 %
Unloading	76.3 dB(A)	74.1 dB(A)	75.9 dB(A)	22.8 %
Travel Unloaded	76.7 dB(A)	82.0 dB(A)	78.4 dB(A)	8.4 %
Technical Pause	72.5 dB(A)		72.2 dB(A)	0.5 %
Average	76.4 dB(A)	77.7 dB(A)	**76.1** dB(A)	

Harvester

The two Valmet 601 harvesters (Harv 1 and Harv 2) didn't have air conditioning or FM radios and Harv 1 worked with the cab open because of the heat. The noise level on this machine, with the transmission in neutral position and an open cabin, was 68. I dB(A). Harv 2, however, had the cab closed and the idling noise level was 63.6 dB(A). Harvester 3 (tracked CAT 320 base machine) had a noise level of 65.4 dB(A) idling, 3.7 dB(A) more with the air conditioning working and an additional 6.6 dB(A) because of the FM radio. The data collection for operational activities was done with the radio off. Harv 1, even with the open cabin under working conditions, didn't exceed the legal limit of 85 dB(A).

It is interesting to note the difference in work elements between the wheeled and tracked harvesters. The work element with the highest noise level for both types of harvesters was bucking. However, the tracked harvester spent about one-half the time in this element compared to the wheeled harvesters. There was also a greater variation in noise between the two Valmet 601 machines than between the tracked machine and Harv 2. The analysis of these percentage time differences was not a matter of this research, but could be studied in another opportunity.

Table 6. Noise level and operational activity of harvesters (Harv).

...	Harv 1	Harv 2	Time	Harv 3	Time
Machine-hour	4600 h	4232 h		2790 h	
Activities					

Cut	83.4 &(A)	74.4 dB(A)	21.5 %	75.3 dB(A)	18.4 %
Delimbing	84.0 dB(A)	75.0 dB(A)	34.0 %	75.0 &(A)	22.2 %
Bucking	83.6 dB(A)	77.0 dB(A)	17.1%	75.3 dB(A)	9.9 %
Moving	83.4 dB(A)	75.3 dB(A)	24.4 %	74.5 dB(A)	46.0 %
Technical Pause	76.5 dB(A)	70.6 dB(A)	3.0 %	73.7 dB(A)	3.6 %
Average	83.4 dB(A)	75.1 dB(A)		74.8 dB(A)	

Processor

The three processors based on CAT 320 tracked machines (Proc 1, 2 and 3) were quite similar to the harvester 3. In fact, one of them had been working as a harvester during the study period. The engine noise, in neutral position, reached an average of 61.1 dB(A). The noise increase with air conditioning was 4.2 dB(A) and the FM radio raised the noise level another 10.4 dB(A). Again, the radio was turned off during the operational data collection.

Table 7. Noise level and operational activity of processors with a CAT 312 crawler base machine (Proc).

	Proc 1	Proc 2	Proc 3	Time*
Machine-hour	2636 h	2528 h	2736 h	
Activities				
Cut		76.8 dB(A)		
Delimbing	75.7 dB(A)	77.1 dB(A)	77.2 dB(A)	35.3 %
Bucking	75.4 dB(A)	77.0 dB(A)	77.2 dB(A)	21.0 %
Moving	75.1 dB(A)	77.0 dB(A)	75.8 (LB(A)	40.2 %
Technical Pause	74.0 dB(A)	74.2 dB(A)	63.0 dB(A)	3.4 %
Average	75.3 dB(A)	76.9 dB(A)	76.3 dB(A)	

* - Doesn't include the processor 2 data.

Skidder

Skidders had the highest reported noise levels in the literature and a similar. result was observed in this study. The CAT 525 wheeled skidder had the highest noise levels of the various types of machines observed. Even so, the shift-level average operational noise

levels did not exceed the legal limit of 85 dB(A). It appears that current designs of wheeled skidders are significantly improved over previous models. Nevertheless, this is a noise level very close to the limit where it is recommended to use personal protective equipment by the operator. The idling noise level, with the transmission in neutral, reached an average 73.0 dB(A) and simultaneously air conditioning added 2.9 dB(A).

Table 8. Noise level and operational activity of skidders CAT 525 (Ski).

	Ski 1	Ski 2	Time
Machine-hour	3067 h	3007 h	
Activities			
Loading	81.1 dB(A)	83.6 dB(A)	14.1 %
Travel Loaded	79.7 dB(A)	84.2 dB(A)	40.3 %
Unloading	78.4 dB(A)	82.7 dB(A)	5.5 %
Travel Unloaded	80.4 dB(A)	82.4 dB(A)	10.0 %
Average	80.1 dB(A)	83.4 dB(A)	

Slingshot

The recently acquired slingshot, a uniquely-designed harvester based on a CAT 320L tracked machine, was analyzed as a case study due to limited data. The basic results were: a) felling - 77.1 dB(A); b) delimbing - 77.0 dB(A); c) bucking - 77.0 dB(A); and d) moving - 77.1 dB(A). The global average was 77.1 dB(A).

All machines in this study would allow an 8-hour shift without the mandatory use of hearing protection for the operators. Nevertheless, the use of hearing protection is recommended in the skidder operation, considering the noise level is close to the Brazilian legal limit. The air conditioning function didn't increase noise levels above action limits, but regular maintenance should be performed to reduce its noise level and minimize the possibility that the machine would have to function with an open cabin due to malfunction.

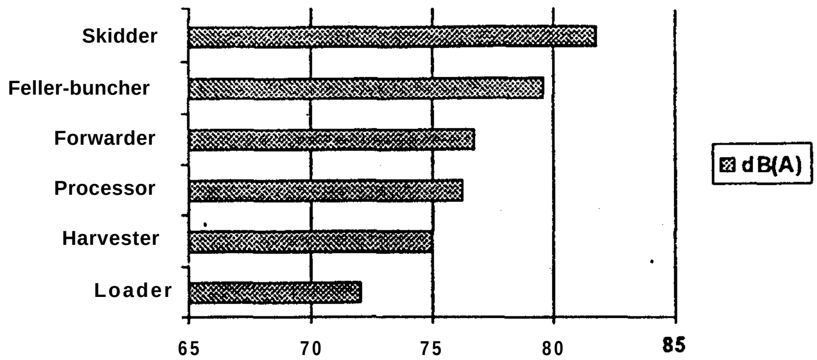

Figure 1. Average operational noise level of the forest machines in this study.

4. CONCLUSION

In this initial evaluation of noise levels on forest machines in Brazil, with new machines in good shape, all observed noise levels were below the legal limit of 85 dB(A). The different work activities didn't greatly influence the observed noise levels, except during forwarder travel, maybe because of a higher speed in that specific situation.

The same evaluation will be repeated after these machines been used for a period of time to determine the effectiveness of the noise level control as the machines wear. The most positive conclusion of this study is that the new forestry machine models are not harmful to the operator's hearing capacity and provide a healthier work environment in the forest than forest machines of the past.

5. LITERATURE CITED

FERNANDES, J.C. Avaliação dos níveis de ruido em tratores agricolas e seus efeitos sobre o operador. Botucatu, 1991. ,172 p. Tese (Doutorado), Faculdade de Ciências Agronomicas, Universidade Estadual Paulista.

FIEDLER, N.C.; A.P. SOUZA; L.J. MINETTE; C.C. MACHADO & V.C. CERESOLI. Avaliação do ruido emitido por máquinas utilizadas na colheita de madeira. In: II Simpósio Brasileiro sobre Colheita e Transporte Florestal, Salvador, 1995. Anais. SIF/UFV. P. 187-193.

FISCHER, E.L. Measurement and abatement of noise in the timber harvesting industry.

Unpublished Master Thesis. Industrial Engineering, West Virginia University. 152 p.,

1978.

FOLKEMA, M.P. Evaluation of Kockums 880 “Tree King” feller-buncher. FERIC, Pointe Claire. Technical Report TR-13. 16 p., 1977.

FOLKEMA, M.P. Evaluation of the Tanguay EC-200 delimber. FERIC, Pointe Claire. Technical Note TN-63. 21 p., 1982.

HEKDERSDORF, E. Evaluation of new logging machines: Morard Limber. PPRIC, Pointe Claire. Logging Research Reports, LRR/52. 26 p., 1973.

HEIDERSDORF, E. Deutz air-cooled diesel engines as an alternative for skidders. FERIC, Pointe Claire. Technical Note TN-68. 12 p., 1983.

HOPE, P.A. Ergonomic evaluation of stroke delimbers. FERIC, Pointe Claire. Technical Report TR-72. 34 p., 1986.

ISO. International Standard 5 13 1. Acoustics-Tractors and machinery for agriculture and forestry-Measurement of noise at the operator’s position-Survey method. International Organization for Standardization. Geneva. 11 p. 1996.

LEVESQUE, R. Short-term evaluation of the Timbo 25 18 feller-buncher in Eastern Canada. FEFUC, Pointe Claire. Technical Note TN-72. 27 p., 1983.

LEVESQUE, R. Evaluation of the Koehring K2FF feller-forwarder. FERIC, Pointe Claire. Technical Note TN-SO. 28 p., 1985.

LILEY, W.B. The Iwafuji T30 skidder. LIEU, New Zealand. Vol. 8 1. 4 p., 1985.

McDONALD, M.J.; L.H. POWELL & D.W. MYHRMAN. Evaluation of Bombardier B- 15 choker arch skidder and comparison with FMC 2 10 CA skidder. FERIC. Pointe Claire. Technical Note 21. 27 p., 1978.

MYLES, D.V.; R. HIRVONEN; T.F.W. EMBLETON & F.E. TOOLE. Anacoustical study of machinery on logging operations in Eastern Canada. Forest Management Institute, Ottawa. Information Report FMR-X-30. 41 p., 1971.

POWELL, L.H. Evaluation of logging-machine prototypes: Drott feller-buncher. PPRIC, Pointe Claire. Woodlands Report WR/29. 14 p., 1970.

POWELL, L.H. Evaluation of new logging machines: Tanguay Tree-Length harvester. PPRIC, Pointe Claire. Logging Research Reports, LRR/56. 24 p., 1974 a.

POWELL, L.H. Evaluation of new logging machines: Arbomatik roughwood processor. PPRIC, Pointe Claire. Logging Research Reports, LRR/58. 20 p., 1974 b.

REIF, Z.F. & A.R. HOWELL. Study of the exposure to noise of operators of mechanized equipment in logging operations in Eastern Canada. Forest Management Institute, Ottawa. Information Report FMR-X-53. 56 p., 1973.

RYANS, M. Evaluation of the Donaren 180D powered disc trencher. FERIC, Pointe Claire. Technical Report TR-54.38 p., 1982.

SAAD, E.G. Introdução à Engenharia de Segurança do Trabalho: textos básicos para estudantes de engenharia. São Paulo, FUNDACENTRO. 547 p., 1981.

SAE. Sound Measurement-Off-road Self-propelled Work Machines-Operator-Work Cycle. Standard J1 i 56. Society of Automotive Engineers. Warrendale, PA. (SAE 1990)

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