ASSESSING THE LEVEL OF SERUM HEAVY METALS (LEAD, CADMIUM AND ARSENIC) AMONG KOTA BHARU FIREFIGHTERS

By

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Dissertation submitted in partial fulfillment of the requirements for the degree of Bachelor of Health Science (Honours) (Environmental and Occupational Health)

June 2016

ACKNOWLEDGEMENT

First of all, I praise to Allah the Almighty for having made everything possible by giving me strength, perseverance and His blessings. I would like to take this opportunity to express my utmost gratitude to the individuals that have given their time and effort in helping me throughout the process of completing this project successfully. My special appreciation goes to my parents, Ramlan bin Omar and Rasidah binti Rahman, and my family members for their continuous support and moral encouragements.

I would like to express my deepest gratitude to my supervisor, Assoc. Prof. Dr. Hasmah binti Abdullah, and co-supervisor, Dr. Zefarina binti Zulkafli, for their guidance, encouragements, advices, and support in assisting me from the beginning until I have successfully completed this thesis. A great appreciation as well to my course coordinator of this Final Year Project, Dr. Nurul Ainun binti Hamzah who monitored, guided and gave great motivation in finishing this research for two semesters.

My gratitude is extended to those who have directly and indirectly assisted me in the process of completing my thesis. I want to specially thank the science officer, Pn. Azizah binti Abdullah, who has helped me in the heavy metal analysis procedure, Pn. Nor Azita binti Mohd.Nasir and Ms. Siti Aishah Nor binti Marabi, the phlebotomist and certified nurse responsible in the blood withdrawal process of the USM staffs and Kota Bharu firefighters, En. Wan Mohd. Sahnusi in assisting me with the heavy metal analysis. To all the lecturers, laboratory officers and staffs of Environmental and Occupational Health Programme, thank you for helping and providing me with all the necessary information as well as assisting me in completing this project.

Special thanks to all the respondents from Fire and Rescue Department Kota Bharu for their willingness to participate in this project. I also feel indebted to Hazmira binti Mohd

Kasri, Nurfadzlina binti Deruis, Amirul bin Rosle Amin and all my colleagues who gave me countless help in this study. Last but not least, I would like to thank those who have directly and indirectly been involved in the success of completing this thesis.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percent
&	And
>	More than
°C	Degree Celcius
AAS	Atomic Absorption Spectrophotometer
ACGIH	American Conference of Government Industrial Hygienists.
As	Arsenic
As^{2+}	Arsenic (II) ion
As^{3+}	Arsenic (III) ion
ATSDR	Agency for Toxic Substances and Disease Registry
B-Cd	Blood Cadmium
B-Pb	Blood Lead
BEI	Biological Exposure Indices
Cd	Cadmium
Cd^{2+}	Cadmium (II) ion
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disorder
e.g.	Exempli Gratia (For Example)
et al.,	And others
x g	Times Gravity
µg/dL	Microgram per deciliter
EU	European Union
FRDM	Fire and Rescue Department of Malaysia
IARC	International Agency for Research on Cancer
IQR	Interquartile Range
KB	Kota Bharu
min	Minute
n.d	No date
NHLBI	National Heart, Lung and Blood Institute
NIOSH	National Institute for Safety and Health
NRC	National Research Council
OSHA	Occupational Safety and Health Administration

O_2	Oxygen
Pb	Lead
Pb^{2+}	Lead (II) ion
PMR	Penilaian Menengah Rendah
PPE	Personal Protective Equipment
SCBA	Self-Contained Breathing Apparatus
SD	Standard Deviation
SPM	Sijjil Pelajaran Malaysia
SPSS	Statistical Package for Social Sciences
SRP	Sijil Rendah Pelajaran
STEL	Short term exposure limit
STPM	Sijil Tinggi Pelajaran Malaysia
TLV	Threshold Limit Value
TWA	Time-Weighted Average
USDC	United States Department of Commerce
USM	Universiti Sains Malaysia
WHO	World Health Organisation

PENILAIAN TAHAP SERUM LOGAM BERAT

DALAM KALANGAN AHLI BOMBA KOTA BHARU

ABSTRAK

Anggota bomba sering terdedah kepada pelbagai bahan berbahaya dalam kepekatan yang signifikan. Mereka terdedah kepada zarah asap yang tersebar melalui penyedutan atau kulit dan pencemaran pakaian, diikuti dengan penyerapan bahan kimia terserap melalui kulit di lokasi kebakaran atau di kemudian waktu. Kajian ini bertujuan untuk mengenalpasti kandungan logam berat (plumbum, kadmium dan arsenik) di dalam serum dalam kalangan anggota bomba. Satu kajian berbentuk keratan rentas menggunakan kaedah persampelan mudah telah digunakan untuk merekrut 17 anggota bomba dari Balai Bomba Kota Bharu sebagai kumpulan kajian dan 17 kakitangan dari Universiti Sains Malaysia, Kampus Kesihatan sebagai kumpulan kawalan. Sampel darah telah diambil daripada semua subjek secara sukarela dan disiasat bagi parameter berkaitan. Arsenik adalah logam berat yang paling tinggi dikesan di dalam serum anggota bomba Kota Bharu diikuti plumbum dan kadmium. Keputusan yang diperolehi menunjukkan bahawa tiada perbezaan yang signifikan dalam tahap serum logam berat anggota bomba Kota Bharu berbanding dengan kumpulan kawalan ($p>0.05$). Tidak ada perbezaan yang signifikan di dalam serum logam berat anggota Bomba Kota Bharu dan kumpulan kawalan dengan status merokok. Keputusan menunjukkan bahawa tahap plumbum dan arsenik adalah lebih tinggi dalam kalangan bekas perokok manakala tahap kadmium adalah lebih tinggi dalam kalangan perokok. Perbandingan antara perokok dan kumpulan bukan perokok, perokok dan kumpulan bekas perokok dan bukan perokok dan kumpulan bekas perokok tidak menunjukkan perbezaan yang signifikan dalam semua kumpulan yang diuji. Kejadian kebakaran terkini yang berbeza-beza yang disertai oleh anggota bomba boleh mengakibatkan tahap logam berat menjadi tidak signifikan. Faktor-faktor lain yang boleh mempengaruhi tahap logam berat seperti status merokok, umur, pengambilan makanan laut, faktor pekerjaan dan penggunaan alat lindung diri. Kajian ini menekankan tentang pentingnya pengetahuan tentang pendedahan pekerjaan kepada asap kebakaran, kebersihan diri dan alatan serta memakai alat lindung diri untuk mengurangkan risiko pendedahan logam berat.

ASSESSING THE LEVEL OF SERUM HEAVY METALS AMONG KOTA BHARU FIREFIGHTERS

ABSTRACT

Firefighters are frequently exposed to significant concentrations of hazardous materials. They are exposed to smoke particles that spread through inhalation or skin and clothing contamination, with following absorption of adsorbed chemicals through the skin at the fire scene or at later times. This study aimed to investigate the occurrence of heavy metals (lead, cadmium and arsenic) in serum among firefighters. A cross-sectional study design utilizing convenient sampling method was used to recruit 17 firefighters from Kota Bharu firestation as the exposed group and 17 staffs from Universiti Sains Malaysia, Health campus as the control group for this study. Blood samples were collected from all volunteer subjects and investigated for relevant parameters. Arsenic was the highest heavy metal level detected in Kota Bharu firefighters followed by lead and cadmium respectively. The results obtained showed that there was no significant difference in serum heavy metal levels in Kota Bharu firefighters as compared to normal control group ($p>0.05$). There was also no significant difference in serum heavy metals of Kota Bharu firefighters and normal control group and smoking status. It showed that lead and arsenic levels were higher among ex-smokers while cadmium levels were higher among smokers. Comparison between smoker and non-smoker group, smoker and ex-smoker group and non-smoker and ex-smoker group showed no significant difference in all the groups tested. The varying recent fire incidents experienced by the firefighters may lead to the insignificant level of the heavy metals. Other factors may also influence the heavy metal levels such as smoking status, age, seafood intake, occupational factors and PPE usage. This study stresses on the importance of acknowledging the occupational exposure to fire smoke, personal hygiene and cleanliness as well as wearing personal protective equipment to minimize the risk of heavy metal exposure.

CHAPTER 1

INTRODUCTION

1.1 Study Background

Firefighting is one of the most challenging and dangerous profession which exposes firefighters to various hazards (Fernando *et al.*, 2016).The materials that are burned during a fire consist of organic materials, in which the primary chemical element is carbon. The carbon compounds evolve to carbon dioxide and water when burned completely. However, even in furnacelike conditions, combustion is seldom complete and thus, carbon monoxide is an ever present and expected toxicant (Stefanidou *et al.*, 2008).

Firefighters are frequently exposed to significant concentrations of hazardous materials which include carbon monoxide, hydrogen cyanide, hydrogen chloride, benzene, sulphur dioxide, various aldehydes and some particulates (Al-Malki, 2009). Characteristic trace and heavy metal elements such as lead, boron, cadmium, selenium, arsenic, antimony and molybdenum may also be present in smoke (Bates, 1980).

It has long been a major interest of occupational health investigators regarding the health effects of exposures related to fighting fires (Giudotti and Clough, 1992). The potential of experiencing acute and/or chronic respiratory health effects related to exposures during firefighting activities among firefighters has long been recognized (Fabian*et al.*, 2010). The firefighters are not only exposed to gases, but they are also exposed to the smoke particles that might spread through inhalation or skin and clothing contamination, with following absorption of adsorbed chemicals through the skin at the fire scene or at later times (Fabian *et. al*, 2011).

It is difficult to predict firefighters' exposures to specific environmental chemicals or combustion products because of the variability of fuels (e.g., plastics, wood, and petroleum products) and fire characteristics (e.g., temperature, duration, and availability of oxygen in the fire environment) (Dobraca *et al.*, 2015). Furthermore, there are currently very few biomonitoring studies of the firefighters and they may have a greater exposure to many hazardous chemical which identifies them as an important group to study (Dobraca *et al.*, 2015).

1.2 Problem Statement

Chemical in the fire smoke exposure among firefighters is one of the major issues that may affect their health. Recently, there are many previous studies that relate the fire smoke exposure with its impact on the firefighters' health. A study has recorded that the firefighters' exposure to heavy metals has been present in smoke and on turnout gloves used by the firefighters. Furthermore, the presence of metals (including lead, manganese, and mercury) on firefighter gloves from smoke and soot deposition indicates that there is additional exposure potential when the gloves are removed (Fabian *et al.*, 2010).

The potential of developing acute and/or chronic respiratory health effects to the firefighters due to the exposure of fighting fires routine activities has long been acknowledged (Fabian *et al.*, 2011). In suppression and overhaul phases in firefighters' work routine, asphyxiants, irritants, allergens, and chemicals carcinogenic for various tissues are present (Fabian *et al.*, 2010). The chemicals do not only affect the respiratory system in general due to effect of the fire smoke, but it may also cause adverse affects other vital systems of the body as well.

Exposure to these gaseous and particulate agents has been linked to acute and chronic effects resulting in increased firefighter mortality and morbidity (higher risk of specific cancers and cardiovascular disease) (Fabian *et al.*, 2010). Stefanidou *et al.* (2008) also stated that these chemicals have been associated with the incidence of cardiovascular, respiratory, or neoplastic diseases. There is a recent case-control study of cancer in California firefighters which identified an association between firefighting occupation and certain types of cancer such as testicular, malignant melanoma, brain, oesophageal and prostate cancer (Bates, 2007).

Besides that, it is also found that long-term repeated exposure to fire smoke may accelerate cardiovascular mortality and the initiation/progression of atherosclerosis (Fabian *et al.*, 2010). Atherosclerosis is a disease in which plaque builds up inside the arteries; blood vessels that carry oxygen-rich blood to the heart and other parts of the body. It hardens and narrows the arteries over time, thus limiting the oxygen-rich blood flow throughout the body. This condition may lead to serious health problem such as heart attack, stroke and even worse death (National Heart, Lung and Blood Institute (NHLBI), 2015).

The hematological features of the firefighters may experience significant changes due to their occupational exposure to lead. It is known that anemia is produced due to the defect in hemoglobin synthesis by lead (Takano *et al.*, 2015). There was a previous study which associated blood lead level > 10 μg/dl with the increased risk to anemia. The result of the study showed that there was a significant association of severe and moderate anemia with 10-20 μg/dl blood lead levels (Hegazy *et al.*, 2010). It is also found that lead exposure has been closely associated with neurotoxicity, cardiovascular and renal disease, and all-cause mortality (Bellinger, 2011).

Firefighters' exposure to fire smoke may also expose them to cadmium. Renal injuries (including tubular and glomerular dysfunctions) were known as the most significant effect related to cadmium toxicity after prolonged exposure. Besides that, the exposure may also cause immune deficiencies, apathies, bone injuries (osteomalacia and osteoporosis), femoral pain, lumbago and skeleton deformations (Bertin and Averbeck, 2006).

The awareness on the importance of respiratory protection equipment, such as self-contained breathing apparatus (SCBA) utilisation is still low in firefighters' certain work conditions. Firefighters are trained to use the equipment when they are exposed to adverse environmental conditions such as high temperatures and carbon monoxide levels (Fabian *et al.*, 2011). In some situations, respiratory protection equipment may be inadequate or not felt to be needed resulting in unrecognized exposure (Edelman *et al.*, 2003). For example, during the overhaul phase, SCBA are typically not worn when the direct smoke or other threat from the fire is assumed to have diminished (Fabian *et al.*, 2011). They are exposed of inhaling unknown concentrations of residual gases and/or smoke particles contaminated with absorbed chemicals during the overhaul operations (Fabian *et al.*, 2010).

Besides that, potentially hazardous yet tolerable situations such as outside fires of vehicles, brush, detached garages, and smaller structures might also not require the usage of SCBA (Fabian *et al.*, 2011). The respiratory protective equipment was not used in many cases of the worst exposure to the hazardous materials due to the visual impression of low smoke intensity (Brandt-Rauf *et al.*, 1988). In other words, the utilisation of SCBA is emphasised when the smoke is visibly seen with the naked eyes. Therefore, the levels of these materials represent the actual direct exposure to the firefighters (Brandt-Rauf *et al.*, 1988). This provides as a probable explanation for the increasing risk of illnesses among firefighters.

1.3 Research Objectives

1.3.1 General Objective

To investigate the occurrence of heavy metals (lead, cadmium and arsenic) in serum among firefighters in the Kota Bharu firestation.

1.3.2 Specific Objectives

1) To determine the level of serum heavy metals (lead, cadmium and arsenic) in the blood of firefighters.
2) To compare the levels of serum heavy metals (lead, cadmium and arsenic) between firefighters and normal control subjects.
3) To compare the levels of serum heavy metals (lead, cadmium and arsenic) between smoking firefighters, non-smoking firefighters and ex-smoking firefighters.
4) To determine the association of serum heavy metals (lead, cadmium and arsenic) with associated factors.

1.4 Research Hypothesis

1) There is significant difference in the levels of serum heavy metals between firefighters and normal control subjects.
2) There is significant difference in the levels of serum heavy metals between smoking firefighters, non-smoking firefighters and ex-smoking firefighters.
3) There is significant association of serum heavy metals with associated factors.

1.5 Significance of the Study

This study will be very beneficial to the firefighters community. The results obtained from the biological monitoring conducted on the firefighters will enable them to know whether they are exposed to chemicals during their occupational firefighting activities. Besides that, it will also help them to acknowledge the need of complete and proper protective and prophylactic measures in order to prevent such hazardous health effects that might endanger firefighters working under highly dangerous conditions. Most importantly, from this study, they will understand the necessity of fulfilling and participating in regular medical check-ups and laboratory investigations to allow early detection of any renal, hematological or other possible changes in their bodies as a result of their occupational exposures.

CHAPTER 2

LITERATURE REVIEW

2.1 Fire Smoke

Smoke from fires constitute of suspended liquid and solid particulate matter, gases and vapours which resulted from the combustion or pyrolysis of material (International Agency for Research on Cancer (IARC), 2010). According to Guidotti and Clough (1992), the variable compound mixture present in smoke individually possesses specific toxicological properties and contributes to interactive toxic effects. They further added that the toxicity of smoke varies greatly, depending primarily on the fuel, the heat of the fire, and whether or how much oxygen is available for combustion. The complexity of the chemical composition of smoke is also due, in part, to the presence of secondary products; after the products of combustion are formed, they remain chemically active and continue to react long after the fire has ceased to burn.

There are several factors which makes the characterization of exposures to fire gases and smoke which are work schedules of 10-24 hour shifts for 188 days in a year, variations between firefighters' time spent at fires, complex mixture of gases, vapours and particulate matter exposure, unknown effect of heat, gases and free radicals may also be adsorbed onto particulate matter and, the difficulty in collecting samples at unpredictable locations in a dangerous and rapidly changing environment (IARC, 2010).

However, this contradicts with Decker and Garcia-Cantu (1986) which states that all smoke, including that from simple wood fires, is hazardous and potentially lethal with concentrated inhalation. This means that the exposure of the firefighters to fire smoke remains present even in occurrences of small fire. In this study, the firefighters were selected without considering the types of fire, duration of firefighting in order to test whether these factors influence the effect of fire smoke on the firefighters.

2.2 Toxic Chemical Compounds in Fire Smoke

The components of fire smoke differ depending on the burning fuel nature as well as the conditions related to the combustion. The different types of fire occurrences generate and release various kinds of toxic chemical compounds. According to Douglas *et al.* (1985), many variables control the resulting by-products of combustion, the most important being the composition of the burning material. Sparrow *et al.* (1982) said that the other key factors include the temperature at which pyrolysis or combustion occurred the concentration of oxygen present, and the efficiency of combustion.

Several previous studies of exposures of firefighters have shown that several of these potentially hazardous by products of combustion are encountered during the normal occupational activities of firefighters. Fabian *et al.* (2011) monitored exposure conditions during structural fire suppression activity (knockdown and overhaul) and search and rescue operations. The result of monitoring showed multiple asphyxia (e.g. carbon monoxide, carbon dioxide and hydrogen sulfide), irritants (e.g. ammonia, nitrogen oxides, and sulfur dioxide), allergens, and chemicals carcinogenic for various tissues (e.g. benzene, chromium, formaldehyde, polycyclic aromatic hydrocarbons, and certain heavy metals) were found in smoke during firefighter operations.

From the environmental monitoring and medical surveillance programme conducted by Brandt-Rauf *et al.* (1989) to evaluate potential health hazards from firefighting that caused acute pulmonary effects after toxic exposures, it was found that there are significant levels of carbon monoxide, benzene, sulphur dioxide, hydrogen cyanide, formaldehyde, hydrogen chloride, various halogenated organics (dichlorofluoromethane, trichloroethylene, perchloroethylene, chloroform, methylene chloride, trichlorophenol), toluene, and particulates were found.

Another study conducted by Brandt-Rauf *et al.* (1988) to assess the types and levels of exposure encountered by firefighters during their routine occupational duties. Personal, portable, ambient environmental sampling devices were used to monitor the members of the Buffalo Fire Department during firefighting and the results indicate that firefighters are frequently exposed to significant concentrations of hazardous materials including carbon monoxide, benzene, sulphur dioxide, hydrogen cyanide, aldehydes, hydrogen chloride, dichlorofluoromethane, and particulates.

The fire smoke constituents vary depending on the combusted materials and other factors, however benzene, formaldehyde, polycyclic aromatic hydrocarbons and fine particulates are commonly present (IARC, 2010). In another study, detectable blood levels of mercury were found in six firefighters, and one elevated level was found over the course of the study period of the exposure to smoke and other contaminants from the extensive fires (Smith *et al.*, 2013). All of the results of these studies confirmed that there was a high possibility that the firefighters may be routinely exposed to toxic materials during the course of their activities.

2.3 Firefighters

There are many duties related to firefighters which consist of controlling and extinguishing fires that may threaten life, property or environment, prevention of fire, emergency medical service, search and rescue, hazardous material response as well as disaster management (United States Department of Commerce (USDC), 2000).

Municipal firefighters are involved in two more or less distinct phases in municipal structural firefighting which are knockdown (controls and extinguishes fire) and overhaul (remaining small fires are extinguished) (IARC, 2010). Similarly, wildland firefighters also involve in two phases which consist of "attack" and "mop-up" whereby the fire are fought over a long period of time, which may lasts hours, days or weeks (IARC, 2010).

Firefighters are at risk of facing various hazards due to their occupation, to carcinogens and toxic agents, heat, physical stress and psychological stress, therefore potentially exposing themselves to particular health concerns including cardiovascular diseases and cancers (Rim, 2013). Firefighters, who are directly exposed to the smoke plume and outside the immediate vicinity of the fire source (e.g. incident commander) are expected to be affected greatly by the generated toxic compounds in fire smoke (Veronika and Josef, 2012). Not only that, firefighters might be exposed to diesel/gasoline exhaust when vehicles exit and return to the firestation as well as being exposed to diesel emission from response vehicles that remain running at the fire operation scene (IARC, 2010).

Firefighters have high risk of poisoning due to the inhalation of toxic combustion gas of the fire atmosphere (Stefanidou *et al.*, 2008). Table 2.1 presents occupational exposure limits for selected chemicals to which firefighters are exposed according to the American Conference of Government Industrial Hygienists (ACGIH), (2007). In addition, the firefighters use heavy equipment and carry people or objects during firefighting, as well as the impact of external stress (heat, humidity, oxygen (O_2) decrement, carbon dioxide (CO_2) increment, emotional stress), thus, causing the health effects to be aggravated (Naeher *et al.*, 2007). International Agency for Research on Cancer (2007) included fire fighting in assessing the carcinogenicity of a range of occupations, convened by a working group. The overall evaluation concluded that the occupational exposure as a firefighter is possibly carcinogenic to humans (Group 2B).

Currently, there are very few biomonitoring studies involving firefighters which have greater exposures to many hazardous chemicals, thus, making them an important group to be studied (Dobraca *et al.*, 2015).

Table 2.1: Regulations and guidelines for the chemicals measured in smoke at fires

Chemicals measured at fires	Units	BEI		TLV/TWA		STEL		Ceiling	Permitted excursion	Maximum excursion
		ACGIH	EU	ACGIH	EU	ACGIH	EU	ACGIH	ACGIH	ACGIH
Arsenic	mg/m3	Yes		0.01		-		-	0.03	0.05
Asbestos	f/cm3	-		0.1	0.1	-		-	0.3	0.5
Acetaldehyde	pm	-		-		-		25	-	25
Benz[*a*]anthracene	mg/m			-		-		-		
Benzene	ppm	Yes	Yes	0.5	1	25		-	-	-
Benzo[*a*]pyrene	mg/m3									
1,3-Butadiene	ppm	Yes		2		-		-	6	10
Cadmium	mg/m3	Yes		0.01		-		-	0.03	0.05
Carbon black (total)	mg/m3	-	Under discussion	3.5	Under discussion	-	Under discussion	-	10.5	17.5
Dichloromethane (methylene chloride)	ppm	Yes		50	Under discussion	-		-	150	250
Ethylbenzene	ppm	Yes		100	100	125	200	-	-	-
Formaldehyde	ppm	-			Under discussion	-		0.3	-	-
Furan/tetrahydrofuran	ppm	-		-	50	-	100	-	-	-
Isoprene	ppm	-		-		-		-	-	-
Lead	mg/m3	Yes		0.15	0.15	-		-	0.45	0.75
Naphthalene	ppm	-		10	10	15		-	-	-
Particulate matter (respirable)	mg/m3	-		3		-		-	9	15
Particulate matter (total)	mg/m3	-		10		-		-	30	50
Pentachlorophenol	mg/m3	Yes		0.5				-	9	15

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Table 2.1, Continued

Polychlorinated biphenyls (Aroclor; 54%) (Chlorodiphenyl)	mg/m3	-	0.5		-		1.5	2.5
Polycyclic Aromatic Hydrocarbons	mg/m3	Yes	0.2		-	-	0.6	1.0
Styrene	ppm	Yes	20		40	-	-	-
Sulfuric acid	mg/m3	-	0.2	Under discussion	-	-	-	-
Tetrachloroethylene (Perchloroethylene)	ppm	Yes	25	Under discussion	100.0		-	-
Trichloroethylene	ppm	Yes	10	Under discussion	25.0	-	-	-
Trichloromethane (chloroform)	ppm	-	10	2	-	-	30	50
Trichlorophenol	ppm	-	-		-	-	-	-

Source: American Conference of Government Industrial Hygienists (ACGIH) (2007).

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2.4 Health Effect of Smoke Exposure

There are many recent epidemiological studies which showed that there is an association between firefighting with significant increased risk for specific types of cancer. Mortality and morbidity among firefighter are increasing as they have higher risk of developing specific cancers and cardiovascular diseases due to the acute as well as chronic effects affecting their health because of the exposure to gaseous and particulate agents in their working environment (Fabian *et al.*, 2010).

In a study, it was found that the mortality risks for lung cancer and leukaemia were modestly increasing with firefighter exposures (Daniels *et al.*, 2015). Besides that, a study also showed that the risk of developing colon cancer and brain cancer among firefighters were moderately elevating (Kang *et al.*, 2008). Figure 2.2 shows the occupationally related disease of firefighters which shows that the leading cause of premature departures in the case of occupationally related disease were lung disease, heart disease, followed by cancer as reported by the International Association of Fire Fighters (IAFF) (2000).

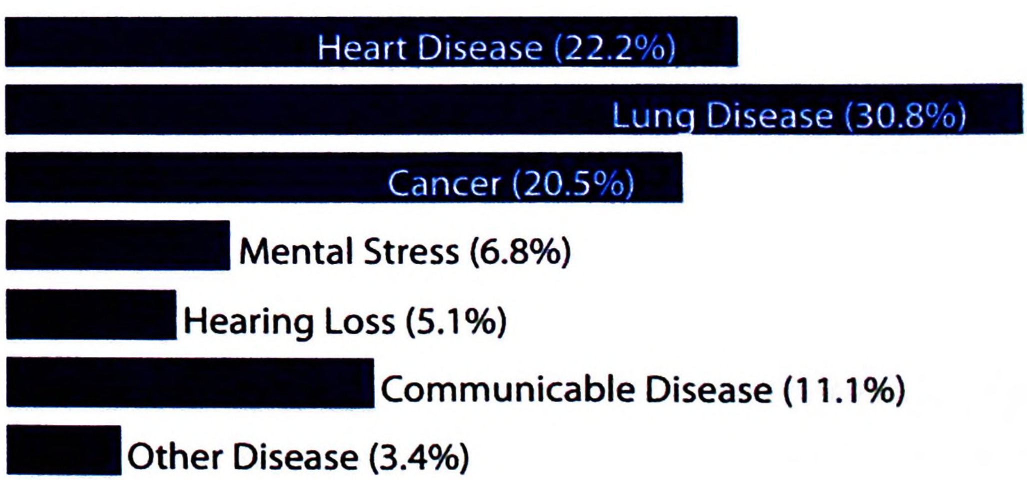

Figure 2.1: Breakdown of line of duty disability retirements by occupational disease
Source: International Association of Fire Fighters (IAFF) (2000).

Exposure to respirable particles in the ultrafine range which are less than 0.1 micron in diameter is another additional cardiovascular risk factor which have been found present in smoke (Fabian *et al.*, 2010). Most of the health effects caused by fire smoke inhalation are preventable (Stefanidou *et al.*, 2008).

2.5 Heavy Metal

Heavy metal is defined as any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech Water Treatment and Air Purification, 2004). Arsenic, cadmium, chromium, cobalt, lead, mercury, and nickel are among the metals that have been classified as human carcinogens or considered to be human carcinogens by the International Agency for Research on Cancer (2010).

These metals are important in maintaining various biochemical and physiological functions in organisms when they are in very low concentrations, however, becomes harmful when they exceed certain threshold concentrations (Jaishankar *et al.*, 2014). Toxic metal ions that have similar physiochemical properties to essential ions (e.g., charge and size), they may compete ions for biological binding sites, leading to perturbation of biomolecular structure and function as well as a disturbance in metal homeostasis (Beyersmann and Hartwig, 2008).

2.5.1 Cadmium

Cadmium is a metal found in the Earth's crust, associated with zinc, lead, and copper ores (Agency for Toxic Substances and Disease Registry (ATSDR), 2012). Mining, metallurgy industry and manufacturers of nickel-cadmium batteries, pigments and plastic stabilizers are the main causes associated with cadmium occupational and environmental pollution (Bertin and Averbeck, 2006). The main routes of cadmium exposure are through the inhalation of dust and fumes, cigarette smoking, food as well as incidental ingestion from contaminated hands (ATSDR, 2012). Generally, the cadmium exposure towards human occurs through the respiratory or gastrointestinal tracts, while cigarette smoke and food (from contaminated soil and water) are the important non-industrial exposure sources (Johri *et al.*, 2010).

Cadmium that is inhaled will enter the body approximately about 5-50% through the lungs. Ingestion of food and water containing small amount of cadmium, about 1-10%, will enter the body through the digestive tract. Dermal contact, however, is not the route of cadmium exposure as it does not enter the body through the skin (ATSDR, 2012). Bone is the sensitive target of cadmium toxicity following oral exposure, while for inhalation exposure is the lungs. Kidney, on the other hand, is the sensitive targets of cadmium toxicity for both oral and inhalation exposure (ATSDR, 2012). The body is able to change most cadmium to a form that is not harmful. However, too much cadmium may overload the kidney and liver ability to transform (ATDSR, 2012).

Reliable indicator for recent exposition of cadmium is blood concentration, whereas for past exposure, body burden and renal accumulation, urinary concentration is used (Jin *et al.*, 2002). The excretion of cadmium from the body via urine and faeces (Godt *et al.*, 2006). Kidney is the main organ that would be affected due to long-term accumulation of cadmium in the body (Orlowski and Piotrowski, 2003). Accumulation of cadmium in the kidney happens due to life-long intake, thus causing tubulus cell necrosis (Godt *et al.*, 2006). Figure 2.3 shows effects of cadmium on several organ systems which are the kidney, respiratory system, reproductive system and skeletal system.

Recent data indicate that adverse health effects of cadmium exposure may occur at lower exposure levels than previously anticipated, primarily in the form of kidney damage but possibly also bone effects and fractures (Järup, 2003). Several previous studies have associated firefighting occupation with cadmium exposure.

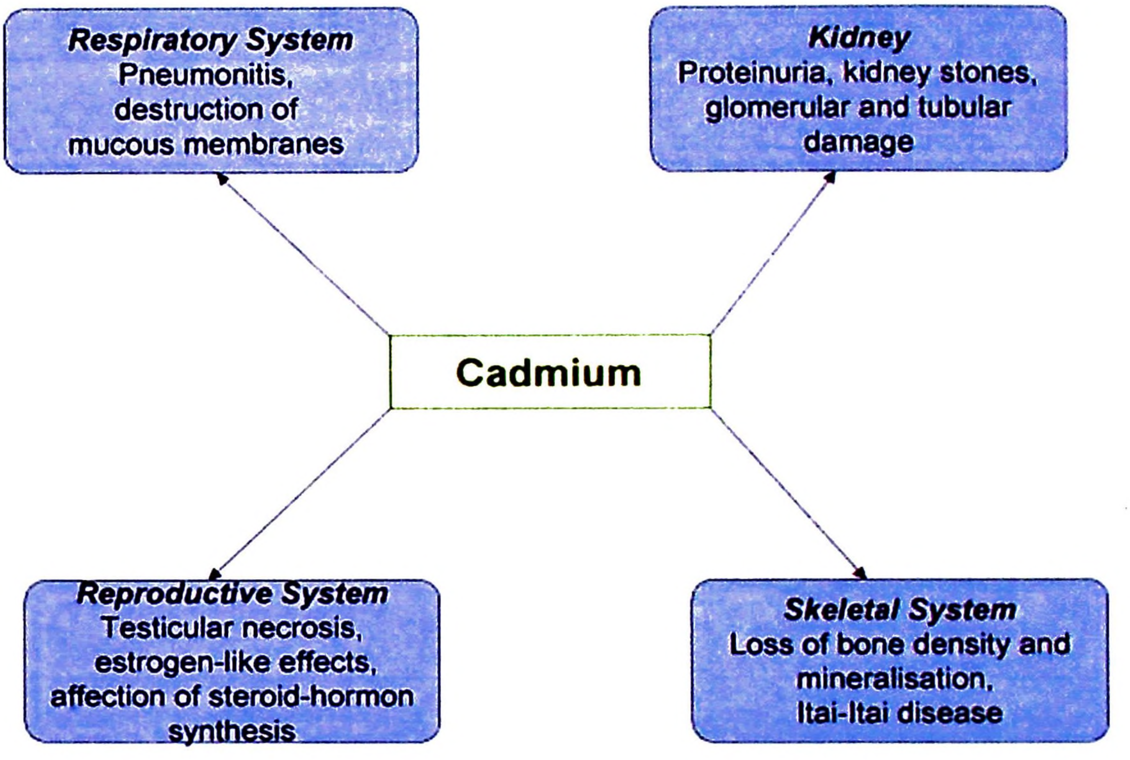

Figure 2.3 Effects of cadmium on several organ systems

Source: Godt *et al.* (2006).

2.5.2 Lead

Lead is a heavy, low melting, bluish-grey metal that occurs naturally in the Earth's crust. It is rarely found naturally as a metal, and is normally found combined with two or more other elements to form lead compounds (ATSDR, 2007). There are many sources of lead. It is mostly as the result of human activities such as mining, smelting, refining and informal recycling of lead; use of leaded petrol (gasoline); production of lead-acid batteries and paints; jewellery making, soldering, ceramics and leaded glass manufacture in informal and cottage (home-based) industries; and use in water pipes and solder (World Health Organisation (WHO), 2010). Burning solid waste containing lead, windblown dust, volcanoes, exhaust from workroom air, burning or weathering of lead-painted surfaces, and cigarette smoke are among the causes of lead released into the air (ATSDR, 2007).

Lead that enters the body comes from breathing in, or swallowing airborne dust, dirt or chemicals that contain lead (ATSDR, 2007). Body burden measurements (lead in blood, teeth or bone) can be used to directly assess human exposure or indirectly, by measuring levels of lead in the environment either through air, dust, food or water (Prüss-Üstün *et al.*, 2004). The approximated half-life of blood lead for adults is 30 days (ATSDR, 2007). Lead in the body is distributed to the brain, liver, kidney and bones. It is stored in the teeth and bones, where it accumulates over time (WHO, 2010).

There are a few previous studies which associates the exposure to fire with increased blood lead level in firefighters. In a study conducted by Arafa and Afify (2011), the results of the lead blood level assessment among Egyptian firefighters showed a highly statistically significant high blood lead level ($p<0.05$) in fire fighters (10.9 ± 1.6) as compared to normal control subjects (8.3 ± 2.4) .

Similar results were obtained in the study on the New York City Firefighters responding to the World Trade Center fire and collapse which stated that lead levels were statistically higher in exposed fire fighters than in control group (Edelman *et al.*, 2003). However, there is a contradiction in the results obtained in the study conducted by Al-Malki (2009) which reported that there is no difference in blood lead level between firefighters and control group. In order to clarify further whether there is an association between firefighters' exposure to fire and blood lead level, a study will be conducted to proof the association relationship. In contrast to the previous study's results, a study reported that there is no difference in blood lead level between firefighters and control group (Al-Malki, 2009).

2.5.3 Arsenic

Arsenic is a naturally occurring element that is extensively distributed in the Earth's crust and is classified chemically as a metalloid, however, it usually referred to as a metal (ATSDR, 2007). There are many ways arsenic can be released into the atmosphere and water, whether through natural activities, for instance, minerals dissolution into the groundwater, volcanic activity, wind-blown dusts, and exudates from vegetation or human activities, such as, combustion of fossil fuels, mining, metal smelting, production and use of agricultural pesticides, and timber treatment with preservatives (WHO, 2010).

Arsenic exposure in human occurs primarily by ingestion, or inhalation, as well as absorption through the skin (Ratnaike, 2003). For occupational exposure to arsenic, it occurs primarily by inhalation (Järup, 2003). Arsenic is easily available, odourless, tasteless, potent and discreet remained as a popular poison which is undetectable in food (Hughes *et al.*, 2011). Biomarkers of exposure used in order to detect arsenic concentrations are blood, urine, hair and nails (Järup, 2003).

The half life of arsenic differs between ten hours and four days (National Research Council (NRC), 2000). Arsenic affects human differently based on whether they are exposed acute exposure or long term exposure. The effects of acute arsenic poisoning are nausea, vomiting, abdominal pain, and severe diarrhoea (Ratnaike, 2003). This may be followed by numbness and tingling of the extremities, muscle cramping and in extreme cases, leads to fatality (WHO, 2010). Chronic exposure to arsenic leads to hyperpigmentation as well as both palmar and solar keratoses (Ratnaike, 2003).

Besides that, it may also increase risk of cardiovascular disease, high blood pressure, peripheral neuropathy, gastrointestinal symptoms, conjunctivitis, diabetes, renal system effects, enlarged liver, bone marrow depression, and destruction of erythrocytes (WHO, 2010).

CHAPTER 3

METHODOLOGY

3.1 Study Design

This was a cross-sectional study and is defined as the third variation of the observational study (Gehlbach, 1993). This study is the best way to determine the prevalence and useful at identifying associations. It begins with a population and makes simultaneous assessments of outcomes, descriptive features, and potential predictors. All the data collection is done on the spot. The most important advantages of cross sectional study are general quick and cheap, no follow up and less resource are required to run the study (Mann, 2003). However, this type of studying does not permit distinction between cause and effect and cannot predict future health events (Page *et al.*, 1995)

3.2 Study Location

This study was conducted at Kota Bharu Firestation which is located within the Kota Bharu district. This location was chosen as a baseline study in order to assess the level of serum heavy metals in firefighters.

3.3 Study Participants

Two groups have participated in this study whereby the studied group comprises of firefighters who were exposed to fire smoke due to their occupational activities of firefighting. The firefighters selected in this study were among those which met the inclusion criteria required. The other group is the normal control group which were selected among the staffs from Universiti Sains Malaysia, Health Campus, Kubang Kerian, who were not occupationally exposed to fire smoke due to firefighting.

3.4 Inclusion and Exclusion Criteria

The exposed group and non-exposed group subjects where selected based on the inclusion criteria and exclusion criteria as shown in Table 3.1 and Table 3.2 respectively.

3.4.1 Exposed Group: Firefighters

Table 3.1: Inclusion and Exclusion Criteria for Exposed Group

Inclusion criteria	Exclusion criteria
Male or female.	Suffering from acute and/or chronic illnesses (as hypertension, diabetic, cardiac or occupational disease).
Age between 20-60 years old.	Unwilling to consent or participate in the research.
Employed as full-duty active firefighters for at least 12 months.	
Directly involved in fire fighting activities/Have experience in fighting fires.	

3.4.2 Non-exposed Group: Staffs

Table 3.2: Inclusion and Exclusion Criteria for Non-exposed Group

Inclusion criteria	Exclusion criteria
Male or female	Suffering from acute and/or chronic illnesses (as hypertension, diabetic, cardiac or occupational disease).
Age between 20-60 years old.	Unwilling to consent or participate in the research.
Not involved in firefighting activities	
No previous occupational exposure with firefighting.	

3.5 Study Period

This study was conducted from September 2015 to June 2016.

3.6 Sampling Size

The sample size was calculated based on a variable using single mean formula.

$$n = \left[Z \frac{\sigma}{\Delta} \right]^2$$

$$n = \left[\frac{1.96\sigma}{\Delta} \right]^2$$

Based on Al-Malki (2009), the standard deviation of lead in blood is 1.06 among firefighters with an assumption of 0.5 µg/L. The expected response rate is 80%, thus the sample size also included 20% in the calculation for unresponsive subjects in this study. The sample size calculated was 20 subjects for each group (exposed and non-exposed group). Thus, the total number of subjects for both groups combined was 40 subjects.

3.7 Sampling Method

The sampling methods used in this study involved convenience sampling.

3.8 Sampling Reagents, Apparatus & Materials

3.8.1 Reagents

The reagents used in the determination of serum heavy metal are listed in Table 3.3.

Table 3.3: List of reagents used in serum heavy metal determination

No.	Reagents used	Company/Sources
1	67% Nitric Acid	Merck, KGaA
2	99% Perchloric acid	Sigma-Aldrich

3.8.2 Apparatus

The apparatus used in the determination of serum heavy metal are listed in Table 3.4.

Table3.4: List of apparatus used in determination of serum heavy metal

No.	Apparatus used	Company/Sources
1	Volumetric flask with stopper 10 mL	Iwaki Pyrex®
2	Beaker 50 mL and 100 mL	Pyrex, England
3	Pasteur pipette	School of Health Sciences
4	Amber bottle	LabStock
5	Test tube rack	School of Health Sciences
6	Ice box	School of Health Sciences
7	Glass rod	School of Health Sciences
8	Measuring cylinder 50 mL and 100 mL	HmbG Ev 20°C^{MC}
9	Centrifuge tube	School of Health Sciences