EXPOSURE TO PARTICULATE MATTER (PM_{10}) IN INDOOR AIR AND LUNG FUNCTION TEST AMONG DENTAL LABORATORY TECHNOLOGISTS AND ADMINISTRATION WORKERS IN KOTA BHARU

by

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A dissertation submitted in partial fulfillment of the requirements for the Degree of Bachelor of Health Sciences (Hons) (Environmental and Occupational Health)

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CERTIFICATE

This is to certify that the dissertation entitled 'Exposure to Particulate Matter (PM_{10}) in Indoor Air and Lung Function Test among Dental Laboratory Technologists and Administration Workers in Kota Bharu is the bonafide record of research work done by Nur Diyanah Saidi, Matric Number 109514 during the period of July 2013 to June 2014 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfillment for the degree of Bachelor of Health Sciences (Hons) (Environmental and Occupational Health). Research work and collection of data belong to the Universiti Sains Malaysia.

Date: 3/7/14

APPROVAL PAGE

This is to certify that I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation submitted in partial fulfillment for the degree of Bachelor of Health Sciences (Hons) (Environmental and Occupational Health).

Date: 03.07.2014

Date: 02/07/2014

DECLARATION PAGE

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions.

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LIST OF ABBREVIATIONS AND SYMBOLS

ALA	American Lung Association
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular Disease
DOSH	Department of Occupational Safety and Health
dB(A)	decibels
EPA	Environmental Protection Agency
et al.	*et alia* (and others)
etc.	*et cetera* (and other things)
FVC	Forced Vital Capacity
FEV_1	Forced Expiratory Volume in One Second
FEV_1 / FVC	Forced Expiratory Volume in Second over Forced Vital Capacity
HUSM	Hospital Universiti Sains Malaysia
HSL	Health and Safety Laboratory
HVAC	Heating Ventilation Air Conditioning
IAQ	Indoor Air Quality
ICOM	International Conference of Medicine
IQR	Inter quartile range
NDEP	Nevada Division of Environmental Protection
NIOSH	National Institute of Safety and Health, US
LFT	Lung Function Test
MOH	Ministry of Health
OSHA	Occupational Safety and Health Administration
OSHS	Occupational Safety and Health Sydney
p	*p value*
PEL	Permissible Exposure Limit
PM	Particulate Matter
$PM_{2.5}$	Particles with aerodynamic diameter smaller than 2.5 µm
PM_{10}	Particles with aerodynamic diameter smaller than 10 µm
PPE	Personal protective equipment
PPSG	Pusat Pengajian Sains Pergigian
RTC	Rural Trade Centre
SPSS	Statistical Package for the Social Sciences
TSPs	Total Suspended Particulates
TWA	Time-weighted Average
USEPA	United States Environmental Protection Agency
USM	Universiti Sains Malaysia
VOCs	Volatile Organic Compounds
WEL	Workplace Exposure Limit
WHO	World Health Organization
µg/m³	microgram per cubic meter
mg/ m³	milligram per cubic meter
L	litre
°C	degree celsius
X^2	statistic for testing hypothesis
n	sample size
%	percentage
< / >	less than / more than

PENDEDAHAN KEPADA ZARAH TERAMPAI (PM_{10}) DALAM UDARA DALAMAN DAN UJIAN KEFUNGSIAN PARU-PARU DALAM KALANGAN JURUTEKNOLOGI MAKMAL DAN PEKERJA PENTADBIRAN PERGIGIAN DI KOTA BHARU

ABSTRAK

Zarah terampai (PM) adalah bahan yang boleh menjejaskan kualiti udara dan juga kesihatan masyarakat sekeliling. Kajian ini adalah satu kajian perbandingan bertujuan untuk membuktikan terdapat hubungan yang signifikan antara pendedahan kepada PM_{10}, keupayaan fungsi paru-paru dan simptom pernafasan dalam kalangan juruteknologi makmal dan pekerja pentadbiran pergigian menggunakan kaedah persampelan secara berturutan. 60 subjek telah dipilih dari sebuah klinik pergigian swasta, lapan klinik pergigian awam dan satu pejabat pentadbiran pergigian di Kota Bharu. 40 subjek terdiri daripada juruteknologi pergigian dan 20 subjek adalah pekerja pentadbiran pergigian. Soal selidik telah digunakan untuk mengumpul data mengenai sosio-demografi, ciri-ciri kerja dan simptom pernafasan dalam kalangan subjek. Pemantauan kawasan dan individu dijalankan untuk mengukur tahap kepekatan PM_{10}. Pendedahan individu PM_{10} diukur menggunakan *TSI SidePak AM510 Personal Aerosol Monitor* yang dipakaikan pada pekerja selama lapan jam dalam zon pernafasan dengan tiub sedutan fleksibel diklipkan pada bahu dan pam dipakai pada tali pinggang. Median bagi purata pendedahan PM_{10} yang dicatatkan dalam kumpulan juruteknologi pergigian adalah lebih tinggi 0.09 (IQR 0.07-013) $\mu g/m^3$ berbanding kumpulan pekerja pentadbiran 0.02 (IQR 0.02) $\mu g/m^3$ ($p<0.05$). *COSMED Pony FX Desktop Spirometer* telah digunakan dalam ujian fungsi paru-paru yang dilakukan tiga kali bagi setiap subjek dan hasil terbaik dipilih. Ujian fungsi paru-paru tidak memberi sebarang perbezaan yang signifikan antara kedua-dua kumpulan. Hanya simptom *wheezing* ($p=0.038$) dan batuk teruk ($p=0.005$) mempunyai hubungan signifikan dengan pendedahan terhadap PM_{10}. Simptom pernafasan bergantung kepada tempoh pendedahan, umur dan sensitiviti individu yang terdedah. Bacaan PM bagi pemonitoran kawasan dan diri melebihi had pendedahan yang dibenarkan. Kesimpulannya, tidak terdapat hubungan yang signifikan antara pendedahan kepada PM_{10} dengan ujian fungsi paru-paru. Pihak pengurusan perlu memastikan langkah pencegahan dan kawalan dilaksanakan secara berkesan dan memberi latihan kepada pekerja yang terdedah.

EXPOSURE TO PARTICULATE MATTER (PM_{10}) IN INDOOR AIR AND LUNG FUNCTION TEST AMONG DENTAL LABORATORY TECHNOLOGISTS AND ADMINISTRATION WORKERS IN KOTA BHARU

ABSTRACT

Particulate matter (PM) is the substance that could affect the air quality as well as the health of surrounding people. This cross-sectional comparative study aimed to prove there is a significant relationship between exposure to PM_{10}, lung function capability and respiratory symptoms among dental laboratory technologists and administration workers using consecutive sampling method. Sixty subjects were recruited from one private dental clinic, eight public dental clinic and one dental administration office in Kota Bharu. Fourty subjects were dental technologists and twenty subjects were dental administration workers. Self-constructed questionnaire was used to gather data on socio-demographic, work characteristics and respiratory symptoms among subjects. Area and personal monitoring were conducted to measure PM_{10} concentrations. For personal PM_{10} exposure, TSI SidePak AM510 Personal Aerosol Monitor was attached to the worker for eight hours within breathing zone by clipping flexible suction tubing on the lapel and the pump was worn on a belt. The median of average exposure to PM_{10} recorded in dental technologists group is significantly higher 0.09 (IQR 0.07-0.13) $\mu g/m^3$ compared to the dental administration workers group 0.02 (IQR 0.02) $\mu g/m^3$ ($p<0.05$). COSMED Pony FX Desktop Spirometer was used in lung function test (LFT) which performed three times for each subject and the best result was selected. The LFT gave no significant difference between these two groups. Presence of respiratory symptoms depend on the duration of exposure, age and sensitivity of the exposed person. PM readings for both area and personal monitoring exceeded the PEL. Only wheezing ($p=0.038$) and severe cough ($p=0.005$) were significantly associated with average PM_{10} exposure. In conclusion, there was no significant relationship between exposure to PM_{10} with LFT. The management have to ensure the prevention and control measures are efficiently implemented and give training to the exposed population.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Indoor air quality is an important determinant of a healthy building design. Our building interiors, usually describe as providing safe spaces from the harmful effects of outdoor air pollution and harsh climates, may actually be more polluted than the surrounding ambient environment (Spengler and Chen, 2000). On average, individuals spent 92% of their day inside of the buildings and only 8% was actually spent outside (Sarigiannis and Mucci, 2009). Acceptable indoor air quality is air in which there are no known contaminants at harmful concentration as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction (ASHRAE, 2001).

Indoor air pollutants can be originated from various sources. They might be coming from the activities of building occupants as well as the materials that come off of the buildings. Sources of indoor air pollutants can either come from non-biological sources or biological sources. Biological sources includes indoor allergens, fungi, bacteria and viruses (Montanaro, 1997). Natural sources, combustion and man-made sources are contributing factors to pollutants from non-biological sources (Jones, 1998).

Indoor particulate matter (PM) has been associated with increased respiratory symptoms. Environmental Protection Agency is concerned about particles that are 10 microns in diameter or smaller because those are the particles that generally pass through the throat and nose, and finally enter the lungs (EPA, 2013). Once inhaled, these particles can affect the lungs and cause serious health effects (NDEP, 2013). Most indoor air pollutants directly affect the respiratory and cardiovascular systems (IQAir, 2004). Several independent groups of investigators have shown that the size

of the airborne particles and their surface area determine the potential to elicit inflammatory injury, oxidative damage, and other biological effects. These effects are stronger for fine and ultrafine particles because they can penetrate deeper into the lower respiratory tract and can reach the alveoli in which 50% are retained in the lung parenchyma (Valavanidis *et al.*, 2006).

A study conducted in 421 houses in northern-central Italy showed a positive correlation between indoor $PM_{2.5}$ exposure and the presence of bronchitis and asthmatic symptoms, especially during the winter season (Simoni *et al.*, 2002). This might support a prior study findings conducted in Oslo homes showed that indoor suspended PM contained a large amount of potential allergen carriers (Ormstad, 2000). The presence of organic pollutants together with these allergens or endotoxin may exert a proinflammatory effect, leading to the exacerbation of allergic diseases such as asthma (Leung *et al.*, 2002). The direct human health effects of indoor air pollution on the respiratory system vary according to both the intensity and the duration of exposure, and also with the health status of the population exposed. Certain parts of the population may be greater at risk, for example, children and elderly, those already suffering from respiratory disease, hyper-responders and people exercising (IQAir, 2004).

The adverse effects of indoor PM are dependent on deposition in the respiratory tract and the ability of the respiratory tree to remove them, which is directly related to particle size and chemical composition (Bernstein *et al.*, 2008). Indoor PM may carry toxic pollutants and reaction products into the airway, generating oxidative stress (Ormstad, 2000). Many organic chemicals associated with ambient particulate matter are redox active and have been shown to induce pro-inflammatory responses through the generation of oxidative stress (Leem *et al.*, 2005). Symptoms related to poor indoor air quality can be easily mistaken for

symptoms of other illnesses such as allergies, stress, colds, and influenza (OSHA, 2011).

There is a growing public awareness regarding the risk associated with poor indoor air quality in the home and workplace. A major limitation of understanding the adverse health effects of these specific air pollutants is the inability directly to equate measurable ambient air concentrations to personal exposure (Bernstein *et al.*, 2008). Actual human exposures are often difficult to quantify because of the behaviour and activity patterns of individuals can strongly affect their levels of exposure (Harrison, 1997).

A systematic approach should be used by an employer when addressing air quality in the workplace. Management needs to be receptive to potential concerns and complaints, and to train workers on how to identify and report air quality concerns. If employees express concerns, prompt and effective assessment and corrective action is the responsibility of the management (OSHA, 2011). The first and fundamental step in the control of hazards is their recognition. This is essential to establish priorities for action and to select appropriate control strategies (WHO, 1999).

It has been estimated that air pollution reduces the life expectancy of every person in the United Kingdom by an average of 7 to 8 months, with estimated equivalent health costs of up to 20 billion pound each year (Crump, 2004). Hence, it is crucial to maintain the proper condition of indoor air quality. Some changes to a better ambient might be costly but it is worth it to compare with the high cost of health care.

1.2 Problem Statement and Significance of Study

Since the 1970s, many energy-conserving buildings have been built in the North America and Europe. Improved energy conservation was mainly achieved through reducing exchanges between outdoor fresh air and indoor air. Meanwhile, synthetic materials and chemical products have been widely used in these airtight buildings (Zhang and Smith, 2003). Rising expectations of occupants for healthy work environments are forcing building owners, operators, and managers to reconsider the importance of indoor air quality (IAQ). In a survey conducted by the International Facility Managers Association, IAQ and thermal comfort were the top operational issues in all types of buildings (Tatum, 1998). It is estimated that approximately 3% of cardiopulmonary and 5% of lung cancer deaths are attributed to PM globally (WHO, 2013).

In the past decades, many studies highlighted the role of ambient airborne PM as an important environmental pollutant for many different cardiopulmonary diseases and lung cancer (Valavanidis *et. al*, 2006). PM pollution is also linked to an increased risk for hospital admission for cardiovascular and respiratory diseases, increased risk of myocardial infarction among the elderly, triggering of acute cardiac decompensation in heart failure patients, and an increase in the rate of hospital admissions for exacerbation of congestive heart failure (Wellenius *et al.*, 2005). A recent scientific report from the American Heart Association concluded that PM is a modifiable risk factor contributing to cardiovascular morbidity and mortality (Brook *et al.*, 2010).

In the case of dental settings, both substances (such as acrylate compounds, organic solvents, disinfectants, etc.) and dental materials routinely used in the course of dental procedures can spread into air within the dental working environment and affect the related indoor air quality possibly giving rise to dermatological and

respiratory effects (Leggat *et al.*, 2007). The dental setting is a complex environment in which a lot of diverse operations take place and in which different patterns of exchange with outdoor do exist (Santarsiero *et al.*, 2009).

Dental technologists are exposed to several fibrogenic dusts and many cases of *pneumoconiosis* have been reported since 1962. Self-employed dental technologists were particularly at risk for occupational lung disease whom most worked without ventilation for more than eight hours a day. Lung fibrosis may be induced by silica dust and probably also by other particles generated during the production of dental prostheses, such as aluminium oxide, asbestos fibres, various metals such as cobalt-chromium-nickel alloys and beryllium (Choudat *et al.*, 1993).

Future investigations into air pollution-induced cardiovascular diseases must not only include more studies to determine the mechanisms of action but also examine the role of each specific component of air pollution to determine what combination of particles is to blame for this sudden increase in environment-induced health concerns. This information is crucial for policy makers to determine acceptable levels of air pollution and to design ways to minimize the harmful effects of particles on the body (Qinghua *et al.*, 2010).

Therefore, it is important to carry out this study in order to evaluate the difference in quality of indoor air between dental laboratories and dental administration department and relate it with the current respiratory health condition of the workers. It is also crucial to assess any ventilatory impairment occurring to the workers.

1.3 Research Hypothesis

1. The PM concentrations in indoor air of dental administration department are lower than the PM concentrations in indoor air of dental laboratories.
2. The lung function capability among dental administration workers are better than the lung function capability among dental laboratory workers.
3. The higher the concentrations of PM, the lower the lung function capabilities among laboratory technologists compared to the administration workers.
4. The higher the concentrations of PM, the higher the respiratory symptoms reported among dental laboratory technologists compared to administration workers.

1.4. Objectives

1.4.1 General objectives

The main purpose of this study is to prove that there is significant relationship in the effect of PM on lung function among dental laboratory technologists.

1.4.2 Specific objectives

1) To determine the levels of personal PM exposures among technologists in dental laboratory and workers in dental administration department.

2) To measure the lung function capability among technologists in dental laboratory and workers in dental administration department.

3) To compare the levels of PM exposures and lung function between the dental laboratory technologists and the dental administration workers.

4) To investigate the relationship between the levels of PM exposures and reduced lung function and respiratory symptoms among dental laboratory technologists.

1.5 Study Framework

The study framework is summarised as shown in Figure 1.1. The sampling of the study were held in Administration Department and Dental Laboratory of School of Dental Science, HUSM and selected dental clinics all over Kota Bharu, Kelantan. The laboratories presumably contain various contaminants, mostly PM. The main PM are PM_{10} and $PM_{2.5.}$ These particulates can enter human body mainly through inhalation. For the work area ambient air quality, monitoring was done by Handheld 3016 IAQ Particle Counter Area Monitor for eight hours throughout the daily working period at each sampling location. To estimate the exposure level of these particulates to each worker, the sampling was carried out using personal aerosol exposure monitoring instrument. The SidePak AM510 Personal Aerosol Monitor was used for this sampling purpose. Prior the personal aerosol monitoring, the lung function test (LFT) was conducted, using portable spirometer for each workers. In addition, questionnaires were given to be answered by each subject after the LFT are performed. Afterwards, the gathered data from the area monitoring, LFT, personal aerosol monitoring and questionnaires were analysed for any correlations. The difference of particulate matter effects on lung function between dental laboratory technologists and dental administration workers were compared.

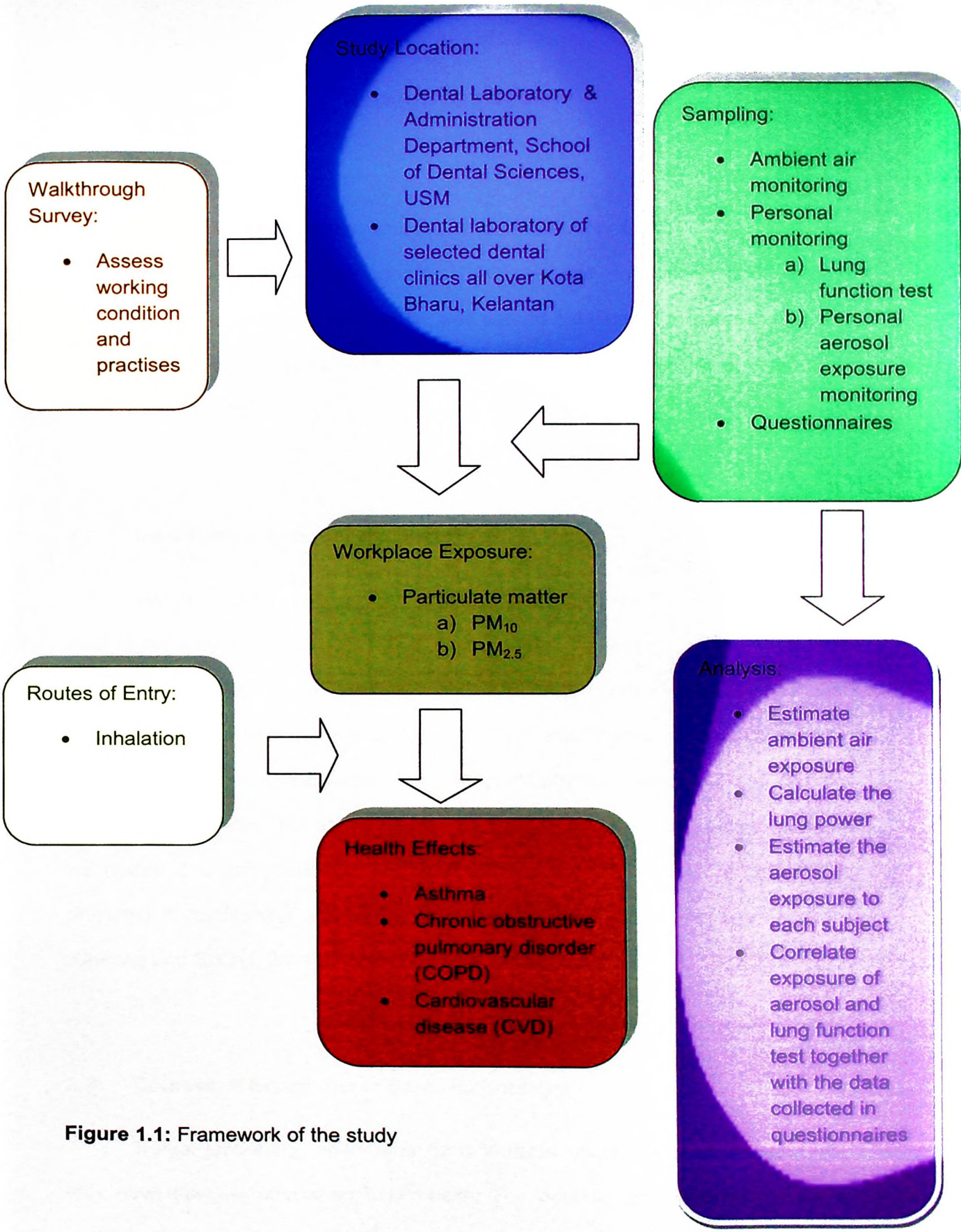

Figure 1.1: Framework of the study

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Search

Literature search on keywords such as respiratory health effects, particulate matter exposure, indoor air quality (IAQ), dental laboratory and settings, cardiovascular disease and ambient air was carried out using Google search engine, books and e-journals from USM Hamdan Tahir Library to gather pile of facts on the study subject matter.

2.2 Introduction to Indoor Air Quality

IAQ in a building is a very important element to ensure the health and comfort level of the building occupants. This is because work productivity may be interrupted due to the polluted environmental condition and consequently to bad work performance (Kamaruzzaman and Sabrani, 2011). Indoor environment in a restricted space is a complex and dynamic combination of physical, biological, and chemical factors that can affect the occupants' health and physical reactions anytime whether we realise it or not (Hodgson, 2002). The only aspect to achieve high IAQ is by providing a comfortable and clean indoor environment for the building occupants (Cheong and Chong, 2001).

2.3 Sources of Exposures in Dental Laboratory

Dental laboratory technicians have multiple occupational exposures, which may have adverse effects on their health. The potential occupational risk factors include chemical, physical, biological and other job-related factors (OSHA, 2002).

Exposure to physical risk factors include nuisance dust, noise, vibration, machinery and working space. Chemical risk factors consist of gases, fumes, vapours and liquid. While biological risk factors include infection, bacteria and viruses (OSHS, 2010).

Dental materials comprise of a widely different composition, such as metals, resin-based synthetic polymers, cements and impression materials (Adel and Mostafa, 2012). Kim *et al.*, (2002) also stated that the significant exposure among dental technicians is commonly to dust. Dust is generally understood to be an aerosol of solid particles, mechanically produced, with individual particle diameters of 0.1 µm upwards (HSL, 2000). There are three dental procedures that promotes dust formation which are polishing and grinding, sandblasting and mixing and investing (OSHS, 2010). Reactions to metals chromium, cobalt and nickel has also been previously reported (Franz, 1982) due to exposure to inorganic dust in the manufacturing of cobalt-chromium based dental constructions (Seldon *et al.*, 1995).

2.3.1 Particulate Matter (PM)

Particulate Matter (PM) is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air. The particles are identified according to their aerodynamic diameter. PM with aerodynamic diameter below than 2.5 µm are more dangerous since, when inhaled, they may reach the peripheral regions of the bronchioles, and interfere with gas exchange inside the lungs (WHO, 2011). Common chemical constituents of PM include sulfates, nitrates, ammonium, other inorganic ions such as ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal material, particle-bound water, metals (including cadmium, copper, nickel, vanadium and zinc) and polycyclic aromatic hydrocarbons. In addition, biological components such as allergens and microbial compounds are found in PM (WHO, 2013). The size distribution of total suspended particles (TSPs) in

the ambient air is trimodal, including coarse particles, fine particles, and ultrafine particles (Pope and Dockery, 2012).

2.3.1.1 $PM_{2.5}$

$PM_{2.5}$ are particles with an aerodynamic diameter smaller than 2.5 μm (WHO, 2011). These pollutants are made up of a number of components, including NH_3, organic chemicals, volatile metals, soil or dust particles, and allergens (Hu and Jiang, 2013). Unlike most air pollutants that consist of only one chemical compound, $PM_{2.5}$ particles consist of multiple compounds and are formed from primary and secondary participles (Ji *et al.*, 2013). They are finer particles which considered to be more dangerous than coarser material (PM_{10}) because they are small enough to evade the body's respiratory defense mechanisms and lodge deep in lung tissue. For that reason, these tiny particles appear to have the greatest health-damaging potential (WHO, 2013). However, these particles are formed from gas and condensation of high-temperature vapours during combustion. The major sources of $PM_{2.5}$ are fossil fuel combustion, vegetative burning and the smelting and processing of metals (Fierro, 2000). Since $PM_{2.5}$ participles consist of multiple compounds, multi-pollutant controls are needed to reduce $PM_{2.5}$ pollutants (Wang and Hao, 2012).

2.3.1.2 PM_{10}

Coarse particles (PM_{10}) have an aerodynamic diameter between 2.5 μm and 10 μm. They are formed by mechanical disruption such as crushing, grinding and abrasion of surfaces, evaporation of sprays and suspension of dust (Fierro, 2000). The highest concentration of PM_{10} is often observed during the dry season and has been found significantly associated with haze (Lodhi *et al.*, 1997). In 1987, the Unites

States Environmental Protection Agency (USEPA) switched its air quality standards from Total Suspended Particulate (TSP) to PM_{10} standards which also been adopted in Brazil, Japan, and the Philippines. Like a few other Asian countries in the world, PM_{10} has become a common air pollution problem in Malaysia (Kim *et al.*, 2006). Various studies have shown that PM_{10} aggravates many serious effects on human health (Awang *et al.*, 2000). Some industrial and other processes that produce large amounts of dust, such as cement manufacturing, mining, stone crushing, and flour milling, also tend to generate particles larger than 1 micron and mostly larger than 2.5 microns (World Bank Group, 1998). Besides, PM_{10} includes both fine particles ($PM_{2.5}$) and coarse particles, which is the subset of PM_{10} that is larger than 2.5 μm and smaller than 10 μm (USEPA, 2006). The fact that dental procedures involve processes that produced large amount of dust with mostly larger than 2.5 microns ($PM_{2.5}$) and both fine and coarse particles are included in PM_{10}, thus make PM_{10} suitable as the study parameter.

2.3.1.3 Permissible Exposure Limit

Air quality guidelines and standards were developed in an attempt to reduce adverse impacts on human health and the environment (Fierro, 2000). Very little information is available regarding permissible exposure levels for the home or non-industrial workplace for known indoor air pollutants. Many experts recommend indoor air pollutant levels be maintained at 50% or less than the National Ambient Air Quality Standards for outdoor air pollutants established by the Environmental Protection Agency (Bernstein *et al.*, 2008).

Table 2.1: Outdoor ambient air quality standards

Year	Indicator	Averaging Time	Level
1987	PM_{10}	24-hour	150 $\mu g/m^3$
1997	$PM_{2.5}$	24-hour	65 $\mu g/m^3$
	PM_{10}		150 $\mu g/m^3$
2006	$PM_{2.5}$	24-hour	35 $\mu g/m^3$
	PM_{10}		150 $\mu g/m^3$
2012	$PM_{2.5}$	24-hour	35 $\mu g/m^3$
	PM_{10}		150 $\mu g/m^3$

Source: Environmental Protection Agency (EPA) (2013).

According to Table 2.1 above, the average outdoor ambient air quality standards for PM_{10} for the four consecutive years is 150 $\mu g/m^3$. As mentioned by the allergists, the recommended level of indoor ambient air quality should be maintained at 50% or less than the outdoor (Bernstein *et al.*, 2008). Therefore the recommended level of indoor air quality standards of PM_{10} is 75 $\mu g/m^3$ or less for 24-hour period.

2.3.2 Other Exposures

There are numerous chemical hazards in denture production. They include solvents, mineral acids, gases and vapours released during polymerisation, metal casting, and porcelain baking, as well as dust coming from plaster, metal alloys, ceramics, and acrylic resins (Torbica and Krstev, 2006). The noise in the dental laboratories is mostly caused by grinding, cutting, and polishing operations and exhaust ventilation. The noise levels might probably exceeds the action levels for harmful noise during cutting and grinding metal surfaces and plaster casts (up to 92 dB(A)) (Nakladalova *et al.*, 1995). Dental laboratory personnel are at risk of acquiring infections from dental prostheses that have not been properly disinfected. Studies on

dental workers, including dental technicians, suggest that hepatitis A virus can be considered a hazard and that the risk increases with exposure duration (Ashkenazi *et al.*, 2001). Dental technicians reported a high prevalence (42%) of foreign bodies in their eyes during a one month period. Therefore protection of the eyes should also be emphasized (Al Wazzan *et al.*, 2001).

2.4 Prevention and Control Measures

2.4.1 Elimination

The USEPA, the American Lung Association (ALA) and other experts agree that source control is the only completely effective way to remove pollutants from indoor environments. They also agree that total eradication of indoor air contaminants often is not feasible or practical. A more realistic goal is to use building materials, furnishings, finishes, office equipment and cleaning products and processes that emit low levels of volatile organic compounds (VOC). Surface cleaning also removes larger particles and kills bacteria and viruses on floors, furniture, walls, doorknobs, bedding and linens and bathroom fixtures. In addition, keeping the heating, ventilating and air-conditioning (HVAC) system in good working order and air ducts and drip pans clean is important for minimizing dust and particle accumulation and indoor mold growth within the system (Air Quality Sciences Inc., 2008).

With the exception of off-gassing new building materials, sources of indoor air contaminants can usually be controlled or managed by the owner. These include proper use of bathroom and kitchen exhaust fans, discontinuing indoor tobacco smoking, proper ventilation of gas stoves and furnaces, proper storage of cleaning supplies, fuels and chemicals, and adequate cleaning procedures including the indoor air conditioning coil and duct system (Indoor Air Quality Journal, 2010).

2.4.2 Engineering Controls

2.4.2.1 Ventilation

Ventilation and air cleaning are invaluable for picking up where controlling sources of indoor air pollutants leaves off. The two work hand-in-hand, as many types of air cleaners are an integral part of the HVAC system. A well-designed and properly operating HVAC system brings in and conditions outdoor air and circulates the air through the building. The primary benefit beyond warming, cooling and managing the humidity the air is to dilute indoor air pollutants to minimise their impact on the indoor environment and building occupants (Air Quality Sciences Inc., 2008). Localized ventilation systems are based on the capture of the pollutant at, or as close as possible to, the source. The capture is accomplished by a bell designed to trap the pollutant in a current of air. The air then flows by conduits with the help of a fan to be purified. If the extracted air cannot be purified or filtered, then it should be vented outside and should not be recycled back into the building (ILO Encyclopaedia of Occupational Health and Safety, 2011).

2.4.2.2 Air Cleaning

Simply stated, with respect to air cleaning the goal is to remove indoor pollutants by trapping them inside a mechanical device. Effective air cleaning will efficiently help to protect HVAC systems and components, protects furnishings and décor of occupied spaces, reduce housekeeping and building maintenance, reduce furnace and heating equipment fire hazards, and protects the building occupants (USEPA, 2006). Experts emphasize, however, that air-cleaning devices alone cannot ensure good IAQ, particularly where ventilation itself is inadequate. As noted, air cleaning is most effective when used in conjunction with source control and ventilation (USEPA, 2006).

2.4.3 Administrative Control

Administrative controls consist of various policies and requirements that are established at an administrative level. This includes ensuring that all laboratory personnel have been provided with adequate training to enable them to conduct their duties safely. Laboratory personnel also require prior approval and additional control measures for certain particularly hazardous operations or activities. Policies such as restricting access to areas in which particularly hazardous chemicals are used, posting appropriate signs to identify specific hazards within an area and various standard practices for chemical safety and good housekeeping be observed at all times in the laboratory may also be practiced (OSHA Lab Standard, 2012).

2.4.4 Housekeeping

Common housekeeping practices contribute to improving chemical hygiene and safety. A clean, organised work area is much safer than a cluttered or dirty one. Some appropriate housekeeping measures include keep all work areas, especially laboratory benches, clear of clutter and obstruction, cleaned regularly all working surfaces and floors, kept in the proper containers and labeled properly the wastes, should never block the access to emergency equipment, showers, eyewashes and exits and most importantly, laboratory staff should be considerate and aware of the housekeeping staff. The typical housekeeping staff is not as highly educated on laboratory exposures and their hazards as most laboratory workers (Worcester Polytechnic Institute, 2014).

2.4.5 Personal Protective Equipment (PPE)

When exposure to hazards cannot be engineered completely out of normal operations or maintenance work, and when safe work practices and other forms of

administrative controls cannot provide sufficient additional protection, a supplementary method of control is the use of protective clothing or equipment. This is collectively called personal protective equipment, or PPE. PPE may also be appropriate for controlling hazards while engineering and work practice controls are being installed (OSHA, 2013). Such equipment should be adequate to ensure personnel are protected from any exposure to the eyes, skin, and respiratory tract (OSHA Lab Standard, 2012).

2.5 Routes of Exposures

The way a harmful material enters the body is called the route of entry. The four routes of entry are skin absorption, inhalation, ingestion and injection. The respiratory system which involve inhalation is the major route of entry for airborne particulates. The deposition of particulates in different parts of the human respiratory system depends on particle size, shape, density, and individual breathing patterns (World Bank Group, 1998). Because of their small size, particulate matter are inhaled deeply into the lungs, with a portion depositing in the alveoli and entering the pulmonary circulation and presumably the systemic circulation (Qinghua *et al.*, 2010).

Skin absorption or percutaneous absorption can occur when water-soluble materials dissolved in sweat and pass through the skin into the bloodstream, causing systemic intoxication. It must be noted that spraying out the dust during work station cleaning will often lead to skin exposure and absorption, even when protective clothing is worn (de Verdee *et al.*, 1998). Often observed from the dental technologists working habit, they used to periodically spray out the dust that deported on their lab coats. Ingestion is likely when poor hygiene following eating, drinking or smoking in contaminated or dirty workplaces. Particles do not need to be airborne.

They can dissolved in water and contaminate exposed person through solution (WHO, 1999).

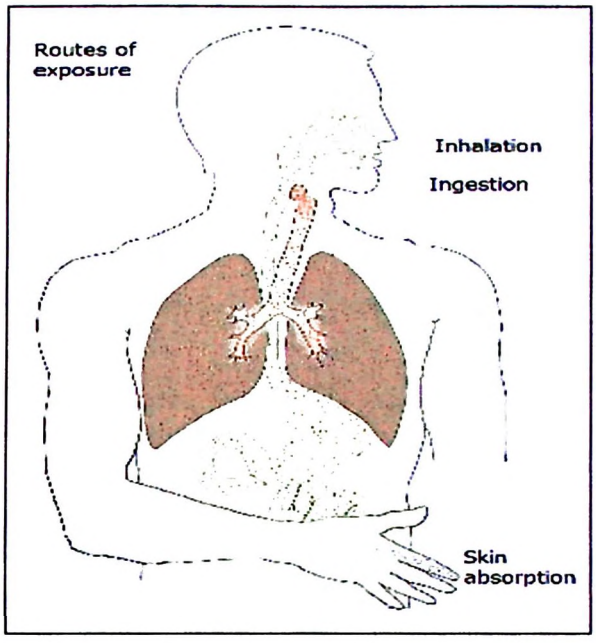

Figure 2.1: Routes of Exposure

Source: Public Health England (2013)

2.6 Respiratory Symptoms

The respiratory symptoms of PM are likely to arise depend on several factors, including the size and composition of the particles, the level and duration of exposure, age and sensitivity of the exposed person. Symptoms of exposure may include sore throat, persistent cough, burning eyes, wheezing, shortness of breath, tightness of chest and chest pain (Minnesota Department of Health, 2011). By irritating the lining of the airways and lungs, PM_{10} can cause nausea and irritation of the nose and throat (Environment Agency, 2012). A percentage of workers whom exposed to dust reported recurrent and prolonged cough, phlegm, wheeze, bronchitis, shortness of breath and bronchial asthma (Neaimi *et al.*, 2001).

2.7 Health Effects

The effects of PM on health occur at levels of exposure currently being experienced by most urban and rural populations in both developed and developing countries. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer (WHO, 2011). Some scientific studies have linked breathing PM to a series of significant health problems, including nose and throat irritation, increases in respiratory symptoms (like coughing and difficult or painful breathing), aggravated asthma, decreased lung function, lung damage, bronchitis and early death (IQAir, 2004).

The dental laboratory technologists are frequently exposed to a considerable amount of metallic and acrylic dust during finishing and grinding when making dental prostheses. These hazardous materials increase the risk of *pneumoconiosis*, asthma, pneumoconiosis hypersensitivity, chronic obstructive pulmonary diseases (COPD), cancer and fibrosis (Alavi *et al.*, 2011). A cross-sectional study designed to ascertain the prevalence of respiratory disorders in dental laboratory technicians conducted in Rasht, North Iran showed that the prevalence of respiratory dysfunction and chest x-ray findings were high (85.7%) (Alavi *et al.*, 2011). A 7-year follow-up study held to determine respiratory changes in dental technicians. Information on respiratory symptoms and demographic features questionnaires was applied. Pulmonary function tests were also performed and there was a significant worsening on spirometric findings indicated deteriorated health conditions after several years (Derya *et al.*, 2013).

2.7.1 Asthma

Asthma is a chronic lung disease characterised by reversible airway obstruction resulting from inflammation of the lung's airways and a tightening of the

muscles around them. Some degree of airway obstruction is often constantly present in those with asthma, but more severe reactions can occur due to exposure to a variety of triggers. Asthma triggers vary depending upon person and environment, but some known triggers include cigarette and other smoke, mold, pollen, dust, animal dander, exercise, cold air, household, and industrial products, air pollutants and infections (ALA, 2010). People with asthma are often referred to as "twitchy", meaning they seem to overreact to stimuli such as aero-allergens and cold, dry air. Asthma symptoms can be mild, moderate or severe, vary from person to person, flare up from time to time and then not appear for long periods and vary from one episode to the next (Asthma Society of Canada, 2012).

The relationship between PM_{10} air pollution and asthma is stronger than for $PM_{2.5}$ (Choudhury *et al.*, 1997). Epidemiological and animal studies demonstrate that PM can exacerbate asthma and increase atopy and airway hyperreactivity. There was also human-time series and controlled exposure studies show that asthmatics may be at increased risk to the cardiac effects of PM (Peden, 2009). Substances that can cause occupational asthma are called respiratory sensitisers. Some are most likely to come across from dust of latex rubber. This will affect people working with latex gloves, such as nursing, dentistry or laboratory technicians (Asthma UK, 2013).

2.7.2 Chronic Obstructive Pulmonary Disease (COPD)

Chronic Obstructive Pulmonary Disease (COPD) is a disease state characterised by airflow limitation that is not fully reversible. The airflow limitation is usually both progressive and associated with an abnormal inflammatory response of the lungs to noxious particles or gases (HSE UK, 2005). It is progressive and potentially life threatening, but not contagious. The term 'obstructive' means the person is not able to exhale well, which leaves 'old' air in the lungs and reduces the

amount of 'new' (oxygenated) air the person can bring in with the next breath (Handbook of Disabilities, 2007).

Of all the other risk factors, exposure to ambient PM, especially the inhalable particulate matter (PM_{10}), has become an important risk factor for the development of respiratory diseases including COPD. Ambient PM_{10} is associated with increased COPD hospitalisations and mortality (Zhu *et al.*, 2012). PM_{10} shows a stronger association with COPD than many other factors, even after adjusting for other major risk factors such as cigarette smoking (Schwartz, 1995).

2.7.3 Cardiovascular Disease (CVD)

Cardiovascular disease (CVD) is the leading cause of death in industrialised countries accounting for 42% of deaths in the European Union. Causes of CVD include exposure to environmental tobacco smoke, particles, carbon monoxide and other gaseous pollutants (Executive Agency for Health and Consumers, 2008). Analyses of a less severe episode observed stronger pollution-related associations with cardiovascular than with respiratory deaths (Pope and Dockery, 2012). The first American Heart Association scientific statement on "Air Pollution and Cardiovascular Disease" concluded that exposure to PM air pollution contributes to cardiovascular morbidity and mortality. Reductions in PM levels are associated with decreases in cardiovascular mortality within a time frame as short as a few years (Brook *et al.*, 2010). In addition, there have been many insights into the mechanisms whereby PM could prove capable of promoting CVDs (Simkhovich *et al.*, 2008).

2.7.4 Other effects

Scientists are evaluating new studies that suggest that exposure to high particle levels may also be associated with low birth weight in infants, pre-term deliveries and possibly fetal and infant deaths (USEPA, 2006). Even if in healthy condition, people may experience temporary symptoms, such as irritation of the eyes, nose, and throat (Arizona Department of Environmental Quality, 2006). The short term adverse health effects caused by PM include respiratory problems like wheezing, coughing, shortness of breath and chest tightness or pain (Roohi and Nazir, 2010).

2.8 Lung Function Test (LFT)

Lung function tests (LFTs) is a generic term used to indicate a battery of studies or maneuvers that may be performed using standardised equipment to measure lung function. LFTs can include simple screening spirometry, formal lung volume measurement, diffusing capacity for carbon monoxide, and arterial blood gases (Gildea and McCarthy, 2011). LFT is a way to identify various patterns of functional impairment, assessing the severity of functional defects, evaluating disability, determining suitability for certain jobs or activities and progression of diseases and its response to therapeutic measures. Commonly LFT measures of lung volumes, forced expiratory flow rates, diffusing capacity, maximum inspiratory and expiratory pressures and arterial blood gases (Fraser *et al.*, 2005). A study in Taiwan carried out to measure lung function of 45 dental technicians and monitored workplace concentrations of PM had shown that workplace PM was associated with a non-significant decrease in lung function of dental technicians (Hu *et al.*, 2006). Thirty six dental technicians working in the province of Sivas were included in the study to assess lung function of the subjects. From the results of lung function of the dental

technicians, there was no significant different found between the exposed group and the control group except for FEV_1 (Ozdemir *et al.*, 2010).

2.8.1 Spirometry

Spirometry is the most frequently performed pulmonary function test. In order to achieve a valid test result, occupational spirometry should attempt to record three or more acceptable curves with FVC and FEV_1 repeatability of 0.15L or less (American College of Occupational and Environmental Medicine, 2000). Once valid test results were obtained, correct interpretation of worker respiratory health depends on two factors. First, selecting and consistently using appropriate reference values to define the normal range for FVC, FEV1, and FEV1/FVC and secondly following an appropriate algorithm to categorize the worker's spirometry results as normal or abnormal. The measured FEV1/FVC, FVC, and FEV1 values from a worker's valid test are compared with normal ranges specific for the worker's age, measured standing height, gender, and ethnicity (OSHA, 2013). Valid test is achieved when the flow-volume curve emphasizes start of test, rising immediately to a sharp peak and smoothly descending to zero flow, while volume-time curve emphasizes end of test, initially rising rapidly, and then gradually flattening out (American College of Occupational and Environmental Medicine, 2000).