ASSESSMENT OF NOISE EXPOSURE IN INDOOR FIREARM SHOOTING RANGE AT POLICE HEADQUARTERS

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RESEARCH REPORT SUBMITTED TO THE FACULTY OF ENGINEERING UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE IN MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

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DEDICATION

Special dedication to…

God for giving me inspiration and

Always accepting my prayer

My lovely wife, kids, mother, father,

Dear siblings, friends

And those who have helped and supported me

I could not have done this without any one of you

Thank you for your loving support of my dream …

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ABSTRACT

The indoor firearm shooting range is an enclosed area to conduct firearm shooting practice by armed force department. The firearm shooting practice will generate impulsive noise containing a series of energy pulses in short duration and high sound pressure level. In this respect, exposure to this noise will damage the hearing ability of the shooter and nearby humans. The aim of this research is to assess the noise level at the shooting and surrounding area, noise exposure level and evaluation of the existing earmuff. The research location is at Police Headquarters indoor firearm shooting range. The shooting range accommodates 6 shooters at a time and firing 30 to 50 rounds of bullets for a session by every shooter. The Sound Level Meter used to assess the noise level and Noise Dosimeter used to assess the noise exposure level. Additionally, existing earmuff evaluated was based on Noise Reduction Rating (NRR) which used in the shooting area. The research results show that the noise level exit the permissible exposure limit (PEL) of 90dBA. The noise exposure level measured on the shooter is 110dBA and instructor is 127.6dBA which is exited the regulated level. The hearing protector used in the shooting range found insufficient NRR to protect the hearing of the user. The firearm shooting practice is exposed the people around to a high level of noise without proper noise protection and this will contribute to the hearing impairment to the user in the future.

Keywords: Noise exposure, shooting range noise level, indoor shooting range, noise reduction rating,

ABSTRAK

Lapang sasar adalah tempat untuk melaksanakan latihan menembak secara selamat oleh badan penguat kuasa undang-undang. Latihan menembak menggunakan senjata api menghasilkan tekanan bunyi yang tinggi dan denyutan hingar dalam jangka masa yang singkat. Bunyi tersebut mempunyai kadar bahaya sehingga merosakkan keupayaan pendengaran para penembak dan orang disekelingnya. Sehubungan itu, kajian ini adalah untuk menilai tahap tekanan bunyi di ruang menembah dan kawasan sekitarnya serta mengukur tahap pendedahan bunyi oleh pengguna lapang sasar dan menilai alat pengedap bunyi sedia ada. Lokasi kajian adalah di lapang sasar tertutup Ibu Pejabat Polis. Lapang sasar tersebut boleh di gunakan oleh 6 penembak secara serentak dimana setiap penembak akan menembak 20 hingga 50 peluru dalam satu sesi menembak. Peralatan mengukur tekanan bunyi dan tahap pendedahan bunyi digunakan untuk kajian ini. Selain itu, peralatan pengedap bunyi telah dinilai berdasarkan spesifikasi peralatan tersebut dengan mengambil kira nilai penapisan bunyi. Hasil kajian mendapati tahap bunyi di kawasan menembak telah melebehi had bunyi yang dibenarkan iaitu 90dBA. Tahap pendedahan bunyi pada penembak adalah 110dBA dan jurulatih adalah 127.6dBA dimana ia melebihi tahap yang ditetapkan oleh pihak yang berkuasa. Selain itu, peralatan pengedap bunyi yang digunakan mendapati kurang sesuai dengan tahap bunyi yang dihasilkan. Latihan menembak mengunakan senjata api menyebabkan para penembak dan orang disekelilingya terdedah kapada tahap bunyi yang tinggi. Tanpa peralatan pelindung yang tepat dan sesuai pengguna lapang sasar berisiko tinggi untuk menghadapi masalah pendengaran di masa hadapan.

Kata kunci: Pendedahan bunyi, tahap tekanan bunyi, lapang sasar tertutup, peralatan pengedap bunyi.

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LIST OF ABBREVIATIONS

NIHL	-	Noise-Induced Hearing Loss
SPL	-	Sound Pressure Level
PPL	-	Personal Protection Equipment
RMP	-	Royal Malaysian Police
DOSH	-	Department of Occupational Safety and Health
ILEA	-	Indiana Law Enforcement Agency
RBPF	-	Royal Brunei Police Force
STC	-	Sound Transmission Coefficient
CCTV	-	Closed-Circuit Television
VIP	-	Very Important Person
HPD	-	Hearing Protection Device
NRR	-	Noise Reduction Rating
ANSI	-	American National Standards
OSHA	-	Occupational Safety & Health Administration
SWAT	-	Special Weapons Assault Team
NIOSH	-	National Institute of Occupational Safety and Health
ISO	-	International Standard Organization
IGP	-	Inspector General of Police
LCD	-	Liquid- Crystal Display
PEL	-	Permissible Exposure Limit

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Everyday human experience any kind of sound in their daily living environment. The examples of sounds are the human conversation, television, radio, telephone, handphone, household appliance, music instrument, and many more. These sounds normally will be heard at safe levels so it does not affect human hearing or mostly controllable with variables low to high. However, if the normal sounds become very louder and harmful to hearing then it considers noise. The long duration and high frequency of noise exposure can damage inner ear sensitive structures called hair cells which cause noise-induced hearing loss (NIHL). These hair cells are small sensory part that converts sound energy into electrical signals that travel to the brain to translate as a sound. In this context, the damage on hearing ability is cannot be recovered naturally (U.S department 2008).

High-frequency noise is a widespread occupational hazard in many countries with the adverse effect such as high blood pressure, reduced work performance, sleeping difficulties, annoyance and stress, tinnitus, temporary threshold shift, and NIHL. The NIHL will be the most serious effects because it is irreversible damage to hearing mechanisms of the inner ear and involves low-frequency ranges which produce by the human voice

(Nelson, Nelson, & Concha-Barrientos, 2005). This will make a person suffering from hearing the normal human conversation. Most common reason for hearing impairment to occur is because of a single exposure to an intense or impulse sound, such as an explosion and firearm shooting noise. Besides that, hearing impairment also occur due to exposure to loud noise for an extended period of time such as noise generated by machinery and equipment.

The sources of noise that can cause hearing loss to humans are jet-engine, firecrackers, and firearms whereby the noise levels are varied from, 120dB to 150dB (U.S department 2008). A recent data from US Army Special Forces Study on acute noise exposure shows 11% of 72 people who went through live-fire weapons training exercises for three days are sustained NIHL. Similarly, the US Marines are exposed to live-fire exercises for 3-5 days also indicated that 11% of the group had NIHL (Lynch & Kil, 2005). Additionally, the study also shows that the exposure to sound pressure level (SPL) of 140dB for more than 1 minute is possible to cause NIHL to humans. A comprehensive study on firearm noise exposure in the Finnish Forces showed that the cause of acoustic trauma on 65 out of 113 patients (57.5%) is resulting from exposure to a single gunshot (Kardous, Wilson, & Murphy 2005). In this respect, the firearm shooting noise is hazardous to human which can cause NIHL to human.

Generally, in Malaysia firearms are carried and used by security forces such as Military, Police, Immigration, Customs and the limited public with a special license. These people are required to undergo for the high frequent number of shooting training for mastering weapon handling and shooting. The training will be conducted at firearm shooting range and assisted by range instructors. The shooting range can categorize into

two types which are Indoor and Outdoor. The indoor firearm shooting range is an enclosed area to conduct handgun (revolver and semi-automatic pistol) shooting practice by armed force department. The firearm shooting practice will generate impulsive noise containing a series of energy pulses in short duration and high sound pressure level from the expulsion of the air, the bullet, and gasses from the barrel (Bronuzzi, Monai, & Patruccco, 2012).

Exposure to impulsive noise from a firearm can cause acoustic trauma which is a sensorineural hearing loss and develop to permanent hearing impairment over continues exposure (Ristovska, Jachova, & Atanasova, 2015). The aim of this study is to assess the noise level at an indoor shooting range and educate the importance of personal protective device (PPE) during the shooting session. The target group who exposed to firearm noise is the shooter, shooting range instructors and audience. The firearm shooting range instructors are frequently exposed to firing noise. The study will asses noise level at the shooting area, waiting area and noise exposure level to shooter and instructor.

1.2 Problem Statement

The main reason to conduct this research is that there are very few numbers of research studies and information pertaining to firearm noise and shooting range based in Malaysia which Royal Malaysian Polis (RMP) is one of the authorized body to use it. Most of the available information's are not from Malaysia. They are mostly from America and Europe countries.

The main responsibility of RMP is to combat crimes which need to carry and use a firearm during their job routine. Moreover, they also need continuous training on handling and shooting practice which conducted in the firearm shooting range. The continuous shooting practices resulting in expose the officer to firearm shooting noise. Therefore, this research could give information and knowledge to prevent noise exposure.

Besides that, the past 3 years report on Occupational Disease and Poisoning Investigation shows that Occupational Noise-Related Hearing Disorder tops the list. According to Department of Occupational Safety and Health (DOSH), the number of cases investigated involving hearing disorder in the year 2015 is 3377 cases, in the year 2016 is 2876 cases and in the year 2017 is 2478 cases. This statistic shows that the hearing disorder problem in Malaysia is in serious condition. Based on the investigation by DOSH, the statistic of occupational poisoning and disease by sector shows that Government Department has 15 cases on hearing disorder whereby RMP is one of the contributors (Ahmad, 2016).

This is the reason to conduct this research which is aimed to assess the hazard and identify suitable protective measure for the staffs involved in firearm shooting activity.

1.3 Rational of Study

The RMP is the leading law enforcement agency in Malaysia with responsibilities to maintain law and order, preservation of the peace and security of Malaysia, prevention and detection of crime, apprehension, and prosecution of offenders and, the collection of security intelligence (Ho, Syed, & Datu, 2013). The Police force and firearm are two elements which cannot be separated during conducting public security job. The police officer needs high skill to handle and use the firearm whenever to be deployed. For that reason, the police officers need to undergo the shooting training to improve their skills. This helps them to shoot on target without missing. The on target shooting skill can be achieved by conducting the frequent number of shooting training. Indirectly this will expose the officer to high frequent number shooting noise exposure including the range instructor who arranges and conducts the training.

The hazard from shooting training hard to avoid, but it can be controled by applying hazard control measures such as elimination, substitution, engineering control, management and personal protective equipment (PPE). To apply the hazard control measure, they need to know the quantity of the hazard. To identify the hazard, noise measurement and dose level need to be conducted.

1.4 Objective of Study

The research study is aimed to further understand and investigate on noise level at Indoor firearm shooting range and its effect on hearing during shotgun firing session. The indoor shooting range is divided into two parts which is shooting area and waiting area. The objectives of this research study are as follows:-

1. Assessment on noise level at shooting area and waiting area by using sound level meter. The assessment includes primary effect and secondary effect around the shooting range.

2. Assessment on noise exposure level to shooter and instructor during firing session by using Dosimeter.

3. To evaluate the effectiveness of existing preventive measure which is personnel protecting device.

1.5 Scope and Limitation

The scope of the study is within the Bukit Aman Indoor firearm shooting range which focuses on noise produced by the firearm and the effect to the human hearing. The study initiated by gathering information from the shooting range staffs pertaining to their duty routine and practices. Based on the information the study is designed to project the noise level exposed by the shooting range users. The noise assessment guideline and noise

level regulations are referred to the Department of Occupational Safety and Health Malaysia.

The study is limited to one type of firearm which is Glock-22 even though they use many types of firearm. This firearm is widely used by RMP in their daily duty routine. The study boundary is within the noise level measurement and exposure level measurement by using specific tools. The acoustic material used in shooting range and sound analysis is not covered due to lack of instrument and time frame.

1.6 Organization of The Report

This research report consists of five chapters which cover the assessment of noise exposures in indoor firearm shooting range at police headquarter. The overview of the report contents are as follows:-

1. Chapter one covers the introduction and problem statement of the study. It also explains the needs of the noise assessment at shooting range. This chapter also included discussion on the rational, objective, scope and limitation of the study.
2. Chapter two is the literature review which covers the scholarly citation, research and review work related to this study. The chapter also included information which explaining more about the specific area of the study.
3. Chapter three of the study includes the methods of conducting the research study especially on data collection and instrument use.

4. Chapter four is Result and Discussion which interpret the outcome of the result. Noise level and personal exposure level related regulations are widely discussed.

5. Chapter five is the conclusion and recommendation of the study which based on available research information and result from the study. Recommendations on control measure to reduce noise exposure are included.

CHAPTER 2

LITRATURE REVIEW

This chapter will discover the narrative view of current knowledge which involving substantive conclusion, theoretical and methodological contribution to the noise assessment at indoor firearm shooting range. It gathered information from published thesis, dissertation and journal articles as well as books and other recommended resources. Since the research is related to noise and shooting range, the basic information on both topics are discussed in detail. Additionally, the safety and health of the shooting range also studied.

2.1 Firearm Training

Firearm training is required by people who are using and handling firearm in their daily life such as police, military, Navy, Hunter and licensed gun user. This firearm training is to enhance their skills, knowledge and performance and also to maintain the firearm to be in good condition. The major part of the training is handling and shooting with firearm which must conduct in a specific place with safety and health requirement. Conducting the firearm shooting is required shooting range. Shooting range is a secure place to conduct firing activity with supervision by professionals without injuring any people. Firearm training is very important for security and law enforcement officers.

Law enforcement officers must possess a number of unique characteristics and skills that are not common in most professions such as the ability to react under pressure and high levels of physical fitness. Firearm discharge is a critical element to a security personal such as police, customs, Military and Marine officer's career because they are the one that could potentially save people's lives from criminals and terrorist (Donald, Michelle & Gregory 2012). Therefore, firearm training is an important part of the Indiana Law Enforcement Agency (ILEA) training program and includes two weeks of handgun and shotgun instruction. ILEA recruits practice and qualify their shooting skills in various positions including standing, half-kneeling and prone. General firearm instructions at the ILEA include loading and unloading firearms, clearing misfires, site line-up and pressure on trigger. After firearm qualifications are completed, tactical scenarios are then enacted that provide the recruits with a more realistic sensation of firearm use (Donald, et al., 2012). This session needs countless number of shooting using different type of firearm during entire training.

Apart from security personal, recreational shooter, hunter and sports shooter also need shooting practice to improve their skills such as aiming, marksman shoot, static target shooting and moving target shooting, and also maintain their own fire arm performance (Stewart, et al., 2002). Americans own as many as one third of the world's guns, and over 8 million Americans have license to carry guns concealed and millions of South Africa and India residents also have gun license (Carlson 2014). Resent research shows that in America more than 29 million people enjoy take part in target practice, hunting and other shooting sports activities. The study also reveals that U.S. citizens own about 310 million firearms and significant increase in numbers of female and young firearm-users in recent years (Stewart, 2018). Different study at Ashland, USA reveals that, shooting range

operators reported that shooting practices at their range is increased in year 2011. The study interviewed 500 shooting range operators which 42.4 percent revealed the shooting volume sharp increase while 20 percent revealed significant increase and only 10.3 percent said decline in shooting practice (Snow, 2012). This shows the quantity of people who own firearm and the demand for shooting practice to enhance their skills and usage. This will contribute in increase on number of people to expose high level of noise which induce to NIHL.

2.2 Firearm Category

There are two categories of firearms which is handgun and long gun. The handgun has two types which are Semi-automatic and Revolver. Similarly for long gun which are Rifle and Shotgun. The Semi-automatic also called as handgun which loads in advance the next available cartridge to firing position by using bullet discharge energy. Another category of handgun is Revolver with multiple cartridge chambers in revolving cylinder. The Rifle and Shotgun were designed to shoot by placing them on shoulder position with different discharge materials. Rifle is discharge bullets as well as Shotgun is slug or Shotgun shell (O'Neill, O'Neill, & Lewinski, 2016). The handgun can be used in one hand and the long gun needs to use both hands for firing.

2.3 Firearm Noise Effect To Hearing

Firearm shooting will produce impact noises because of quick gas expansion. The moment firearm trigger pulled, the firing hammer pin will hit the back end of the bullet which powered by a tremendous amount of pressure at its back to propels it to forward. The sudden release of explosion pressure which result from bullet discharge produce the high noise level. The noise level can be 140 dB SPL (sound pressure level) in frequencies around 2 and 3 kHz. This type of noise is harmful for human hearing because there is a risk for acoustic trauma if human exposed to 120 dB SPL (Guida, Diniz, & Kinoshita, 2011). Acoustic trauma consists of middle/inner ear injury and its signs and symptoms are sudden hearing loss, tinnitus, fullness of the ear, possible rupture of the tympanic membrane, and possible partial or complete destruction of the ossicular chain (Heupa, Gonçalves, & Coifman, 2011). Normally thresholds from 3 to 6 KHz will harm result from impact noise exposure. The continuous exposure to impact noise may harm other frequencies. Every frequency has capability to detect different type of sound level (Heupa, et al., 2011).

The 4 KHz frequency is one of the critical frequencies because it will affect normal human conversation sound level to be heard. One of the occupations which expose its employee to high noise levels is the military, especially when practicing with firearms and its explosion noises, which are among the number one causes of NIHL in the United States (Guida, et al., 2011) (Heupa, et al., 2011). Usually, firearm shooting will produce impulse noise from 140 dB to 160dB SPL depending to type of bullet caliber and the amount of gun powder used. This exposure no limited to shooter, but it extended to range instructors because there is reported incidence of temporary and permanent hearing loss among range instructors during routine testing and qualification (Murphy, & Tubbs 2007). Many

researches show results which shooting range users, instructors and other people who are near the shooting range will be affected by the high intensity firing noise. The auditory effect of exposure to firearm noise has been investigated in several international studies in many countries such as Southern Brazil Military, Israel Military, Greek Military, Brazilian Navy, Police force from Paraná and Bauru districts in Brazil and Singapore Armed Force which found that most of the personnel who involve in the studies effected by noise produced by firearm and suffering from NIHL (Guida, et al., 2011) (Heupa, et al., 2011).

2.4 Factors Exposure To Firearm Noise

There are few factors which cause noise from firearm expose to human during at shooting range. Normally the exposure will affect the firearm shooter himself, shooting coach or trainer, shooting range staff, shooter's family member and visitor or viewer. Exposure to residents who stay nearby to shooting range not widely stated in any research. The factors exposure to firearm noise is briefly discussed below.

2.4.1 High Frequent Number of Exposure

Practice make perfect, define repeatedly doing something will build one become very skillful. This is implemented by enforcement agencies to polish their officers to become highly skillful. Among the factor involves in noise exposure to human at shooting range is the high frequent number of exposure. Police officer and Military personnel will conduct high number of shooting training and firing to become more perfect and proficient. A study conducted by researcher on Royal Brunei Police Force (RBPF) which found a

number of NIHL among the officers who are required to undergo shooting practice at least annually or when needed. A total of 543 RBPF personnel were identified and tested for the period of 12 month (JAN 2012-DIS 2012) which 365 were exposed to shooting range noise and suffered for NIHL. Overall 64.4% of the study population used hearing protective devices (ear muffs) during shooting practice but they participate in shooting activity every 3 month or more frequent (Win, et al., 2015). Another study by online among Swedish hunters association between shooting history and presence of NIHL, whereby during hunting the shooter fired more than 6 shots without hearing protection device in the preceding 5 years suffered from NIHL (Honeth, et al., 2015). The study also concluded that a normal human may suffer inner-ear damage from just one or a few firings.

2.4.2 Firearm Impulse Noise

Impulse noise is high pressure noise level which produces in millisecond during firearm firing. Almost all firearms generate peak impulse noise levels that exceed the 140dB SPL which more than exposure limits mandated by the Occupational Safety and Health Administration. Big-bore firearms can generate noise levels of more than 165 dB, and guns with short barrels (handguns) and firearms fitted with muzzle breaks can elevate peak SPLs even further (Stewart, 2018). Impact noises are usually produced by quick gas expansion, such as that produced by firearms explosions. These types of sound can reach intensities of more than 140 dB SPL in frequencies around 2 and 3 kHz and, for this reason they are harmful for human hearing (Guida, Diniz, & Kinoshita, 2011). The firearm noise exposure characteristics are overall energy enclosed in the impulse, frequency spectrum, and duration of pressure wave and pressure envelope. Pressure wave duration is time interval between the initial pressure rise of the impulse and the moment the pressure passes

through ambient and pressure envelope duration is the time interval during which the envelope of the signal resides within 20 dB of the peak pressure (Flamme, et al., 2011).

2.4.3 Bystander/ People Closer to Shooter

Sometime firearm shooters will bring along their family members and friends to shooting range. These people are exposed to firearm noise because they don't have any protection even though they stay outside of see through glass wall. Bystander or people stand closer to a firearm shooter is one factor to expose firing noise at shooting range which can damage their hearing ability (Flamme, et al., 2011). Normally the shooting range can accommodate more than 5 shooters at one session shooting with multiple numbers of firing. Research conducted at South Korea Military firearm shooting range among 189 soldiers found that, distance among shooter during firearm shooting session is one of the factors of exposure to firearm noise and induced NIHL. Thus, the level of noise exposure experienced by each soldier was influenced by the gunshot noise of adjacent shooters who next to them. Based on the result of the study, acoustic trauma induced by gunshot noise during mass rifle shooting in the shooting range has different characteristics from solo rifle shooting compared to group rifle shooting (Moon, et al., 2013). The firearm shooting instructor or trainer and staff, who are working at shooting range, are potential to risk of acoustic trauma by indirectly exposed to firearm noise.

2.4.4 Type of Firearm

The type of firearm is also one of the factors expose to firearm noise because the two categories of firearm producing different noise level. Handgun (pistol) firearms are made of short barrel whereby the noise traveling distance to ears is short. The long guns (rifle) made of long barrel and have long distance for firing noise to travel to ears and the shooting position made the distance for each ear is difference. Individuals who use pistols for many years tend to developed hearing loss nearly equally in both ears compared to rifle shooters who are develop hearing loss on a single ear at beginning stage. For right handed shooter develop hearing loss on left ear and vice versa for left hand shooter. (Sataloff, Hawkshaw, & Sataloff, 2010). The study also identified that, individuals who use firearm make by Magnums were sustained a greater hearing loss compared to other manufacturer. Bronuzzi, Monai, & Patruccco, (2012) discover that long barrel firearm's bullet velocity is higher capered to short barrel firearm. Bullet velocity is one of the characteristics to produce high noise level during firearm shooting.

2.4.5 Type of Hearing Protector

The hazard management hierarchies always prefer elimination as a first choice to create 'protected exposure' situation. However, for firearm shooting range the only practical solution is hearing protectors. The right choice and specification of hearing protector is important to attenuate the firing noise and protect the hearing. Types of hearing protector are also one of the factors to noise exposure at firearm shooting range. Normally firearm shooter less interest to use hearing protector because it attenuates the shooting noise, but it also prevents communication and limits user awareness of their immediate

surroundings (Williams, 2011). By using Electronic, Sound Restoration Level-dependent hearing protector which able to communicate both face-to-face and use an electronic communication link meant that hearing protectors could essentially remain in place over the whole duration while on the firing range, thus increasing the wear time and reducing the change on noise injury from unexpected weapon discharges (Williams, 2011). Effective treatments for NIHL, particularly acoustic trauma, are not available. However, it is a disease that can be prevented by wearing hearing protector.

2.5 Shooting Range

Shooting range is specially designed place for firearms safely discharge bullets which occurring in regular and structured basis for target practicing (Minister of Justice Canada 2018). Shooting range is a place for military and enforcement agency to conduct shooting practice by using firearms to shoot a target made from plastic or paper whereby the safety rules and regulation considered very seriously for avoiding firearm accident and injuries (Aryuanto, & Eko, 2011). Shooting range is also a place for exercise accuracy and reflex by enforcement agencies or ballistic sport where by, usually use targets which placed various distance from the shooter (Peb, 2012). The target will be based on various scenarios and type of practice which it may stand still, appear or moving. Normally shooting range comprises 3 main sections which are shooting area, target area and bullet trap area. Shooting area is the place where shooters and shooting range instructors will be placed. There will be shooting booth for shooters to conduct shooting session and change bullet magazine. Target area is the place where targets are positioned according to the distance which shooter intended to practice. Shooting area and target area are divided into lanes to

accommodate many shooters to shoots at a time. The shooting booth and target will be in parallel, so that each shooter has one target to shoot in parallel direction. The number of lane is based on the overall size of the shooting range. The bigger shooting range have bigger number of lanes which possible to accommodate large number of shooters. The bullet trap area is the place where all the bullets shoot by shooter will absorb and capture from escaping out of the range. In a shooting range the target area and bullet trap area is the critical and restricted place where no one is allowed to be there during shooting session. The shooting range and the facilities are supervised by shooting range officer and instructor. They are well trained to handle and manage firearms and shooting session. There are two types of shooting range which is indoor shooting range and outdoor shooting range.

2.5.1 Indoor Shooting Range

Indoor shooting ranges are built as standalone structure with considering the walls, floor and ceiling materials cannot be penetrated by the bullets out of range (U.S Department of Energy 2012). The interior material design also cannot harm the range user because of rebounds of firing bullets. It can be an independent small building like house or a part of larger buildings which mostly at basement. The shooter needs, type of shooting activity, number of targets and number of users are important criteria should consider in a range building. Special and specific consideration needs for ventilation, lighting, safety baffles; acoustic isolation and backstop design because it involves humans' safety and health. Most of the indoor shooting ranges are used for handgun shooting practice which is a short-barreled and small caliber range firearm designed to be shooting with one hand.

2.5.2 Outdoor Shooting Range

Outdoor shooting range is constructed in remote areas which don't have any other activities and sufficient distance with land area available for surface danger zones suitable for all types of firearm (U.S Department of Energy 2012). Outdoor shooting range are based on firearm with maximum caliber, capable of backstop construction, land size for downrange safety area and does not have shelter for target system (Royal Canadian Mounted Police 1999). It capable for long distance shooting with rifles which portable long barrel firearm, up to 1000 meter shooting where considering by the wind and weather situation. The downrange area is the place where firing bullets pass-through beyond the backstop which results from high angle shots and ricochet from backstop and other surface. This area should be clear and safe during firing session to avoid injuries.

2.5.3 Police Headquarters Indoor Shooting Range

The Bukit Aman Indoor Firearm Shooting Range is located at the basement of Tower 2 Royal Malaysian Police (RMP) Headquarters, Jalan Bukit Aman, Tasik Perdana, Kuala Lumpur. It is located in underground whereby one ground lower than the ground floor of the tower. The size of the shooting range is (L 30 X W 10 X H 5) meter with various distance targets shooting options. The available options are begun from 5 until 25 meter of targets shooting. The shooting range renovated in 2010 with most advanced technology in the shooting range design (Figure 2.1 & 2.2). The renovation included high efficiency and non-flammable noise absorption materials applied to the walls, doors, and ceiling. The design of the shooting range was included noise abatement material to minimize the effect of peak sound pressure level (SPL). As a result, all reflecting walls

have been covered with perforated aluminums with opening equivalent to 10 to 15 percent of the area to sound absorption. Additionally, the walls also installed with isolated board and acoustic infill to achieve sound transmission coefficient (STC) 50. Similarly, the doors and windows used also acoustic treatment materials. The double door system comprise of STC 30 acoustic timber doors, fabric finishes acoustic lining and perimeter seal. Furthermore the windows are double glass with vacuum layer and anti-shattering material.

Figure 2.1: Range Firing Area

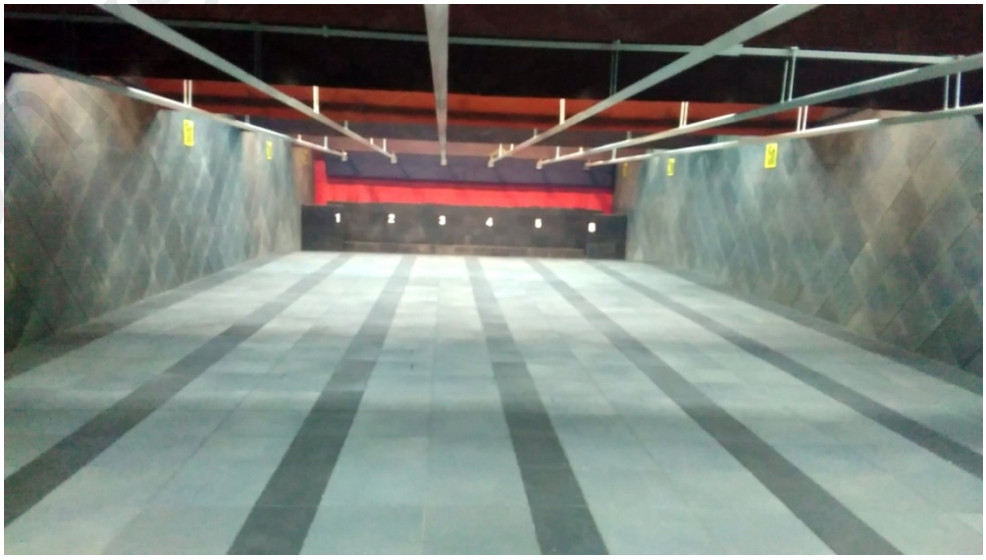

Figure 2.2: Range Bullet Trap

As same as other indoor shooting range, this range also comprises three main sections which are shooting area, target area and bullet traps. Shooting area is equipped with six see through shooting booths to provide designated area for firing and avoid hazards from firing. Similar to shooting area, target area also equipped with six target lane with automated target rail to move according to shooting distance. Other than that, the ranges also equipped with computerize scoring system and CCTV which stored in an enclosed room called Control Room. Furthermore, the underground shooting range is surrounded by soil in the left and back side, ventilation system in the right side and the entrance shared with control room, monitoring area, waiting room and workshop (Figure 2.3).

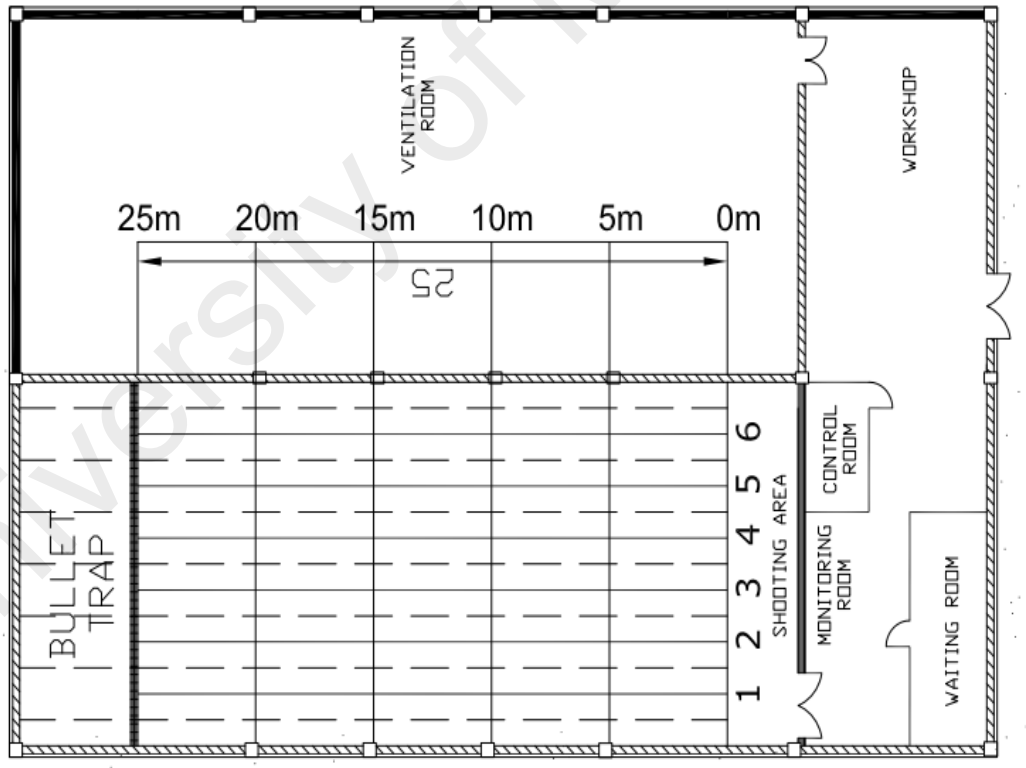

Figure 2.3: Shooting Range Layout

The function of the shooting range is to conduct firearm shooting training for high rank police officers and VIPs and also annual shooting exercise which require RMP regulation. In general, the objective of the shooting practice is to maintain the shooting skills and confidence of the firearm user. Besides that, shooting range also used to test new and repaired firearms by range operators and educate firearm user the latest rules and regulation pertaining to usage and safety of firearm.

2.6 Nature of Sound

Sound is a form of energy like light, heat, electricity and magnetic. Sound allow human to enjoy music and spoken communication with family and friends. Subjectively, sound is described as any disturbance of air, ground and water that produce a sensation of hearing to human. Physically sound is described as “mechanical vibration or disturbance of a gaseous, liquid or solid elastic medium, through which energy is transferred away from the source by progressive sound wave with a speed characteristic of the medium carrying it”. The energy of sound wave is a mixture of an ordinary mechanical kinetic energy of the vibration motion of the medium and potential energy of the medium strained by compression. The sound wave propagates through the passing over the motion from particle to particle. Normally, particles will hit its nearest particle during it displaced from equilibrium position. This will cause the nearest particle to move similar some distance while rebound on his own and this vibration process will continue to other particles. This is the way that energy is transferred in a medium. The duration of the particle vibration is called as time period and the number of vibration in a second is frequency. Wavelength is the wave traveling distance during one time period and velocity is time for the motion to be

transferred the particles. For the sound to hear by human the frequency of vibration should be within 20 to 20,000Hz (Signal, 2005).

The sound measurement parameter normally used is the sound pressure level which in either per square centimeter (bar) or per square meter (Pascals). The average measure of "threshold of hearing" for human is 1000Hz. The quiet sound pressure level is not really zero but it is a very small level of physical pressure amounted 20μ Pascals. This small amount pressure change is sufficient to the human ear membrane redirect at a distance similar to single atom diameter. The human ear able to tolerate 100 Pascals of sound pressure level which discomfort considered and above this level the pain will be felt. The direct application of linear scales on sound pressure measurement will result huge and bulky numbers. Therefore, the unit 'Bel' used which a logical procedure have little relationship with human responses and representing a logarithmic ratio of base ten. Later, a small scale "decibel" (one tenth of a Bel) (dB) was chosen as sound measurement scale. Human ear roughly response in logarithmic manner to the changes in stimulus intensity which easy to interprets using dB (Signal, 2005).

2.7 Noise

Noise defined as acoustic sound waves which disperse with lake of order or control which the amplitude and phase ratio give uncomfortable feeling to hear (Guida, Diniz, & Kinoshita, 2011). However, most of the people think that very lauder sound is noise. But in real situation, noise is a complex sound with minimum periodicity or some situation no periodic at all (Figure 2.4). Noise also formed by non-harmonic motion and is without any

satisfying music quality. Psychologically stated that noise can be intermittent, multi-frequency and impulsive in nature. However, noise is a sound which dislike by the person who hear and may seriously affect the health and well being of human (Signal 2005). The noise which give uncomfortable feeling to human constitute of all intensities, spectral characteristic, intermittence and exposure time, whether impulse or regular. In analyzing noise signal, phase orientation which composed of many frequency component combined in random phase, is importance in considering reflecting or absorbing surface, standing waves and vibration of structure. Noise which is present almost everywhere has become a part of human daily life who living in mechanical age and noise also become by-product of modernization and technology.

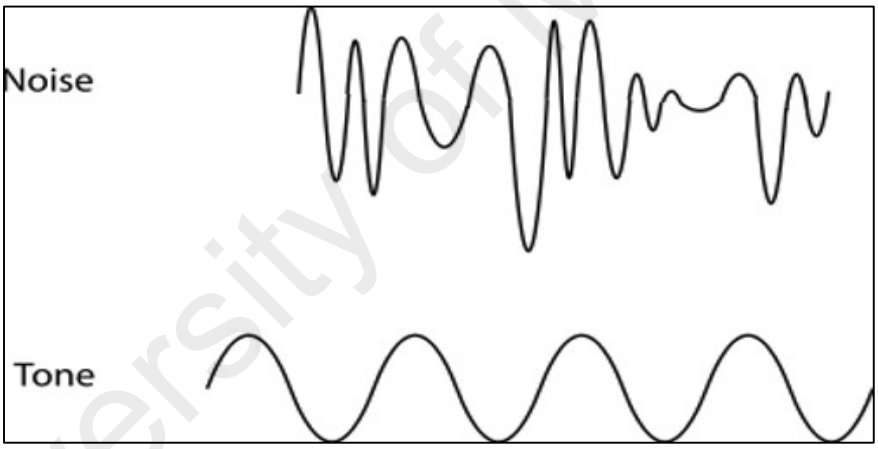

Figure 2.4: Noise and Tone Waveform

2.8 Safety Measure To Prevent Noise Exposure

Noise exposure can be controlled through elimination, isolation (distance and physical barriers), engineering control, insulation and proper equipment maintenance. Other methods including the use of hearing protection devices such as foam ear plugs, molded insets and sound attenuating ear muffs are widely used to prevent hearing loss (Yong, & Wang, 2015). Elimination and isolation noise is the top element in the noise treatment hierarchy. Sometimes, replacing mufflers, keeping equipment in clean and good maintenance, or placing the machine inside an enclosure can shield a person from the risks of NIHL (Fligor, 2011). Wear hearing protection devices (HPDs) such as earplugs or earmuffs, when involved in shooting activities especially at shooting range is a preventive measure. When properly selected and used, HPDs can be powerful tools for preventing NIHL. HPDs manufacturer are required by law to be labeled with a Noise Reduction Rating (NRR) that is based on performance obtained under ideal laboratory conditions. NRR is a unit of measurement used to determine the effectiveness of hearing protection devices to decrease sound exposure within a given working environment.

Classified by their potential to reduce noise in decibels (dB), a term used to categorize the power or density of sound, hearing protectors must be tested and approved by the American National Standards (ANSI) in accordance with the Occupational Safety & Health Administration (OSHA). The higher the NRR number associated with a hearing protector, the greater the potential for noise reduction. It must be emphasized that the best hearing protector is not the one with the highest NRR, but the one that people will consistently wear whenever exposed to loud noise (Fligor, 2011). Early detection of hearing loss through periodic audiometric tests may assist in prevention of further loss, and

recognition of existing loss is important for educational and medico-legal purposes. The Occupational Safety and Health Administration (OSHA) recognized that an annual audio metric test is essential for an effective hearing conservation program. This OSHA required occupational hearing conservation program must incorporate five factors which is (1) periodic noise exposure monitoring, (2) engineering and administrative controls, (3) personal hearing protection, (4) audio metric evaluations and follow-up activities, and (5) employee or management education and training (Hong, et al., 2013). Based on the study conducted at U.S SWAT (Special Weapons Assault Team) shooting range, the measured peak noise levels ranged from 156 to 171 dB which out of range 140dB NIOSH recommended exposure level for officers firing weapons (Murphy, & Tubbs, 2007). The study also explored that measurements of the protection afforded by the HPDs on the mannequin were consistently in the 30-dB range. Those peak reduction results, along with the peak noise levels measured for the weapons, indicate that the officers should consider using dual hearing protection during weapons training exercises (Guidaa, et al., 2013). To overcome the inability to communicate when double protected, the officers should be provided with electronic level-limiting earmuffs and a choice of earplugs. The earplugs can provide an additional 15–20 dB of peak reduction, while the electronic earmuffs can compensate for the reduced speech intelligibility due to double protection. If the protected peak levels are in the 120–130dB range, then the NIOSH formula suggests that 100 to 1000 shots per day would be allowed. This estimate is conservative and officers will not be exposed to an excessive risk of hearing loss if they use double protection. Several hearing protector manufacturers sell combined hearing protector and communication systems that could be adapted for use during weapons training.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter explains the research methods that were used on data and information gathering which begins with research methodology flow chart, description of study design and study area. The data gathering procedure for noise level at shooting area, monitoring area, waiting room, control room, and noise exposure level are reviewed in detail. The mathematical evaluation by considering noise attenuations for existing PPE also included. The description and explanation of each method used in this research are detailed in this chapter. The measurements involved in this study such as noise level measurement and personal noise exposure level were followed the standard and guidelines from two bodies as below:-

a) National Institute of Occupational Safety and Health (NIOSH) Malaysia

b) International National Standard of Acoustic Determination of Occupational Noise Exposure Engineering Method (ISO 9612)

3.1 Research Methodology Flow Chart

The research methodology flow is shown in figure 3.1 which starts from research proposal until report submission.

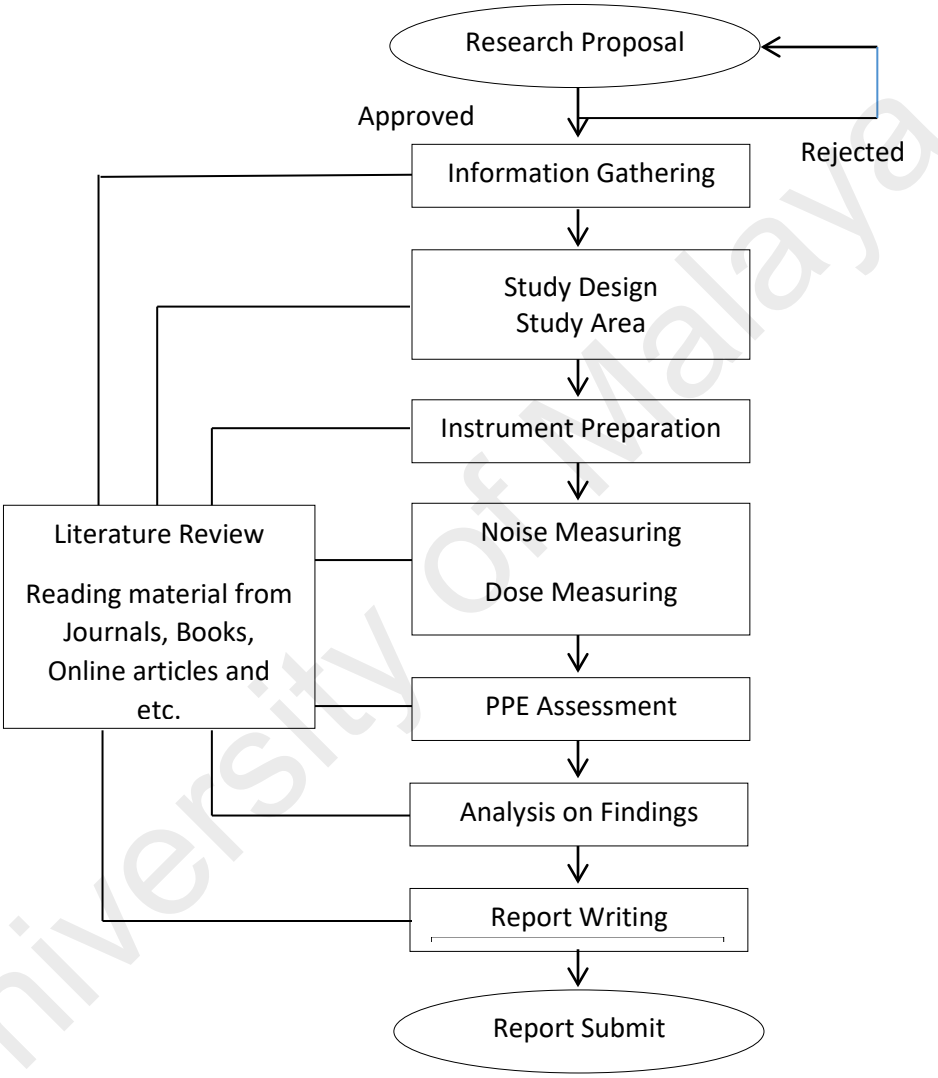

Figure 3.1: Research Methodology Flow Chart

3.2 Study Design

This research study focuses on the assessment of noise exposure in the selected police shooting range based on the area and personal noise exposure and mathematical evaluation of existing PPE. The study is divided into three main sections. The sections are surrounding shooting area noise level, shooting area noise level and also existing PPE evaluation. The surrounding shooting area noise level data recorded at the designated sampling location which is monitoring area, waiting room, control room and workshop. The designated sampling location is the place where people will stay around during shooting activities while waiting for their turn. The collected noise level data used to assess the primary effect and secondary effect on the surrounding area of the shooting range.

The shooting area noise level is based on personal noise exposure which data recorded using dosimeter on the body of the shooter and instructor while conducting the shooting operation. The data obtained are used to assess the overall shooting area noise level and personal noise exposure level. Pertaining to the PPE evaluation, the earmuff model used by shooter and instructor identified and gather the technical specification. The evaluation is focused on the noise reduction level of the PPE and mathematical calculation based on the data collected from the personal noise exposure. This is to assess the effectiveness of the PPE to protect the users hearing.

3.3 Study Area

A formal letter was written to Bukit Aman Inspector General of Police (IGP) Secretariat Royal Malaysian Police (RMP) Corporate Communication Chief Datuk Asmawati Ahmad for application of study area. The application was sent on 8 August 2018 and the reply for approval was on 27 August 2018 with information of responsible contact person (Appendix A). The responsible police officer for RMP Headquarter indoor shooting range is Inspector Mohamad Hafeez Hamzah. The verbal discussion and on-site meeting with the Inspector were initiated on 13 September 2018 with a clear explanation of the objective of the study. The detail of planning and framework for data collection activities was clearly explained. The needs, requirement, and schedule for noise exposure data collection and PPE evaluation also discussed in detail. The Inspector agreed to give full cooperation and instructed his subordinates to assists the data collection process.

The good benefit and outcome of the study that can be shared with the organization from this study had been discussed with the Inspector. Other than that, the indoor range operation procedure, activities conducted and safety practice also discussed and required detail information. The type of PPE, the model number and its specification information also required from the Inspector. After discussion, the site visit session was assisted by the Inspector and shooting instructor. The shooting range has 6 shooting booths whereby can accommodate 6 shooters at a time for shooting. Unfortunately, one of the booths was malfunctioned and the rest are in good condition.

3.3.1 Indoor Shooting Range of Police Headquarters

The Bukit Aman Indoor Firearm Shooting Range is located at the basement of Tower 2 RMP Headquarters, Jalan Bukit Aman, Tasik Perdana, Kuala Lumpur. It is located in underground whereby one ground lower than the ground floor of the tower. The size of the shooting range is (30 X 10 X 5) meter whereby the maximum distance for target shooting is 25 meter. The shooting range renovated in 2010 with the most advanced technology in the shooting range design. The renovation included high efficiency and non-flammable noise absorption materials applied to the walls, doors, and ceiling. The shooting range equipped with 6 shooting booth and target lane, computerized moving target, and scoring system and CCTV. The left and back side of the underground shooting range is covered with soil. Feather, the right side is occupied with the ventilation system and the entrance shared with the control room, monitoring area, waiting room, and workshop (Figure 3.1).

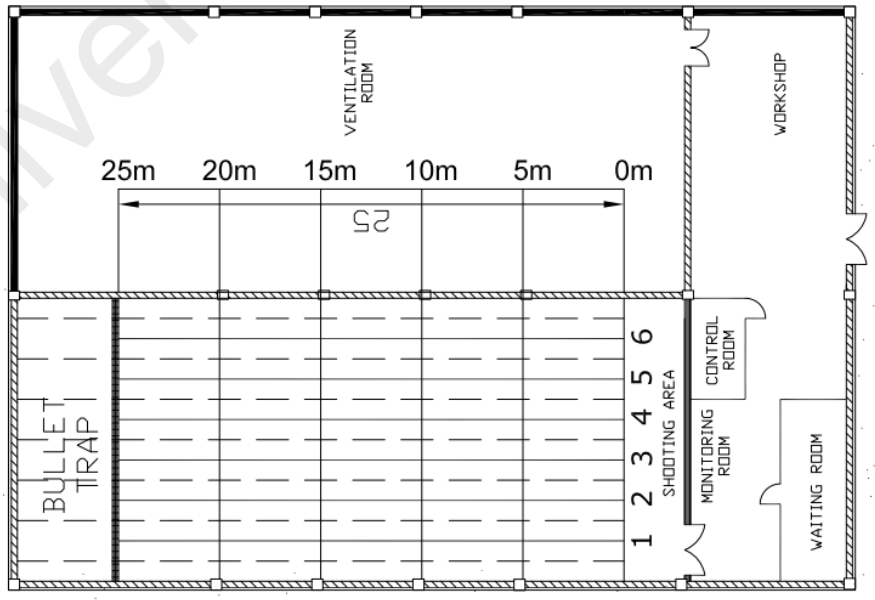

Figure 3.1: Indoor Shooting Range Layout

The function of the shooting range is to conduct firearm shooting training for high-rank police officers and VIPs. The shooting practice based on a request by the relevant department and police officer. Most of the time only static shooting practice conducted in this shooting range. There is no sufficient space to conduct moving shooting practice. Currently, five shooters can practice shooting at a time and each session will be assisted by two instructors. The first instructor positioned at the shooting area and the second instructor positioned at the waiting area or control room. The first instructor will control the entire shooting session by giving shooting, loading and stop command to the shooters. The second instructor will monitor the shooting session from the glass window and do the necessary arrangement for the waiting shooters at waiting area.

Normally every shooter will be given 30 to 50 rounds of bullets to fire which shooting distance beginning from 5 meters to 25 meters targets. They will use their own firearm which provided by RMP or any type of handgun which provided by shooting range. The shooting range is limited to shooting handguns such as pistol and revolver because of the distance limitation. The shooting range also limited to 20 to 50 people shooting a day which come in a group. Shooting session will begin after firearm and range safety briefing.

3.4 Data Collection

3.4.1 Surrounding Shooting Area Noise Level

The noise level measuring at surrounding shooting area was conducted using a sound level meter to record the shooting noise level. During shooting session the sound level meter record noise level at the outside of shooting area which included monitoring area, control room, waiting room, and workshop. This data was used to determine the primary effect and secondary effect of shooting.

3.4.2 Shooting Area Noise Level

The shooting area noise and personal noise exposure level measurements were conducted by recording the shooting noise dosage using Noise Dosimeter. The noise dosimeter mounted on the shoulder of a shooter and instructor who positioned inside the shooting area. The data was analyzed to determine the shooting area noise level, noise dose level at the shooter and instructor. The personal noise exposure measurement is followed the standard and procedure determine by ISO (ISO 9612).

3.4.3 Existing PPE Evaluation

Based on personal noise exposure level and area sound level, evaluate the existing Personal Protective Equipment (PPE) by calculating the amount of Noise Reduction Rating (NRR) which provided by the PPE manufacturer. The NRR of a PPE is the way for measuring the effectiveness of the hearing protection device by calculating the amount of noise attenuation.

3.5 Surrounding Shooting Area Noise Level

The amount of noise level at a particular area measured to determine the sound pressure level (SPL). This process is to identify the primary and secondary effect from the noise produced during the firearm shooting session. The outcomes of the activity are the area noise level and justify the level of exposure to educate the range user. This is to improve the safety and health regulations in the shooting range. The high SPL area should be classified as a danger zone for noise with proper warning signage and compulsory to use ear protection. The proper control measures also should be taken to ensure the safety and health of the shooting range users.

3.5.1 Study Instrument

The surrounding shooting area noise level which involving monitoring area, control room, waiting room, and workshop was measured by using a Sound Level Meter (SLM). The type of compatible SLM used in this study is EXTECH 407730 as shown in figure 3.2(a). The SLM capable of measuring 40 to 130dB with digital display panel and Max Hold captures the highest reading feature. The detail of technical specification and user's guide of the SLM is attached in the Appendix B. The SLM's accessories are according to the standard required by IEC 61672-1:2002, Class-2 instrumentation. Other than that, a measuring tape was used to determine the distance from noise source to the noise level measuring point (Figure 3.2(b)).

Figure 3.2: (a) Sound Level Meter and (b) Measuring Tape

The model and specification of the SLM is as follows:-

- Model : Extech 407730
- Measuring Range : 40 to 140dB
- Basic Accuracy : ± 2dB
- Weighting : A and C
- Respond Time : FAST and SLOW
- Recording : Max & Min value over time
- Condenser Microphone : 12.7mm
- Dimension : 230mm X 57mm X 44mm
- Weight : 160g

3.5.2 Noise Level Measurement

Noise level measurement was conducted by using Sound Level Meter (SLM), measuring tape and calibrator. The walk around survey and meeting with shooting range in-charge officer meet-up was on 13 September 2018. By considering the information given, the area which affected from firearm shooting is identified. The identified area is where people will be around during firearm shooting while waiting for their turn and do minor repair firearm which malfunction. The specified locations to be measured are monitoring area, control room, waiting room, and workshop. The noise level measurement was taken three times at every point of measurement. The SLM was held by a person with a 1.7-meter height near to his ear. At the monitoring area and workshop the SLM was positioned 1 and 2-meter distance from the shooting area wall. However, the control room and waiting room are measured by a sitting passion whereby the people inside this area will be in sitting position. The SLM was prepared with newly replaced battery and calibrated before starting the measurement. The SLM setting parameter also follows the standard setting of a 5dB exchange rate, a range of HIGH (65 ~ 130 dB), Fast response, and A- weighting. Noise level measurements have been performed with the situation of firing 5 rounds of bullet at every point of sample and each point taken three times. Noise level at every situation was recorded. The session was standardized with one type of firearm usage which Glock-19 and 9mm bullets.

3.6 Shooting Area Noise Level

The measurement of noise quantity exposed by shooter and instructor in the shooting range identified as personal noise exposure which can be measured by using the dosimeter. The intention of this process is to estimate the regular exposure of shooter and instructor during conducting shooting session. The outcome of this activity is to educate the range user the noise dose that they expose and the importance of preventive measure to ensure their safety and health.

3.6.1 Study Instrument

The measuring process of personal noise exposure was conducted by using compatible noise logging dosimeter. The manufacture of the noise dosimeter used in this study is Bruel & Kjaer who has played an important role in the field of sound and vibration for the past 75 years. The dosimeter model type is 4448 (Figure 3.3) which works together with Protector PC Software type 7825 for post-processing personal noise exposure level. The special features of this compatible noise dosimeter are shoulder-mounted and cable free comprises the microphone, rechargeable battery, and meter in a single compact instrument. The operation to activate is a simple two-button push and monitor on LCD display together with auto calibration option. Protector Type 7825 software (Figure 3.4) is needed to set up dosimeter and download data after the measurement process. The downloaded measurement data will analyze and calculate the personal noise exposure level with analytical graft data logging list. The detail of technical specification and user's guide of the Dosimeter is attached in Appendix C.

Figure 3.3: Noise Dosimeter

The features of the Dosimeter are as follows:-

- Two pushbuttons to switch on and off, configure it and control the measurements.
- A microphone mounted on the instrument body and protected by a removable protective cover
- A display giving information on instrument status and a selected set of measured parameters
- A warning/status LED
- An analyzer based on digital signal processing, ensuring measurement precision and flexibility to adapt to future needs/requirements
- An infrared (IR) port for measurement data download and detailed instrument configuration

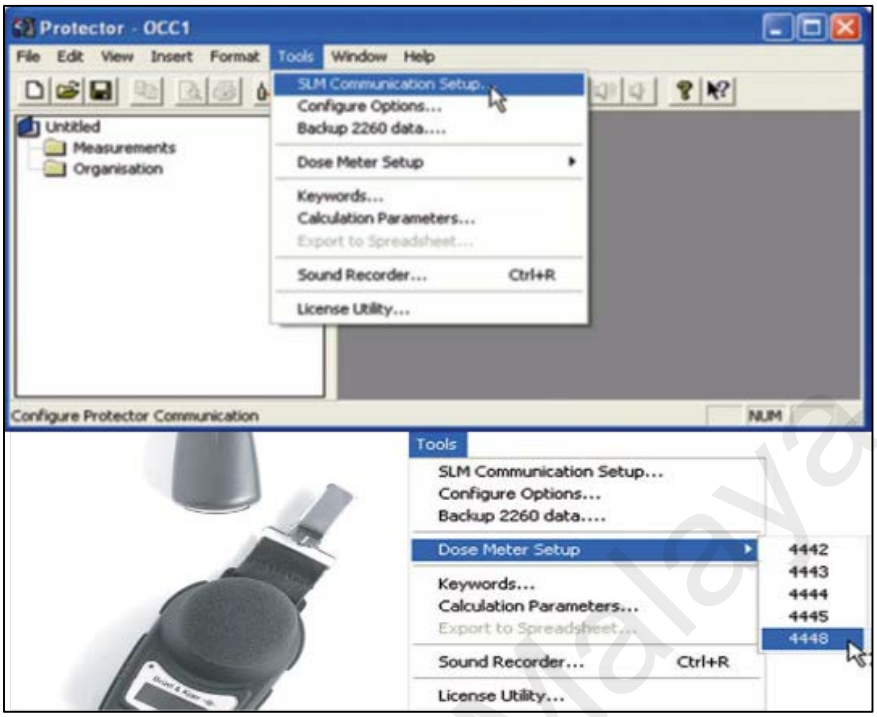

Figure 3.4: Protector Type 7825 software

3.6.2 Instrument Provider

The noise dosimeter used in this study was rented from Gloteq Resources Sdn. Bhd. who providing varies occupational safety and health services with competency certification. The consultancy was founded in 2005 by Mr. Omantaram Kangarajoo who the director and noise competency certificate holder from DOSH. The dosimeter was provided with handling and noise level measuring procedure. The meter also calibrated by certified organization. The details of certificates are in Appendix D.

3.6.3 Sampling Methods

The sampling strategy was designed from an initial meet-up with shooting range responsible officer and the information gathered from instructors. Two category people who are most exposed and very near to the noise source are the shooters and the range instructor. These two group of people will position at shooting area. The noise dosimeter was plugged on the shoulder with microphone facing upward (Figure 3.5) which about 0.1 meters from the entrance of external ear carnal (ISO9612). This will not affect their activities but ensure their safety and avoid false contribution. Once plugged, the dosimeter was switched on and the shooting session begins.

Figure 3.5: Dosimeter Plugging on Shoulder

The measuring strategy for personal noise exposure is task-based. The measurement was conducted in a different situation which begins from single shooting situation until multiple shooting situations up to five shooters. Every situation the shooters are firing 20 rounds of bullets which take about 60 to 90 second. In the beginning, the shooting session conducted with a shooter and an instructor. Secondly, the shooting session conducted with two

shooters and an instructor (figure 3.6). Thirdly, the session continued with three shooters and an instructor whereby the sample shooter in the middle position. Lastly, the shooting session ended with five shooters and an instructor by the sample in the middle position (figure 3.7). The session was standardized with one type of firearm usage which Glock-19 and 9mm bullets.

Figure 3.6: Two Shooters Situation

Figure 3.7: Five Shooters Situation

3.7 Evaluation Existing PPE

The Indoor shooting range is using earmuff as Personal Protecting Equipment (PPE) to protect hearing ability from firearm shooting noise. Earmuff is a device to protect hearing from damage by perfect seal around the ear which depending to protective value. The protection value identified as Noise Reduction Rating (NRR). The NRR is the noise reduction value or attenuation based on the laboratory test. The type of earmuff used in this shooting range is 3M Peltor Optime H10A HV (Figure 3.8, 3.9 & 3.10) with NRR 30dB. The specification of earmuff was collected and reviewed in detail to understand the function and type of protection provided (Appendix E). This earmuff with high visibility has give effective hearing protection by using double-shell technology and recommended noise exposure up to 105 dBA.

Figure 3.8: Earmuff

Figure 3.9: Earmuff Top View

Figure 3.10: Earmuff Side View

The evaluation of the earmuff is based on mathematical calculation which follows the DOSH Industrial Noise Control Module (Ahmad, 2016). The NRR calculation as follows:-

- To check the noise reduction value (NRR -7) / 2
- The worst case scenario in shooting area noise level is 128.3dB based on Dosimeter reading from the shooter.
- The Protected Exposure = $128.3 - \frac{30-7}{2} = 116.8$dB

3.8 Limitation of the Research

The study proposal and objective is based on Bukit Aman Royal Malaysian Police (RMP) Headquarter Indoor Shooting Range. At the beginning of the research the shooting range was actively used for shooting activities. Unfortunately, during data sampling, the shooting range was under maintenance which the management decided to limit the shooting range usage with the limited round of the bullet firing. While waiting for budget to repair, the shooting range management advice the shooter to use outdoor shooting range which located at Bentong, Pahang District Police Office.

Therefore, the real firearm shooting session which exposes the instructor to a frequent number of shooting noise for the entire working shift cannot be obtained. The personal noise exposure measurement are limited to 30 minutes which involving 5 shooters in one shooting session. In a normal situation the shooting range manages to handle 20 to 50 people which involving up to 10 sessions of shooting. The shooters are involved in this study are specially requested for this research purpose.

The Sound Level Meter measuring range is 130dBA which is limited to use outside of the shooting range. The shortage of equipment makes the Dosimeter used as a noise level measuring tool which it capable to do and it also able to measure noise level more than 130dBA. The measurement of LAmax of the dosimeter is Maximum time-weighted sound level.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter included the study result and detailed discussion. The data collected based on the surrounding shooting area and shooting area noise level, personal noise exposure and existing PPE evaluation are analyzed for key findings to be discussed.

4.1 Surrounding Shooting Area Noise Level

The surrounding shooting area is consisting of the monitoring area, control room, waiting room, and workshop. Overall 21 noise level measurement was obtained comprising 7 points of the sample with 3 samples at every point. There are 2 points of the sample at the monitoring area and 3 points of the sample at the workshop area. Every point of the sample, the maximum and minimum value of noise level was obtained. The obtained results mean values are displayed by area in Table 4.1. The noise level measurement was obtained by using sound level meter (SLM) model EXTECH 407730. The setting of the SLM during the measurement is as follows:-

- Range = Auto
- Response = Fast
- Function = A weighted

Table 4.1: Surrounding Shooting Area Noise Level

No	Area	Noise Level (Max) (dBA)	Noise Level (Min) (dBA)
1	Monitoring Area (1m)	99.8	51.1
2	Monitoring Area (2m)	98.5	50.3
3	Control Room	98.4	49.3
4	Waiting Room	88.5	52.6
5	Work Shop (1m)	95.9	49.4
6	Work Shop (2m)	87.8	50.5
7	Work Shop (3m)	78.4	50.8

The research result of noise level at outside shooting area shows that the sound pressure level (SPL) is higher than the permissible exposure level (PEL) 90dB regulated by Department of Occupational Safety and Health, Malaysia (DOSH). The highest noise level was recorded at monitoring area which is 99.8dBA at a meter from the shooting area. The second point of the same area which is 2 meter from the shooting area wall recorded 99.5dBA. The SPL at the control room and waiting room which measured at sitting passion shows 98.4dBA as well as 88.5dBA. However, the three SPL at workshop area recorded in decrease sequence again the distance from shooting area wall which is 95.9dBA, 87.8dBA, and 78.4dBA. The 3m distance from the shooting area wall is the safe working area for the workshop. The minimum level of reading for all area about same which recorded normal room SPL with air-condition running. Base on the research SPL level the area noise mapping can be developed as displayed in figure 4.1.

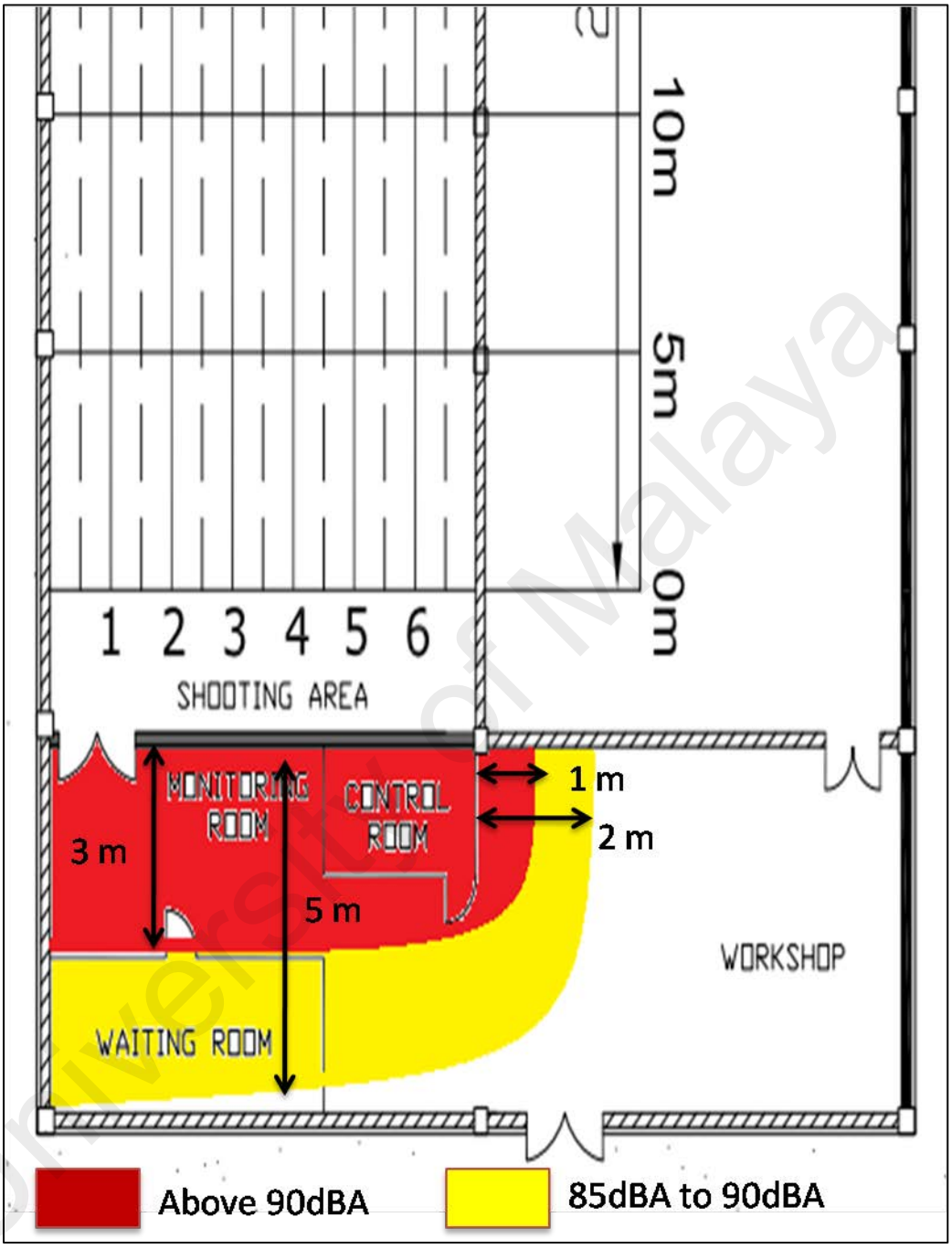

Figure 4.1: Noise Mapping for Shooting Area

4.1.1 Monitoring Area

Monitoring area is exactly next to shooting area which separated by a wall with aluminum framed double glassing window and acoustic double door system. The instructor and other people who are in the monitoring area can view the shooting session. The recorded noise level in this area is 99.8dBA and 98.5dBA which is above the PEL of 90dBA. The noise source is from 5 firearm shooting. The shooting range instructor and the people in the area are exposed to this noise and continuous exposure to this level of noise will damage their hearing.

The Factories and Machinery (Noise Exposure) Regulation 1989 first schedule, is explain the permissible exposure limit according to sound pressure level (SPL) (Appendix F). For 100dBA SPL the exposure time is 2 hour and 99dBA SPL the exposure time is 2 hour 15 minute. In this respect, the instructor and shooters at the monitoring area for more than 2 hours will be exposed to the noise level that may damage their hearing ability. Therefore, the shooting range management should take appropriate action to reduce the noise level or provide a hearing protector which currently not available in the area. Additionally, the area also should be clearly labeled as danger noise zone with appropriate color and signs. The signs must include the impact of exposure according to the time duration. The instructor who assigned to overview the shooting session should rotate the job every two hours with other instructors.

4.1.2 Control Room

The control room is positioned between the shooting area and monitoring area which divided by wall with aluminum framed double glassing windows. The control room is designed to view the shooting area and the monitoring area. Besides that, the room also equipped with the control system for lights, target railing, and ventilation and also monitoring system for shooting marks and CCTV. The recorded SPL at this room is 98.4dBA which is above the PEL of 90dBA which regulated by DOSH. The instructor who assigned to overview the shooting session will be positioned either in the control room or monitoring area. In that case, the same noise control measures in the monitoring area are applicable in the control room.

4.1.3 Waiting Room

The waiting room is located in front of the shooting area which is about 3-meter distance from the shooting area wall. The room is designed using normal see through glass and soft board which occupied with sofa, books and coffee table. The room is for the shooters to relax and read while waiting for their turn to firearm shooting. The recorded SPL at this room is 88.6dBA which is above the action level of 85dBA which regulated by DOSH. Referring to Factories and Machinery (Noise Exposure) Regulation 1989 first schedule, the exposure duration for SPL 88dBA is 10 hour 34 minutes. The maximum range operation time is about 6 hours. The exposure limit is within the permissible level, but noise control measure should be applicable because above the action level.

4.1.4 Workshop Area

The workshop area is located at beside of control room and shooting area border. The area is occupied with workbench and tools for firearm cleaning and repair. The recorded SPL from the distance of the wall 95.9dBA at 1m, 87.8dBA at 2m and 78.4dBA at 3m. The workbench is located 5m from the wall and the working area is safe from noise. However, the location with a noise level above 85dBA should be labeled as noise danger zone with floor marking. This will create awareness to the people who are using that area during firearm shooting.

4.1.5 Shooting Area Noise Level

The recorded noise level during the firearm shooting at the shooter is 128.3dBA and at the instructor is 127.9dBA. The measurement was recorded by using the dosimeter which able to display the immediate sound level. This clearly shows that the noise level is very high if measured nearer to the source. The shooter's noise level is higher than instructor's noise level which is about 0.4dBA. In this respect, the instructor has positioned 1m away from the shooter. Moreover, this result proves the theory which the SPL near to source is higher and reduce by distance (Signal, 2005).

The noise level at the shooting area is above the PEL which the shooting range management should label and apply proper noise danger signage inside the shooting area to create awareness to the shooting range user about danger exposing to a high noise level.

4.2 Shooting Area Noise Exposure Level.

The personal noise exposure level is measured by using two dosimeters model type is 4448 which works together with Protector PC Software type 7825 for post-processing personal noise exposure level. The dosimeters are plugged on two individual which is Muhammad Zainuddin as an instructor and Siti Roslinda as a shooter. The outcome of the result is presented in table 4.2. The measurement duration is about 30 minutes for one session shooting which the shooter firing 100 rounds of bullets with various types of scenarios. The result shows that the Sampling Duration for the instructor is 0.45 hour (27 minutes) and for the shooter is 0.38 hour (23 minutes). Based on the sampling duration, the percentage of Dose for 8 hours TWA for the instructor is 18,298.9% which projected for 5 hours exposure and for the shooter is 1734.1%.

Besides that, the Constant Level of Noise, Leq at the instructor is 127.6dBA and at the shooter is 110.6dBA. The dosimeter also recorded Maximum Level of time-weighted SPL, Max Level for instructor is 127.9dBA and for shooter is 128.3dBA. Furthermore, the maximum peak sound level during the sample, Peak Level for both the instructor and shooter is 143.5dB and type of exposure is intermittent. The overall result shows that the noise level at the Shooting area is exceeded the DOSH requirement, under the Factories and Machinery (Noise Exposure) Regulation 1989. The result is exceeded the 90dBA PEL, 115dBA Maximum Exposure Limit, and 140dBA Impulse/ Peak Noise Limit. The personal noise exposure monitoring worksheet (Appendix G) and dosimeter data logging information (Appendix H) which endorsed by competent noise assessor are attached.

Table 4.2: Dosimeter Result

Name	Job Classification& Task	Sampling Duration (Hour)	Dose (%)	Leq dB (A)	Max Level dB (A)	Peak Level dB	Type of Exposure
Muhammad Zainuddin	Instructor	0.45	18,298.9	127.6	127.9	143.5	Intermittent
Siti Roslinda	Shooter	0.38	1734.1	110.6	128.3	143.5	Intermittent

4.2.1 Personal Noise Exposure

The projected personal noise exposure level, Leq for firearm shooter is 110dBA and for the instructor is 127.6dBA. Moreover, these results show that the shooting range instructor is exposed more noise level than the shooter. Consequently, the shooter only firing in the shooting range for one session, however the instructor continuously conduct the shooting session to other shooters which limited up to 10 sessions a day. Exposing to a high level of noise can cause hearing impairment to the instructor and also to the shooter. The shooting range management is providing personal protective equipment (PPE) which is earmuff to the shooter and instructor. The shooting range management should apply noise control measures such as engineering and administrative control to reduce the noise level and exposure level.

The engineering control measure to overcome this situation is the shooting range design and set up must be best acoustic condition and maintaining very well hygienic environment. The shooting range must equip with significant density that offer the maximum amount of sound absorption at all frequencies and that are capable of

maintaining their absorption coefficient at high-intensity sound level. The material should cover the wall and ceiling of the shooting range.

Besides that, the administrative control measure that can be implementing is job-rotation schedules that limit the amount of time an instructor is exposed to the noise. The shooting range also can develop and implement safe work procedures or standard operating procedures which can limit the noise exposure level. Furthermore, the shooting range management should implement continuous education and training which covers the understanding of hazards and risk in the shooting sessions.

4.3 Personal Protecting Equipment (PPE)

The existing PPE used by the shooting range is earmuffs which act as noise blocker. The earmuff design is to seal around the human ears with rigid cups and soft plastic cushions may be filled with foam, liquid or a combination of both. The mathematical evaluation of existing PPE with Noise Reduction Rating (NRR) of 30 shows that is capable of attenuating 11.5dBA of noise level to the wearers' ear. The user still expose to 116.8dBA noise level which is unhealthy to the hearing ability. This situation is worst to the instructor who exposes to the noise longer period. This problem should be overcome by applying double protection to the ears with the highest NRR value device available in the market and administrative control.

Essentially, the available highest NRR for earplugs is 33 and for earmuffs are 31. The value shows the noise protection level which can be given by the device by wearing it

alone. By wearing combination of both protectors an NRR level of 36 can be reached. In this respect, the noise exposure will reduce to 111dBA and the allowable exposure duration is 26 minutes. Additionally, the shooting range can apply hazard control measure which is administrative control. Administrative control is alter the way the work is done, including timing of work, policies and other rules, and work practices such as standards and operating procedures. In this respect, applying the administrative control by rotating the instructor shift every 26 minutes and end every shooting session within this duration, the shooter and instructor are protected from hearing damage.

Other than that shooting range also must provide high quality earmuff which protect shooters ear during firing session. Double protection of PPE is much better which earplug and earmuff. Otherwise, they can provide electronic earmuff which by wearing, it can hear normal conversation and instruction from the instructor and at the same time will cut down high impulse noise from firing session. The amplifier used in electronic earmuffs included the "smart" capabilities of the ear muffs. These ear muffs would amplify low level sounds. When the sound level picked up by the external microphones reached a dangerous level, the amplifier would simply turn off, leaving the user with the passive protection of the earmuffs. When the dangerous sound went away, the amplifier would resume amplifying the environmental sounds. This earmuff is more convenient and gives comfortable situation to the shooting range user. In this respect, the user would never take off the earmuff during the firing session to hear the surrounding sound.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Occupational hearing loss is one of the major problems in Malaysian industries and also government sector. Based on the yearly report on Occupational Diseases and Poisoning by Department of Occupational Safety and Health (DOSH) shows the occupational hearing loss is in the critical situation. The recorded number of occupational hearing loss is tremendous high compared to other occupational diseases such as Occupational Muscular Skeletal Disorder, Occupational Skin Disease, Occupational Lung Disease, and Occupational Poisoning. In this respect, Royal Malaysian Police which is a government sector is one of the contributors to the recorded occupational hearing loss disease. Meanwhile, the enforcement agency is handling the firearm and conducting shooting activities which producing impulse noise. Therefore, the aim of this research study is to evaluate the current noise scenario in the firearm shooting range involving area noise level and personal noise exposure.

The outcome of the shooting range surrounding noise level result shows that the study area is exposed to noise level above the permissible exposure limit (PEL) of 90dBA. The recorded above PEL noise level is nearer to the shooting area wall which divided

shooting area from monitoring area, control room, and workshop. The facility should adopt noise control measures such as isolation, administrative control, and PPE. The isolation level of the wall which divided the shooting area and the surrounding area should increase by adding more acoustic materials in the shooting area. Besides that, administrative control is providing proper signs to indicate the noise danger area and provide earmuff or earplug as PPE.

The noise level inside the shooting area indicated that the noise level is exceeded the DOSH requirement, under the Factories and Machinery (Noise Exposure) Regulation 1989. The result is exceeded the 90dBA PEL, 115dBA Maximum Exposure Limit and 140dBA Impulse/ Peak Noise Limit. Moreover, the noise level at the shooter is higher than recorded at instructor. The facility should increase noise abatement materials inside the shooting area so that the noise level can be reduced. The personal noise exposure level shows that it exits the permitted level regulated by DOSH and the noise exposure is higher to instructor compared to the shooter because the shooter is been longer duration inside the shooting area. The facility must implement administrative control to reduce the exposure duration and use proper PPE. The evaluation of the existing earmuff shows that the earmuff attenuation is limited and there is lake of protection to the shooter and instructor. The facility management should implement a double protection method for the personal protective device application.

In conclusion, the outlined objective of the study is successfully achieved and the result shows that the noise level at the shooting range is very high and it is unsafe for the human to be in the area without proper protection to the hearing ability. The shooting range management is highly recommended to adopt noise control measure guided by

DOSH and establish a Hearing Conservation Program, especially to the shooting range instructor.

5.2 Recommendation

The research involving firearm shooting range noise assessment and related hazards are limited in Malaysia. The current research study is limited to the indoor shooting range and one type of firearm. Future studies are welcomed to explore more on indoor and outdoor shooting range, comparison within the shooting range and involve varies the type of firearm in their noise exposure level. The noise level measurement also should vary with angle of measurement, the distance of measure from the firearm, and the effect of the acoustic materials in noise abatement. The more research in this field will produce more knowledge and awareness to reduce the risk of hearing impairment among government sector and industries.

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