OCCUPATIONAL NOISE EXPOSURE AND HEARING LOSS PREVALENCE AMONG THE GRASS CUTTERS OF USM, PENANG

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by

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TABLES OF CONTENTS

CHAPTER 3: METHODOLOGY

CHAPTER 4: RESULTS AND DISCUSSIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS AND ABBREVIATIONS

AIHA	American Industrial Hygiene Association
ANSI	American National Standard Institute
ARHL	Age-related Hearing Loss
ASHA	American Speech-Language-Hearing Association
B	Coefficient Value
BP	Back Pack
CI	Confidence Interval
dB	Decibel(s)
dB(A)	Decibel(s), A-weighted
dB(C)	Decibel(s), C-weighted
Df	Degree of freedom
$DOSE_{F\&MNR}$	Noise Dose of Malaysian Factory and Machinery (Noise Exposure Regulations), 1989
$DOSE_{NIOSH}$	Noise Dose of US National Institute for Occupational Safety and Health, 1998
DOSH	Malaysian Department of Occupational Safety and Health
EASHW	European Agency for Safety and Health at Work
EEC	European Economic Community
EPA	US Environmental Protection Agency
ER	Exchange Rate
EU	European Union
f	Frequency
F&MNR	Malaysian Factory and Machinery (Noise Exposure) Regulations
HSE	Health and Safety Executive of UK
HTL	Hearing Threshold Level
Hz	Hertz

IEC	International Electrotechnical Commission
ILO	International Labour Office
ISO	International Organization for Standardization
kHz	Kilohertz
$L_{ASeq,8h}$	Equivalent-continuous sound level normalized 8 hour working Day (A-weighted frequency, slow exponential-time weighted) or daily noise exposure
$L_{ASeq,T}$	Equivalent Continuous-Sound Level (A-weighted frequency, slow exponential-time weighted)
L_{ASmax}	Maximum Sound Level (A-weighted frequency, slow exponential-time weighted)
L_{ASmin}	Minimum Sound Level (A-weighted frequency, slow exponential-time weighted)
$L_{Aeq,T}$	A-Weighted Equivalent-Continuous Sound Level
L_{Upeak}	Peak Sound Level (un-weighted frequency, peak time-weighting)
L_{eq}	Equivalent-Continuous Sound Pressure Level or Sound Level
L_{max}	Maximum Sound Level
L_{min}	Minimum Sound Level
L_{peak}	Peak Sound Pressure Level or Sound Level
MOH	Malaysian Ministry of Health
NHANES	National Health and Nutrition Examination Survey of US
NIHL	Noise Induced Hearing Loss
NIOSH	National Institute for Occupational Safety and Health of US
OR	Odds Ratio
OSHA	Occupational Safety and Health Administrative of US
OSHU	Occupational Safety and Health of USM
p	Significant Level
Pa	Pascal
PEL	Permissible Exposure Limit
P_M	Sound Pressure Amplitude
REL	Recommended Exposure Limit

RMS	Root-Means-Square
S.D.	Standard Deviation
SLM	Sound Level Meter
SOCSO	Malaysian Social Security Organization
SPL	Sound Pressure Level
TWA	Time Weighted Average Sound Level
$TWA(8)_{F\&MNR}$	Time Weighted Average Sound Level normalised 8 hour working day of Malaysian Factory and Machinery (Noise Exposure) Regulations
$TWA(8)_{NIOSH}$	Time Weighted Average Sound Level normalised 8 hour working day of US National Institute for Occupational Safety and Health.
$TWA_{F\&MNR}$	Time Weighted Average Sound Level of Malaysian Factory and Machinery (Noise Exposure) Regulations
TWA_{NIOSH}	Time Weighted Average Sound Level of US National Institute for Occupational Safety and Health
US	United States of America
USM	Universti Sains Malaysia
WHO	World Health Organization
µPa	Micropascal
λ	Wavelength

PENDEDAHAN KEBISINGAN PEKERJAAN DAN KELAZIMAN HILANG PENDENGARAN DI KALANGAN PEKERJA-PEKERJA PEMOTONG RUMPUT USM, PULAU PINANG

ABSTRAK

Pendedahan hingar yang berlebihan boleh menyebabkan pelbagai kesan, termasuk hilang pendengaran. Walaupun hilang pendengaran daripada hingar telah dikenalpasti sejak revolusi industri dan undang-undang perlindungan hingar di tempat kerja telah diwartakan sejak lebih dua dekad, tetapi ianya masih menjadi salah satu daripada masalah utama keselamatan dan kesihatan pekerjaan di banyak negara. Di Malaysia, banyak yang tidak diketahui tentang pendedahan hingar dan hilang pendengaran di kalangan pemotong rumput yang mengendalikan mesin pemotong rumput galas. Tujuan utama kajian ini untuk menentukan paras hingar yang dihasilkan mesin pemotong dan prevalens hilang pendengaran di kalangan kumpulan pemotong rumput USM. Kajian ini melibatkan 42 pemotong rumput dan 28 bekas pemotong rumput daripada Jabatan Pembangunan sebagai pekerja dedahan hingar dan 45 pekerja bukan dedahan hingar yang disampel dari kalangan staf pentadbiran dan sokongan di pelbagai Jabatan USM, Pulau Pinang. Takat ambang pendengaran (TAP) pekerja diukur dengan menggunakan audiometer pada frekuensi 0.25 hingga 8 kHz. Paras pendedahan hingar bagi pemotong rumput dan staf pentadbiran/sokongan diukur dengan dosimeter. Maklumat tentang sosial demografpik pekerja, masalah pendengaran sekarang dan sejarah perubatan lampau, penggunaan bahan kimia ototoksik, hobi, pendedahan hingar yang lalu dan lain-lain faktor risiko dikumpulkan melalui borang soal selidik. Prevalens hilang pendengaran ditentukan berdasarkan kepada TAP pekerja dalam mana-mana telinga yang teranjak melebihi 25 dB(A) pada mana-mana frekuensi. Pekerja pemotong rumput terdedah kepada purata paras hingar sebanyak 93.85 dB(A) (minimum = 86.00 dB(A) dan maksimum = 114.50 dB(A)) dan pekerja bukan dedahan hingar sebanyak 70.40 dB(A) (minimum = 62.20 dB(A) and maksimum = 79.4 dB(A)). Seramai 7.1% pemotong rumput terdedah kepada paras hingar yang melebihi had yang dibenarkan oleh 'Malaysian Factories and Machinery (Noise Exposure) Regulations, 1989' (F&MNR), iaitu 90 dB(A), 8 jam dedahan dan 69% melebihi had yang dicadangkan oleh 'United State National Institute for Occupational Safety and Health' (NIOSH), iaitu 85 dB(A), 8 jam dedahan. Tiada seorangpun daripada pekerja bukan dedahan hingar yang terdedah kepada paras hingar yang melebihi kedua-dua had tersebut. Prevalens hilang pendengaran adalah tertinggi dikalangan bekas pemotong rumput (92.9%), diikuti oleh pemotong rumput (50%) dan seterusnya pekerja bukan dedahan hingar (15.6%). Hilang pendengaran di kalangan kumpulan pemotong rumput dan bekas pemotong rumput adalah bilateral dan simetrikal. Pemotong rumput menunjukkan TAP yang signifikan lemah pada frekuensi tinggi berbanding dengan pekerja bukan dededah hingar dengan ciri hilang pendengaran yang tipikal pada 4 kHz. Analisa univariat dan multivariat menunjukkan bahawa prevalens hilang pendengaran dikalangan pekerja adalah berkaitan dengan pendedahan hingar dari mesin pemotong rumput, umur dan pendedahan hingar lampau pekerjaan majikan terdahulu. Kadar pembentukan hilang pendengaran ialah 9 kali ganda (OR: 8.793, 95% CI: 1.018-75.924) bagi bekas pemotong rumput dan 4 kali ganda (OR: 4.053, 95% CI: 1.397-11.760) bagi pemotong rumput berbanding dengan pekerja bukan dedahan hingar. Kadar pembentukan hilang pendengaran pekerja yang terdedah kepada hingar lampau, ialah 4 kali ganda (OR: 3.512, 95% CI: 1.044-11.813) berbanding dengan mereka yang tidak terdedah. Setahun peningkatan umur meningkatkan 11.2% dalam odds untuk pembentukan hilang pendengaran. Kajian ini menyimpulkan bahawa pemotong rumput terdedah kepada paras hingar yang berbahaya dan mereka berada dalam risiko untuk pembentukan hilang pendengaran.

OCCUPATIONAL NOISE EXPOSURE AND HEARING LOSS PREVALENCE AMONG THE GRASS CUTTERS OF USM, PENANG

ABSTRACT

Exposure to excessive noise can cause many adverse health effects including hearing loss. Even though hearing loss from noise exposure has been recognized since the industrial revolution and the noise legislations in the work place has been enacted over the last two decades, but it remains as one of the most prevalent occupational health problems in many countries of the world. In Malaysia, little is known about noise exposure and hearing loss among grass cutters who operate the back pack grass cutting machine. The main purpose of this study is to determine the level of noise exposure from the grass cutting machine and the prevalence of hearing loss among the workforce of USM grass cutters. This study involved 42 grass cutters, and 28 ex-grass grass cutters of the Development Department as the noise exposed workers and 45 of non-noise exposed workers were selected among the supporting and administrative workers of various departments in USM, Penang. The workers' hearing threshold levels (HTLs) for both ears were assessed by using the audiometer at the frequencies of 0.25 to 8 kHz in a soundproof booth. Personal noise exposure levels of grass cutters and administrative workers were measured by using noise dosimeters. Information regarding the socio-demographic of workers, present and past medical history of hearing problems, use of ototoxic chemicals, hobbies, past noise exposures and other risk factors were obtained using a self-administrated questionnaire. The hearing loss prevalence was determined based on HTL of workers in either ear which is shifted by more than 25 dB(A) at any test frequency. The grass cutters were exposed to an average noise level of 93.85 dB(A) (minimum = 86.00 dB(A) and maximum = 114.50 dB(A)) and the non-noise exposed workers were exposed to an average noise level of 70.40 dB(A) (minimum = 62.20 dB(A) and maximum = 79.4 dB(A)). 7.1% and 69% of the grass cutters were exposed to the noise level exceeding the Malaysian Factories and Machinery (Noise Exposure) Regulations, 1989 (F&MNR) PEL of 90 dB(A) and United State National Institute for Occupational Safety and Health (NIOSH) REL of 85 dB(A) for 8-hour exposure, respectively. None of the non-noise exposed workers were exposed to noise levels that exceeded the NIOSH REL, as well as PEL of F&MNR. The hearing loss prevalence was highest among the ex-grass cutters (92.9%), followed by grass cutters (50%) and non-noise exposed workers (15.6%). Hearing loss was found to be bilateral and symmetrical in both groups of the grass cutters and the ex-grass cutters. The grass cutters showed significantly poorer HTL at a higher frequency as compared to non-noise exposed workers, with a typical characteristic of hearing loss at 4 kHz. Univariate analysis (independent t-test) and multivariate analysis (binary logistic regression model) had demonstrated that the prevalence of hearing loss among the workers was associated with job exposure to occupational noise from the grass cutting machines, aging and past noise exposure in the previous employment. The ex-grass cutters and grass cutters had almost 9-times rate (OR: 8.793, 95% CI: 1.018-75.924) and 4-times rate (OR: 4.053, 95% CI: 1.397-11.760) for hearing loss development respectively, as compared to the non-noise exposed workers. The workers who were exposed to past noise exposure had an almost 4-times rate (OR: 3.512, 95% CI: 1.044-11.813) for the development of hearing loss. One-year increase in age has increased 11.2% in odds for development of hearing loss (OR: 1.112, 95% CI: 1.021-1.211). The study concludes that the grass cutters were exposed to the hazardous noise level and they were at the risk of hearing loss development.

CHAPTER 1

INTRODUCTION

1.1 NOISE AND HEARING LOSS

Noise is unwanted or any undesired sound to the listener which is produced by a vibration body and transported via an elastic medium such as in air (Olishifski, 1975; Behar et al., 2000; Dobie, 2001). Physically, sound (or noise) consists of successive pressure waves in the atmosphere which stimulates the auditory system.

The American Speech-Language-Hearing Association (ASHA) has considered that the sound pressure level (SPL) of above 80 dB(A) is potentially hazardous to health (ASHA, 2007) and any sound below this level is classified as 'quiet' (non-noise) in the Malaysian Factories and Machinery (Noise Exposure) Regulations 1989 (F&MNR, 1989). The National Institute for Occupational Safety and Health (NIOSH) of US has stated that repeated and prolonged exposure to noise levels above 85 dB(A) in the work place posed a significant risk of hearing loss for a percentage of the exposed population (NIOSH, 1998). In particular, NIOSH found that exposure to noise at a level of 80 dB(A), 85 dB(A) and 90 dB(A) for 8 hours a day, 5 days a week, 48 weeks a year for 40 years will produce a noise induced hearing loss risk of 1%, 8% and 25% respectively for those exposed. Therefore, NIOSH recommended that a noise level of 85 dB(A) for an 8-hour exposure as the noise exposure limit (NIOSH, 1998). The US Environmental Protection Agency (EPA) has identified that a sound level of 70 dB(A) for 24 hour exposure as the level necessary to protect the public from hearing loss (EPA, 1974).

The hearing loss of a worker is normally assessed by a pure tone audiometer at frequencies of 0.25 kHz to 8 kHz. The pure tone value of workers' hearing threshold level (HTL) is recorded in audiogram as dB(A) HTL or dB(A) HL (hearing level) (NHANES, 2003) or dB HL (hearing loss) (Mathers et al., 2003). The worker's HTL is not an absolute value, but it is the number of dB(A) that is relative to an audiometric zero (0 dB(A)) of a standardized audiometer at the measured frequency. Therefore, positive values of HTL indicate poorer hearing sensitivity than the audiometric zero, while negative values indicate better hearing. The audiometric zero refers to the average HTL of a large number of healthy young adults (Dobie, 2001). Thus, the HTL of workers within the range of -10 dB(A) and 25 dB(A) at each frequency tested from 0.25 kHz to 8 kHz is generally considered as 'normal hearing' (Brender, 2006; Humes et al., 2005; Miller and Wilber, 1991). However, there is no one universally accepted method for defining the degree of hearing loss. For example, NIOSH defined hearing impairment as an arithmetic average of HTL at the frequencies of 1, 2, 3 and 4 kHz which is above 25 dB(A) (NIOSH, 1998) and the F&MNR (1989) defined hearing impairment as an average of HTL at the frequencies of 0.5, 1, 2 and 3 kHz which is shifted by 25 dB(A) or more. Some researchers defined hearing loss due to noise exposure as the HTL of above 25 dB(A) at the frequency of 4 kHz (Rachiotis et al., 2006; Amedofu, 2002).

Hearing loss that is caused by the cumulative effect of prolonged and repeated noise exposures is commonly referred to as noise induced hearing loss (NIHL) (Lonsbury and Martin, 2001; Dobie, 2001). It often occurs slowly over a period of many years and the affected workers will not be aware of their hearing loss until their speech communication is compromised (Harvey, 1991). Because of that, NIHL is termed as an occupational disease or illnesses, rather than an injury (Suter, 1998). The NIHL is characterised in the audiogram by a drop in the higher frequencies (3 to 6 kHz) compared to lower frequencies (0.5 to 2 kHz) by the largest effect (or noise notch) at 4 kHz (Burns, 1973; Melnick, 1991; McBride and Williams, 2001). Hearing loss due to occupational noise exposure are usually bilateral (both ears) and symmetric (approximately the same in each ear) (NHANES, 2003).

Exposure to impulsive or impact noise at a very high sound level in a single exposure (or relatively a few exposures at very high sound level), such as from an explosion, blast or shot gun fire may also result in hearing loss. This type of hearing loss is known as acoustic trauma (Lang, 1994; Lonsbury and Martin, 2001; Humes et al., 2005; Melnick, 1991). Exposure to peak sound pressure levels of 130 dB(C) to 140 dB(C) can cause workers to suffer from acoustic trauma (EASHW, 2005).

In addition, exposure to loud noise can also cause tinnitus or ringing in the ears (Cunha, 2007). It also may cause interference with communication, sleep disturbance, cardiovascular and psycho-physiological effects, reduced performance, and also provoke annoying responses and changes in social behavior (WHO, 1999).

Under the Factories and Machinery Act 1967, the Malaysian government has enacted the Factories and Machinery (Noise Exposure) Regulations 1989 to protect the workers from being exposed to hazardous noise levels at work places which can cause hearing loss (F&MNR, 1989). The Act is enforced by the Department of Occupational Safety and Health (DOSH), Ministry of Human Resources, which was formerly known as Factories and Machinery Department. The regulations specify that an employer should establish an audiometric testing program for all workers who are exposed to noise level at or above the action level, i.e. 85 dB(A) equivalent-continuous sound level (L_{eq})for an 8-hour exposure, which is equivalent to noise dose of 50% (Regulations 2 & 21(1) of F&MNR (1989)). The audiometric testing program shall include a record of medical and occupational history of the workers, particularly in relation to past ear diseases and exposures to noise. The 90 dB(A) equivalent-continuous sound level is the permissible exposure limit (PEL) for an 8-hour exposure with 5 dB(A) exchanged rates (ER) and 115 dB(A) is the maximum limit of noise exposure level which the workers' noise exposure level should not exceed at any time (Regulations 5(1) & (2) of F&MNR (1989)). For impulsive (or impact) noise, the ceiling limit is 140 dB of peak sound pressure level (Regulation 5(3) of F&MNR (1989)).

NIOSH recommended a more conservative protective limit for occupational noise exposure, i.e. 85 dB(A) time-weighted average sound level (TWA) for an 8-hour exposure with 3 dB(A) exchange rate (ER), which is known as recommended exposure limit (REL) (NIOSH, 1998).

Table 1.1 shows some examples of noise exposure limits for 3 dB(A) ER of NIOSH and 5 dB(A) ER of F&MNR for comparison.

Table 1.1: Noise Exposure Limit of NIOSH 3 dB(A) ER and F&MNR 5 dB(A) ER

Exposure Duration	**Noise Exposure Limit (dB(A))**	
	3 ER of NIOSH REL	**5 ER of F&MNR PEL**
16 h	82	85
8 h	85	90
4 h	88	95
2 h	91	100
1 h	94	105
30 m	97	110
15 m	100	115
1 s	127	Not specified

Sources: F&MNR (1989) and NIOSH (1998)

Even though hearing loss from exposure to noise has been reported since the industrial revolution and the noise legislations in the work place has been enacted since the last two decades, it remains as one of the most prevalent occupational health problems in many countries of the world. In Australia, it is estimated that nearly one-third of industrial workers experience a certain degree of hearing loss as a result of working in noisy environments (WorkSafe, 2003). NIHL in United States is one of the most common occupational diseases and second most self-reported occupational illness or injury (NIOSH, 2001). Hearing loss from noise exposure at the work place is also a significant problem in United Kingdom. It was reported that approximately 170,000 people in the United Kingdom suffer from deafness and tinnitus due to excessive noise exposure at work. These problems occur in many work places, including manufacturing, construction industries, farming, transport operations, mines and quarries (Lawman, 2008).

In Malaysia, a study conducted by Department of Occupational Safety and Health (DOSH, 2007) from 1983-1990, which involved 45,974 workers sampled from 302 factories in local industries indicated that 70% of them were exposed to noise levels above the permissible exposure limit (PEL) of F&MNR; 50% were at risk of hearing impairment; and 22% had hearing impairment. It was also reported in the same study that the percentage of workers exposed to the risk of hearing impairment were 59.2% in textile mills; 54.9% in steel mills; 52.9% in chemical industries; 52.1% in beverage manufacturing; 51.8% in mineral products manufacturing; 49.4% in food manufacturing; 48.9% in metal product manufacturing; and 48.9% in palm oil mills.

Ironically, after 21 years following the enforcement of the Factories and Machinery (Noise Exposure) Regulations 1989 in Malaysia (F&MNR), statistics on occupational diseases reported to Malaysian Social Security Organization (SOCSO, 2000 - 2007) (Table 1.2), have shown that the number of hearing impairment cases caused by noise had increased sharply, from four (4) cases in 2000 to 59 cases in 2002. Only one (1) case was reported in 2003, however it had increased further from 48 cases in 2004 to 90 cases in 2007.

Table 1.2: Numbers of Cases Reported of Occupational Diseases by Causing Agents

Years	**Numbers of Occupational Diseases Cases Reported by Causing Agents**		
	Hearing Impairment Caused by Noise	**Diseases Caused by Chemicals**	**Diseases Caused by Biological Agents**
2000	4	37	3
2001	26	6	4
2002	59	12	4
2003	1	54	2
2004	48	11	3
2005	53	21	3
2006	77	14	2
2007	90	33	1
Total	358	188	22
Source: Annual Reports of SOCSO (2000 - 2007)			

Table 1.2 indicates that the number of cases of hearing impairment caused by noise reported was higher than the numbers for other occupational diseases caused by industrial chemicals or biological agents for almost every year, except in 2000 and 2003. Essentially, the number of cases of hearing impairment caused by noise reported was higher than diseases caused by chemicals and biological agents, i.e. 358 cases of hearing impairment caused by noise , 188 cases due to chemical agents and 22 cases due to biological agents.

Recently, exposure to occupational noise was identified by the Ministry of Health (MOH) as the major cause of hearing loss among Malaysians (KOSMO, 2008). The incidences of such cases is increasing every year when compared to other causes of hearing loss, such as hearing loss at birth. It was also reported that a survey conducted by Malaysian Institute for Public Health showed that 424,000 Malaysians suffered from hearing loss due to machine noise at the work place and 23% of them were not using any hearing protection devices while working (KOSMO, 2008).

In addition, the Malaysian Ministry of Health (MOH) estimated that millions of workers are posed to the risk of hearing loss due to noise exposures in their work places and among them were the grass cutters (MOH, 2000). A study conducted by Hanidza et al. (2006) showed that 88.9% (16 out of 18) of grass cutters who used the back pack (BP) grass cutting machines trimming the grass were exposed to noise levels exceeded the action level of F&MNR, i.e. 27.8% (5 out of 18) exceeded the PEL; 22.2% (4 out of 18) exceeded the maximum limit; and 61.1% (11 out of 18) exceeded the ceiling limit of peak sound level. The study also indicated that all grass cutters were exposed to the noise level exceeded the NIOSH REL and 33% (6 out of 18) of them had hearing impairment.

As a conclusion, it is important to note that this study on grass cutters has never been done before and therefore the literature review is limited.

1.2 GRASS CUTTING SERVICES IN USM CAMPUS

The back pack (BP) grass cutting machine is commonly used for trimming grass in the Malaysian grassed land areas, especially with undulating surface. The BP grass cutting machine has a petrol-powered engine that drives the cutting head containing metal blade or nylon cutting line through a long shaft for cutting the grass.

The Plate 1.1 illustrates the photograph of the BP grass cutting machine which is commonly used in Malaysia.

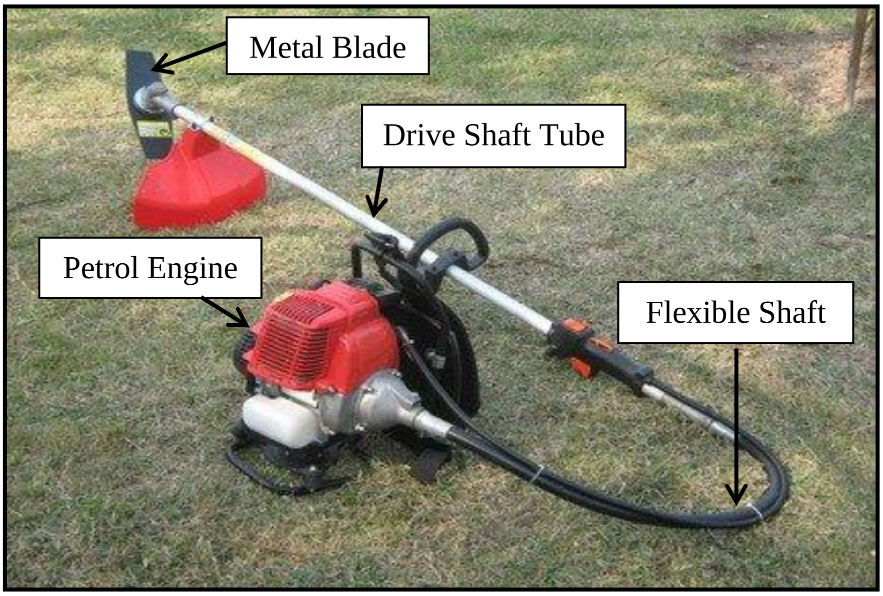

Plate 1.1: The Photograph of BP Grass Cutting Machine

During grass cutting, the operator is exposed to a high noise levels produced by the machine’s engine which is placed at the back of operator, as well as from the rotating cutter at the end of shaft.

The BP grass cutting machine is widely used during leisure time by the part-time users to cut the grass in their home lawns, orchards, paddy fields and other private ground areas. It is also used by occupational grass cutters who provide grass cutting services, such as can be seen along the highways, roadside and any land areas. Most of the occupational grass cutters are contract workers with no or little awareness of the adverse effects of noise on their health (Mallick et al., 2009).

In Universiti Sains Malaysia (USM), the grass cutting service is provided by the Lawn Unit of Development Department which employs permanent staff as grass cutters. They use the BP grass cutting machines for cutting the grass around the campus grounds as shown by the photograph in Plate 1.2.

Plate 1.2: The Photograph of the Grass Cutters Who Use the BP Grass Cutting Machines for Cutting the Grass in the USM Campus.

The Lawn Unit is a part of the Campus Cleanliness and Beautification Section of USM Development Department. The Lawn Unit is responsible for cutting grass, sweeping the roadside and doing other general duties at the campus lawn. When the study was conducted, the Lawn Unit had 101 permanent staff which consisted of 95 manual workers with six (6) foremen (senior manual workers). Fifty one (51) out of 95 manual workers were assigned as the grass cutters.

In order to reduce the effects of noise exposure and physical fatigue among the grass cutters, the management transfers the grass cutters to do lighter duties and non-noisy jobs as they reach the age of 40 years olds, or earlier if the workers have any health problems. During the study, there were 50 ex-grass cutters in the Lawn

Unit who were working either as road sweepers, foremen, supervisors or as other general workers.

The land area of USM Campus covers approximately 416.6 hectares, most of which are occupied by buildings of various departments, such as schools, centres, institutes, hostels, units, etc. For a better arrangement of grass cutting services, the campus area is divided into six (6) zones as shown in the Area Map (Appendix A.1). The grass cutting maintenance operations in each zone is attended by a group of eight (8) to ten (10) grass cutters. Each zone has a different landscapes and types of grass.

As University staff, the official working hours for the grass cutters is from 8.10 am to 5.10 pm on five (5) working days, with Saturdays and Sundays as non-working days. The work schedule for the grass cutters is given in Table 1.3.

Table 1.3: Work Schedule of the Grass Cutters

Time	Activities
8.10 am – 9.00 am	Preparation and checking of grass cutting machines
9.00 am – 10.00 am	Cutting the grass
10.00 am – 10.45 am	Break
10.45 am – 11.45 am	Cutting the grass
11.45 am – 2.00 pm	Break and returning to the office
2.00 pm – 2.30 pm	Preparation and checking of the grass cutting machines
2.30 pm – 3.30 pm	Cutting the grass
3.30 pm – 5.10 pm	Break and returning to the office

Table 1.3 shows that the grass cutters are exposed to noise on an average of three (3) hours daily if they are scheduled for grass cutting. However, their noise exposure may be more if there are official events which require them to work overtime. There is no grass cutting during raining days or if the machines have broken down.

1.3 PROBLEM STATEMENT

The USM grass cutters play a significant role in cropping the grass growth of the campus grounds by cutting them on regular basis. Using the BP grass cutting machine for grass cutting, they are exposed to high noise levels which consequently put them at risk of hearing loss due to noise exposure. Therefore, it is important to carry out this study to determine the level of noise exposure that is received by the grass cutters from the grass cutting machine and the prevalence of hearing loss among them. To date, no such study has ever been done among the grass cutters of USM.

Even though the Malaysian Ministry of Health (MOH) reported that the grass cutters are at risk of hearing loss due to noise exposure (MOH, 2000), but no convincing data are available to prove it. It was found that the only published data on the hearing loss among the grass cutters was from Hanidza et al. (2006) study. However, the sample size of the study was small (18 workers) and no statistical inference results were provided by researchers to demonstrate the association between the levels of noise exposure and hearing loss prevalence. This statement was also raised by Mallick et al. (2009) who reported that “either no or very little work has been done in case of grass-trimming machine noise effects on operators”.

Hence, this study will provide important information for policy makers or any other relevant authorities in order to plan an effective prevention strategy to protect the grass cutters, as well as other users of the BP grass cutting machines from hearing loss due to noise exposure. This study will also provide data base on noise exposure and hearing loss among the grass cutters for future researchers as well as policy makers.

1.4 SCOPE OF WORK

This study involves the grass cutters and ex-grass cutters of the USM Development Department as the noise exposed workers while non-noise exposed workers were sampled among the male administrative and supporting staff from various departments in USM, Penang. The variables of workers such as their personal details, past and present history of occupational and non-occupational noise exposures, health status and other demographic variables were gathered through questionnaires and interviews. The HTL of all workers were measured using the audiometer and the personal noise exposure level was measured using the noise dosimeter for the group of non-noise exposed workers and the grass cutters only. The noise exposure level for the group of ex-grass cutters were not measured since they are no longer working with the grass cutting machine. The workers who met the exclusion criteria were excluded from statistical analysis of study. The variables/data of the noise exposed workers and non-noise exposed workers were statistically analysed, compared and interpreted in order to achieve the study objectives and to answer the research questions. Even though this study is limited to grass cutters of USM, the results of the study can be generalized and extended to other workers who use the BP grass cutting machine for cutting grass.

1.5 OBJECTIVES AND RESEARCH QUESTIONS OF THE STUDY

The objectives of the study are as follows;

(1) To evaluate and compare the noise exposure levels between the groups of grass cutters and the non-noise exposed workers.

(2) To evaluate and compare the prevalence of hearing loss between the groups of grass cutters, ex-grass cutters and non-noise exposed workers.

(3) To evaluate and compare the characteristics of hearing loss (HTL) among the groups of grass cutters, ex-grass cutters and non-noise exposed workers.

(4) To evaluate the most significant risk factors (independent variables) that associated with the prevalence of hearing loss among the workers.

The research questions that were raised in this study are as follows;

(1) What is the level of noise exposure among the grass cutters compared to the non-noise exposed workers? Has it exceeded the noise exposure limit?

(2) What is the prevalence of hearing loss, hearing loss due to noise exposure and hearing impairment among the grass cutters, ex-grass cutters and non-noise exposed workers?

(3) What are the characteristics of hearing loss (HTL) among the grass cutters and ex-grass cutters as compared to the non-noise exposed workers? Is it affected by noise exposure?

(4) What are the most significant risk factors (independent variables) that are associated with the hearing loss prevalence among the workers?

1.6 THESIS ORGANIZATION

This thesis is presented in five chapters. Chapter 1 gives an introduction of the thesis and a general understanding of noise exposure and hearing loss, including hearing loss due to noise exposure. This chapter also presents the organization and duties of USM grass cutters who use the BP grass cutting machine for cutting grass in the campus grounds. Objectives, problem statements, scope and flow of the study are also explained in this chapter.

Chapter 2 reviews the relevant literature regarding noise exposure and hearing loss. It is divided into 3 sections. The first section reviews the physical characteristics of sound (or noise) pressure wave, including the quantities to be measured and their descriptors in various metrics that are used in this study. The second section reviews the basic principles of human hearing and hearing loss, including the characteristics and the types of hearing loss due to noise exposure. Recent field studies of hearing loss due to noise exposure among the workers in most countries are also reviewed in the third section, particularly those that are closely related to this study. The other risk factors that caused hearing loss are also reviewed in this section.

Chapter 3 describes the step-by-step experimental procedures and the equipments which were used in this study for the data collection, as well as the statistical methods that were used for data analysis. Descriptions or definitions and coding of variables that are used for statistical analysis in this study are also presented in this chapter.

Chapter 4 reports the results, analyses and discussions of the study, which are grouped into four sections. The first section presents the result of workers who were selected in this study for the statistical analysis. The second section gives the results of workers' demographics and selected variables that were obtained from the questionnaires of the study, particularly those that are used for univariate and multivariate analysis. The third section presents the analysis results of the noise exposure level for the group of grass cutters and non-noise exposed workers in various forms of measurement metrics and descriptors (e.g. L_{ASeq}, TWA, etc.), as well as the percentages of workers who were exposed to noise levels that exceeded the NIOSH REL and F&MNR PEL. The fourth section presents the analysis results of workers' HTL, which showed the prevalence and characteristic of hearing loss among workers. The fifth section presents the results of univariate analysis (chi-square test) and multivariate analysis (binary logistic regression model), which showed the significant independent variables that are associated with the prevalence of hearing loss among the workers. In addition, this section also shows the probability of hearing loss development among the workers.

Chapter 5 gives the conclusion remarks of this study as well as some recommendations for future research regarding hearing loss prevalence among grass cutters who use the BP grass cutting machines.

CHAPTER 2

LITERATURE REVIEW

2.1 SOUND AND NOISE

Noise is commonly defined as unwanted or any undesired sound to the listener (Behar et al., 2000; Sataloff and Sataloff, 2006c). It means noise is defined more subjectively by the direct sense of human ear rather than physical evidence or objectively. There is no difference between the sound and noise in physical terms as both are expressed in the form of wave motion due to particle displacement in an elastic medium (Dobie, 2001). In addition, the World Health Organization (WHO), defined noise operationally as an "audible acoustic energy that adversely affects, or may affect, the physiological and psychological well being of people" (WHO, 1995). Generally, sound wave is produced by a vibrating body and is propagated from one location to another through an elastic medium such as air, water or solid material (Olishifski, 1975; Behar et al., 2000; Dobie, 2001).

2.1.1 Characteristic and Components of Sound Pressure Wave

In air, the sound waves are described as variations in pressure above and below the static value of ambient atmospheric pressure (Harris, 1991b; Hansen, 2001). The simplest kind of sound wave is known as a pure tone (Harris, 1991b). It is defined as wave sound that has a simple sinusoidal function of the time (Harris, 1991a). Figure 2.1 shows a graphical representation of a pure tone of sound pressure wave (Sataloff and Sataloff, 2006c).

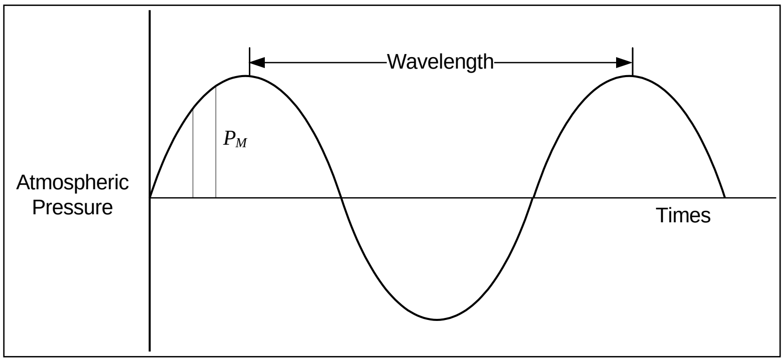

Figure 2.1: Graphical Representation of a Pure Tone of Sound Pressure Wave (Sataloff and Sataloff, 2006c)

Sound pressure wave which consists of a pure tone is characterised by the amplitude, the frequency, the wavelength and the period (Hansen, 2001). The amplitude of sound pressure (P_M) is the maximum pressure value of pressure changes. It is related to the maximum distance of instantaneous individual particles that are vibrating from their equilibrium position. The pressure is the force per unit area, thus the amplitude of sound pressure is expressed as the same unit of pressure, i.e. newton/square meter or Pascal (Pa). In the International System of Unit, it is usually expressed in micropascals (µPa) (Harris, 1991b).

The frequency (f) is the number of pressure variation per second or cycles completed each second (Dobie, 2001). It is measured in hertz (cycle/second). The reciprocal of frequency $\left(\frac{1}{f}\right)$ is called a period, i.e. the time required for the pressure variation to complete one cycle. The wavelength (λ)**,** is the distance that a sound pressure wave travels through a medium during one cycle and is measured in length units, usually in meters (Sataloff and Sataloff, 2006c). The sound speed or velocity (c) is the rate at which sound travels in the propagation medium. It is given by the following equation (2.1) (Harris, 1991b).

$$c = \lambda / T \tag{2.1}$$

where,

λ = wavelength

$T =$ time required for the pressure variation to complete one cycle or period

The sound travels through different media at different speeds, which is primarily determined by the density and the compressibility of the propagation medium (Olishifski, 1975; Behar et al., 2000). Sound travels much faster in solid than water or air. For example, the speed of sound is approximately 332 m/s in air, 1500 m/s in water and 5365 m/s in steel (Behar et al., 2000).

2.1.2 Types of Noise

The type of noise is determined by its temporal variations in sound pressure (or duration) and the way it is distributed. Suter (1991) classified the types of noise into continuous, varying, intermittent and impulsive as follows: “continuous sounds have little or no variation in time; varying sounds have different maximum levels over a period of time; intermittent sounds are interspersed with quiet periods; and impulsive sounds are characterized by relatively high sound levels and very short durations”.

The F&MNR classified the types of noise into continuous, intermittent and impulsive as follows: “continuous noise means noise which has negligibly small fluctuations of sound level within the period of observation; intermittent noise means a sound level which suddenly drops to the ambient level several times during the period of observation; and impulsive noise means a variation in sound level that involves a maximum at intervals of greater than one per second" (F&MNR, 1989).

Some typical examples of the noise types as classified by US Environmental Protection Agency (EPA) are given in the following Table 2.1 (Goldstein, 1978).

Table 2.1: Classifications of Ongoing Noise Exposure

Types of Exposure	**Typical Examples**
Steady	Weaving room noise; sound of a waterfall; shipboard noise; interior of a vehicle or aircraft noise; turbine noise; hum of electrical machinery
Fluctuating	Traffic noise; airport noise; many kinds of recreational noise; radio and TV
Intermittent	Many kinds of industrial noise (e.g., construction or maintenance work); many kinds of recreational noise (e.g., rock concerts, chain sawing); light traffic noise; occasional aircraft flyover noise; many kinds of domestic noise (e.g., use of electrical appliances in the home)
Impulsive	Gunshot; hammering; explosions; jackhammer
	Source: Goldstein (1978)

2.1.3 Sound Pressure Measurement and Their Descriptors

Various descriptors are used in sound pressure measurement. Some of these that are used for sound pressure measurement in this study are reviewed and described as follows.

2.1.3.1 Sound Pressure and Sound Pressure Level

Most of the sound-measuring instruments measure the magnitude of sound pressure wave as a root-means-square (RMS) amplitude. It means that the instantaneous sound pressure (which can be positive or negative) are squared, averaged and the squared root of the average is taken as the magnitude of sound pressure wave (Hansen, 2001). The measurement of RMS sound pressure, in Pa, is in a linear scale. Because the range between hearing threshold (20 μPa) and pain threshold (20 x 10^6 μPa) is very wide and the response of human ear to sound is logarithmically rather than linear, so the logarithmic ratio scale of sound pressure is usually used instead of sound pressure scale (Bruel & Kjaer, 2000). This scale of logarithmic ratio is called sound pressure level (or sound level), which is given by the following equation (2.2) (Harris, 1991b).

$$L_P = 10log_{10}\left(\frac{P}{P_o}\right)^2 = 20log_{10}\left(\frac{P}{P_o}\right)\ dB\ re\ P_o \qquad (2.2)$$

where,

L_P = sound pressure level or sound level
P = RMS sound pressure in Pa
P_o = reference RMS sound pressure, generally 20 μPa

Any doubling of sound pressure value is equivalent to a six (6) dB increase for sound pressure level and a multiplication of sound pressure by factor of 10 is equivalent to an increase of 20 dB in sound pressure level (Harris, 1991b).

2.1.3.2 Frequency-Weighting Networks

The human ear does not respond equally to all frequencies in the hearing range. So the amplitude of all parts of the frequency spectrum of the measured sound is weighted (or filtered) through the weighting networks (or filter) in a sound level meter (SLM) to provide an output of the measured sound signal which is similar to the characteristic of the human ear when responding to sound (Cunniff, 1977; Bruel & Kjaer, 1984; Davis, 2006). The output characteristic of the weighted signal has been internationally standardized as A, B, C and D weighting. The A-weighted network provides human response for low sound pressure levels, B-weighted for moderate sound pressure levels and C-weighted for high level of noise exposures, while D-weighted is a special characteristic for aircraft noise measurements. The A-weighting network is widely used because it correlates well with subjective test of human hearing (Bruel & Kjaer, 1984) and it represents more accurately the ear’s response to loud noise when measuring sounds to estimate the risk of hearing loss due to noise exposure (Sataloff and Sataloff, 2006c).

There are other alternative selections for frequency-weighting network, which is termed as flat, linear or un-weighted network. This weighting was originally used to measure the peak level of the sound pressure for impulsive or impact noise, but now the C-weighted is more preferred in many regulations or standards (Johnson et al., 2001). However, the un-weighted network is specified by F&MNR for measuring the peak sound pressure level of impulsive or impact noise (F&MNR, 1989).

2.1.3.3 Exponential-Time-Weighting

An exponential-time-weighting is referred to as the response speed of the detector in sound level meter (SLM) (Davis, 2006). There are three different response speeds (exponential-time-weighting) that has been standardized and in wide use, i.e. slow (S), fast (F) and impulse (I) response (Hassall, 1991; Johnson et al., 1991; Davis, 2006).

Slow response has a time constant of 1000 ms for signals that increase or decrease with increasing time and 125 ms for fast response. Slow time-weighting or response provides more damping on the SLM display than the fast response, which is useful when estimating the average level of a sound that fluctuates rapidly, especially when using conventional SLM.

Impulse response has time constant of 35 ms for rise and 1500 ms for decay. It is primarily used for assessing human loudness response to impulse noise, but now the peak response (peak time-weighting) is widely used instead for assessing the risk of hearing damage due to impulsive or impact noise (Hassall, 1991).

2.1.3.4 Maximum and Peak Sound Level

The maximum sound level (L_{max}) is the highest RMS value of the frequency and exponential-time weighted sound level and the peak sound level (L_{peak}) is the highest instantaneous value of sound level that is occurring at any time during the observation periods (Marsh and Richings, 1991; Lawman, 2008).

The measurement of L_{max} and L_{peak} are required by many regulations and standards for worker's protection due to a very high level of noise exposure. L_{max} is measured by a RMS detector and L_{peak} by peak detector (Davis, 2000).

L_{peak} is measured without frequency-weighting or exponential-time-weighting and should include all frequency components within the bandwidth of the measured sound (Marsh and Richings, 1991).

2.1.3.5 Equivalent-Continuous Sound Level

Equivalent-continuous sound level (L_{eq}) is one of the most fundamental concepts in sound measurement. It is defined as "the steady period of time, has the same total energy as the actual fluctuating noise" (Hansen, 2001). As the sound is time varying in nature, it is not easy to measure L_{eq} with conventional sound level meter (SLM). The preferred measuring instrument is an integrating-averaging SLM, as well as personal sound exposure meter. Such meters will automatically integrate the sound measured to give a final result of L_{eq}. For example, the Spark Dosimeter calculated the L_{eq} with the following equation (2.3) (Davis, 2000).

$$L_{eq} = 10Log_{10}\left(\frac{1}{T}\int_{T}^{T_2}\frac{P^2(t)}{P_o^2}dt\right) \tag{2.3}$$

where,

$P(t) =$ instantaneous, frequency weighted (A or C) sound pressure in Pascal

P_o = reference sound pressure, 20 µPa

T= measurement period (run time or history time interval), $T = T_2 - T_1$

However, the A-frequency-weighting is the most commonly used for a measurement of L_{eq}, which is specified as L_{Aeq}. In particular, the ISO 1999 specified A-weighted equivalent continuous sound level for estimating noise-induced hearing impairment as $L_{Aeq,T}$, which is given by the following equations (2.4) (ISO, 1990).

$$L_{Aeq,T} = 10Log_{10}\left(\frac{1}{T}\int_{T_1}^{T_2}\frac{P_A^2(t)}{P_o^2}dt\right)dB \qquad (2.4)$$

where,

P_A = A-weighted sound pressure, in pascals.

P_o = reference sound pressure, 20 µPa

T = measurement period, $T = T_2 - T_1$

As sound is a form of energy that can cause hearing loss, thus L_{eq} is a useful parameter to assess hearing loss due to noise exposure because it provides the measurement for both sound pressure level and duration of noise exposure in combination to determine the energy that the human ear receives (Bruel & Kjaer, 1984). It is also in accordance with the equal-energy hypothesis, which states that "the equal amounts of sound energy will produce equal amounts of hearing impairment, regardless of how the sound energy is distributed in time" (NIOSH, 1998).

$L_{Aeq,8h}$ is specifically termed as daily personal noise exposure of workers, $L_{EP,d}$ by Health and Safety Executive of UK (HSE, 2002), or noise exposure level normalized to a nominal 8-hour working day, $L_{EX,8h}$ (ISO, 1990) and is given by the following equations (2.5) (Lester and Malchaire, 2001).