UNIVERSITI PUTRA MALAYSIA

EXPOSURE TO FINE PARTICLE (PM2.s) & ULTRAFINE PARTICLE (UFP) AND LUNG FUNCTION AMONG PHOTOCOPIERS WORKERS

NUR AYUNI BINTI BAHRUDDIN

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ABSTRACT

EXPOSURE TO $PM_{2.5}$ & UFP AND LUNG FUNCTION AMONG PHOTOCOPIERS WORKERS

NUR AYUNI BINTI BAHRUDDIN

Introduction: The photocopy workers are potentially exposed to high concentration of particles emitted from photocopiers as it is the source of indoor air pollutant which includes of fine particles ($PM_{2.5}$) and ultrafine particles (UFP). Previous studies have shown particulate air pollution influences the respiratory symptoms and associated with decrease in lung function as these tiny particles are able to travel deeply into the respiratory tract and reaching the lungs. **Objective:** The aim of this research is to determine the relationship of exposure to $PM_{2.5}$ and UFP with respiratory health among photocopiers workers. **Methodology:** A cross-sectional comparative study was involved of 30 workers of photocopiers as the exposed group and 30 of administrative staff as comparative group who fulfilled the inclusive criteria. The sampling of personal exposure to $PM_{2.5}$, UFP have been conducted and questionnaire adapted from standardized ATS has been used to assess the respiratory symptoms and lung function test have been conducted to each respondents. **Result:** The result showed the mean personal exposure to $PM_{2.5}$ (62.30 $\mu g/m^3$) and UFP (14567.10 pt/cc) among exposed group were much higher compared to the comparative group ($PM_{2.5}$= 13.10 $\mu g/m^3$, UFP= 3662.60 pt/cc). There was a significant association between personal exposure to $PM_{2.5}$ with lung function of FVC % predicted (r= -0.404, p= 0.027) and UFP with lung function of FEV_1 % predicted (r= 0.377, p=0.040). The reported respiratory symptoms of cough (26.7%), phlegm (16.7%), chest tightness (3.3%), and wheezing (6.7%) were much higher in exposed group compared to comparative group. **Conclusion:** The continuous exposure to the $PM_{2.5}$ and UFP among photocopiers workers can cause lung function impairment as the findings showed respiratory symptoms was higher among exposed group compared to the comparative group. There was also a significant association between personal exposures to $PM_{2.5}$ and UFP with lung function among exposed group. The photocopy owner should control the emission and exposure to $PM_{2.5}$ and UFP by regularly service or maintenance of photocopy machine and improve the indoor environment by ensures good ventilation.

Keywords: Exposure, $PM_{2.5}$, UFP, lung function effect, photocopiers, Selangor

ABSTRAK

PENDEDAHAN KEPADA PARTIKEL HALU & ULTRA PARTIKEL DAN FUNGSI PARU-PARU DI KALANGAN PEKERJA MESIN PENCETAK

NUR AYUNI BT BAHRUDDIN

Pengenalan: Pekerja mesin pencetak yang terdedah kepada $PM_{2.5}$ dan UFP boleh mendapat kesan jangka masa pendek seperti gejala respiratori batuk, kahak, kesesakan dada dan nafas berbunyi serta kesan jangka masa panjang seperti penurunan fungsi paru-paru. Partikel halus ini mampu untuk bergerak jauh ke dalam saluran pernafasan dan sampai ke paru-paru. **Objektif:** Objektif kajian ini adalah untuk menentukan hubungan di antara pendedahan kepada $PM_{2.5}$ dan UFP dengan pernafasan paru-paru. **Metodologi:** Satu kajian keratan rentas melibatkan 30 pekerja mesin pencetak sebagai kumpulan terdedah dan 30 kakitangan pentadbiran sebagai kumpulan perbandingan yang dimana memenuhi kriteria inklusif. Pensampalen tahap pendedahan peribadi kepada $PM_{2.5}$ dan UFP telah dijalankan dan borang soal selidik diadaptasi oleh ATS telah digunakan untuk menilai gejala respiratori serta ujian pernafasan respiratori telah dijalankan terhadap setiap responden. **Keputusan**: Hasil menunujukkan min kepekatan pendedahan kepada $PM_{2.5}$ (62.30 µg/m) dan UFP (14567.10 pt/cc) adalah lebih tinggi di kalangan kumpulan terdedah berbanding kumpulan perbandingan. Terdapat hubungan signifikan di antara pendedahan kepada $PM_{2.5}$ dengan fungsi paru-paru FVC % predicted ($r= -0.404$, $p= 0.027$) dan UFP dengan fungsi paru-paru FEV_1 % predicted ($r= 0.377$, $p=0.040$). Gejala respiratori batuk (26.7%), kahak (16.7%), kesesakan dada (3.3%) dan nafas berbunyi (6.7%) adalah lebih tinggi bagi kumpulan terdedah berbanding kumpulan perbandingan. **Kesimpulan:** Pendedahan berterusan kepada $PM_{2.5}$ dan UFP di kalangan pekerja mesin pencetak boleh menyebabkan kerosakan fungsi paru-paru seperti yang ditunjukkan oleh kajian ini. Gejala respiratori di kalangan kumpulan terdedah adalah lebih tinggi berbanding kumpulan perbandingan dan terdapat hubungan signifikan di antara pendedahan kepada $PM_{2.5}$ dan UFP dengan fungsi paru-paru di kalangan pekerja mesin pencetak. Pemilik mesin pencetak haruslah mengawal pelepasan dan pendedahan kepada $PM_{2.5}$ dan UFP dengan sentiasa servis atau menjaga mesin pencetak dan menambahbaik persekitaran dalaman dengan memastikan pengudaraan yang baik.

Kata Kunci: Pendedahan, $PM_{2.5}$, UFP, Fungsi paru-paru, Mesin Pencetak, Selangor

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LIST OF ABBREVIATIONS

ATS	American Thoracic Society
FVC	Force vital capacity
FEV_1	Forced Expired Volume in one second
NIOSH	National Institute of Safety and Health
OSHA	Occupational Safety and Health Act
$PM_{2.5}$	Fine particles
SPSS	Statistical Package Social Science
UFP	Ultrafine particles
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Photocopiers are electronic devices that use ink toner, light and electrical charges to produce photos of documents that are placed on the glass under the document handling cover, at the top of the machine. Photocopying process history is beginning when there is new printing process invented by Chester F. Carlson in 1938. The process, called *xerography* which come from Greek word where the word of '*xerox*' means dry and '*graphein*' means write, used an electrostatic dry-printing process. But in the 1960s, the Xerox Corporation began marketing the machine as a copier (Samuel, 2000).

Basically, a copy can be made through two ways of input or documents which are digital original or hard copy original. Digital original document is consisting of the sources from USB drive, email, CD, digital camera and many others, while hard copy original document is any form paper such as A4, A3, and postage stamp. Once a copy to be made by using the hard copy original document, a man power is needed

to open the copier lid and then place the document to be photocopied by face it down on the glass (Workers Health Center, 2011).

After that, the options have to be selected in order to choose number of pages, enlargements and lighter or darker. Lastly, start button will be press. However, for the digital original, no man power is needed to operate the photocopiers. Then, the output of the photocopying are available in many form that depend on the requirement of customer such as from business card to A3 form, black or white, folded booklet or prepunched for ring binder. Generally, inside of a photocopier is consisting of photoreceptor drum or belt, corona wires, lamp and lenses, toner and fuser (Workers Health Center, 2011).

The process of photocopying is involve of four parts which are charging, exposure, developing and transfer. Firstly, in charging part, the surface of a cylindrical drum is given an electrostatic charge by either a high voltage wire called a corona wire or charge roller. The drum is coated with a photoconductive material which is a semiconductor that becomes conductive when exposed to light. Then, the second part of exposure will take over when a bright lamp illuminates the original document, and the white area of the original document reflects the light onto the surface of the photoconductive drum. The areas of the drum that are exposed to light) become conductive and therefore discharge to ground. The area of the drum that not exposed to light remain negatively charged. The result is a latent electrical image on the surface of the drum (Scientific American, 2003).

After that, in the developing part is the process where the toner which is positively charged is applied to the drum to develop the image, it is attracted and sticks to the areas that are negatively charged. Lastly, the transfer part will happen when the resulting tonner image on the surface of the drum is transferred from the drum onto a piece of paper with a higher negative charge than the drum (Scientific American, 2003).

Based on the London Hazard Centre (2002), there are 5 most commonly sources of contaminates produced by the process of photocopying and printing. There are exhaust, fuser, paper path, drum and toner. Exhaust of the photocopiers can produce ozone, VOC, CO_2, and all other by-products of the copying/printing process that are vented straight to the office environment. Then, fuser of heated paper and toner can produce CO_2, formaldehyde, silicon, and oil fumes.

Other than that, the transport of large volume of paper can produce heated paper dust. Besides that, drum that using impregnated selenium or cadmium will produce hazardous gas when heated in the copying/printing process. For example, ozone is produced during the high voltage discharge process and nitrogen oxide may also be produced in some machines. Lastly, toner itself used in the photocopying becomes the contaminants as it is fine particles. The heated toner is highly toxic and toner dust is classified as a nuisance dust (London Hazard Center, 2002).

Particulate matter or particle pollution is a mixture of solid or liquid particles found in the air. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that they can be detected only with an electron microscope. Because particles originate from a variety of mobile and stationary sources such as diesel trucks, woodstoves, power plants, and so on, their chemical and physical compositions vary widely. Particulate matter can be directly emitted or can be formed in the atmosphere when gaseous pollutants such as SO_2 and NOx react to form fine particles (EPA, 2011).

In general, particle pollution consists of a mixture of larger materials, called "coarse particles," and smaller particles, called "fine particles." Coarse particles have diameters ranging from about 2.5 micrometers (μm) to more than 40 μm, while fine particles, also known as known as $PM_{2.5}$, include particles with diameters equal to or smaller than 2.5 μm (EPA, 2011).

Particles that are less than 100 nm in diameter are commonly defined as ultrafine which is 0.1 μm. Ultrafine particles are generally made from combustion processes in which growth of the particle is from molecules upwards and so these particles can be extremely small, much smaller than the problem particles in dusty trades (Donaldosn *et al.,* 2001).

1.2 Problem statement

The increasing use of photocopiers is very significant today. This is because there are an increasing number of people who often look for copy centers that provide photocopying and printing services especially the students. Photocopying is become the important information sources for the students as proved by Kakai (2004). Kakai (2004) has found that students more prefer to have photocopying services to get their information sources rather than buying original books at bookshops. They always need whether color or black-white copying and binding services for their school requirements. Even though this study is happen in overseas, this situation is also happen in Malaysia as there is increasing number of students.

There is increasing number of admission of students into the high educational institution in Malaysia. According to Ministry of Higher Education, Malaysia (2011), the number of students entered high educational institutions which comprised of public university, private university, Polytechnic, 'Kolej Komuniti' and 'Kolej TunAbdul Razak' were increased from 2005 to 2007 which is 262,626 students and 358,053 respectively. Even though, there is no statistic to show the increase number of photocopy centers, but due to increase number of students in high educational institution, this situation also has contributed to the increase number of photocopy shops as there is high requirement of photocopying services among this group of people.

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This rapid use of photocopiers will lead to health problems to the workers who handle the photocopy machine. This is because the photocopiers can contribute to the release of health hazard which are chemical fumes, gases and particulate matter (Workers Health Center, 2011). The significant hazards from the photocopiers are ultrafine particles besides the fine particles. It has been shown in the study conducted by Adetunji *et al.*, (2009) that photocopier as the main source to the increase of nano-particle count in a room.

USEPA (2011) had established National Ambient Air Quality Standards for $PM_{2.5}$ in 1997 and revised them in 2006. The short-term standard (24-hour or daily average) is 35 micrograms per cubic meter of air ($\mu g/m^3$) and the long-term standard (annual average) is 15 $\mu g/m^3$ (EPA, 2011). While in 2011, National Institute of Safety and Health (NIOSH), the US OSH institute has proposed recommended exposure limits of 2.4 mg/m^3 and 0.3 mg/m^3 for fine and ultrafine particles respectively (IFA, 2011).

Based on the nature of the photocopiers workers, they are working directly with the photocopy machine in order to make copies which this situation can increase the personal exposure towards the fine and ultrafine particles emitted from the photocopiers. Furthermore, most of the photocopy shop is using ventilation fan which this can contribute the particulate emitted from photocopiers passing into the room. Indeed, this can be a great effect exposure towards the workers. Therefore,

their health may be impacted with this exposure especially when have exposed in long term period.

According to the New York State of Department Health (2011), the photocopiers workers that exposed to fine particles can get short-term health effects such as eyes, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. This is because fine particles are able to travel deeply into the respiratory tract and reaching the lungs. Besides that, exposure to ultrafine particles can cause decrease of respiratory functions and increase in respiratory symptoms such as cough, phlegm, wheezing and chest tightness and thus it can lead to increase of medication use.

From all these health-related issues linked to the photocopiers workers, the researcher desires to find if there is any significant relationship between the exposure level to fine and UFP with lung function among the photocopiers workers in area of Selangor and also assess the respiratory symptoms experienced among them. For that, the personal exposure to the fine particles and UFP was measured using the specific instruments and measured lung function status.

1.3 Study justification

Nowadays, increasing use of photocopying machine become significant in Malaysia and this situation indirectly contributes to more involvement of workers in

this sector. For that, their health status has to be concerned. However, in Malaysia there is limited study about the exposure to fine and ultrafine particles and its effect to the worker's health. However, there is still some study has been conducted in overseas that looking into this situation. For an example, study of a cross-sectional study of respiratory and irritant health symptoms in photocopier workers in Taiwan by Yang (2008) only looks on the respiratory symptoms and does not includes the lung function.

So, it is important to conduct this study as it aims to evaluate the exposure to fine and ultrafine particles among workers and its effect to respiratory health which include the lung function. Indirectly, this study will be able to identify the workers who have respiratory symptoms at early stage and provide some basic information on abnormality of lung function among them. Therefore, this study is act as a preliminary study that shows the exposure level of these particles and effects to respiratory health among the photocopiers workers in area of Selangor.

Indirectly, this study also aims to create awareness to the people about the susceptibility to respiratory health problems that can be documented among population who's heavily exposed to the fine and ultrafine particles from photocopiers emission. Therefore, it is important to the photocopiers workers to know the effect of these pollutants towards the deterioration of lung functions and respiratory health. Moreover, photocopiers workers also will be educated on the

photocopy machine pollutants and can generate better understanding about particulate matter exposed during their daily job.

The reason of why Selangor area is chosen as study location in this study is because the photocopy shop is focused in this area which are Bangi, Kajang and Serdang as there are many institutional education and colleague present there. Therefore, there is much easier to get the respondents which are the photocopy workers in this area compared to the other area.

This study also will be beneficial to the workers as the data from this study will help the workers to know their lung function status after exposed to the ultrafine and fine particles emitted from the photocopiers. Based on that data, the workers can take precautionary steps or control measures to control this situation and further can prevent from getting the adverse respiratory health effect in the future.

Then, for the important of the business, the owner of photocopy shops can use the data resulted from conducting this study for the purpose to increase the photocopy machine and shop maintenance in order to reduce and control the exposure to fine and ultrafine particles emitted from the photocopiers. So that, they can prevent and control the respiratory health problems among their workers and also to themselves that may arise from the exposure to these particles and further can increase their health status to much higher level.

1.4 Conceptual framework

The conceptual framework of this study is ilustrated in the figure 1.1 below:

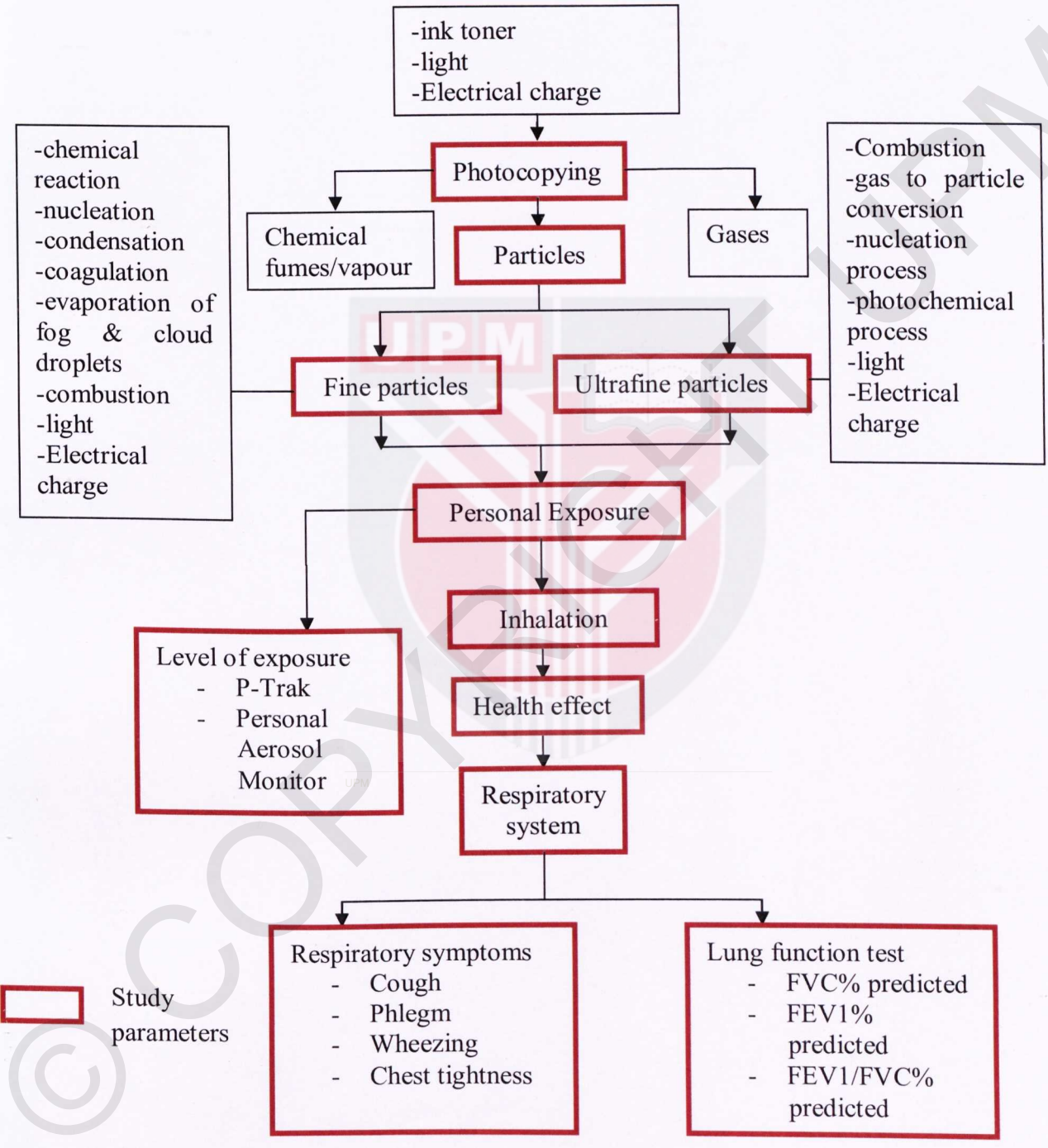

Figure 1.1: Conceptual framework

1.5 Study Objective

1.5.1 General objective

1. To determine the relationship between exposure to fine particle ($PM_{2.5}$) and ultrafine particle (UFP) with respiratory health among photocopiers workers

1.5.2 Specific objective

1. To determine the exposure of $PM_{2.5}$ and UFP among respondents
2. To compare personal exposure to $PM_{2.5}$ and UFP between exposed group and comparison group
3. To compare respiratory symptoms between exposed group and comparison group
4. To compare the level of lung function in parameter of FVC % predicted, FEV_1 % predicted and FEV1/FVC % predicted between exposed group and comparison group
5. To determine the association between personal exposure to $PM_{2.5}$ and lung function among exposed group
6. To determine the association between personal exposure to UFP and lung function among exposed group
7. To determine the association between duration of work and lung function among exposed group

1.6 Hypothesis

1. The personal exposure to $PM_{2.5}$ and UFP are significantly higher among exposed group compared to comparative group
2. The respiratory symptoms are significantly higher among exposed group compared to comparative group
3. Lung function (FVC, FEV_1) are significantly lower among exposed group compared to comparative group.
4. There is a significant association between personal exposure to $PM_{2.5}$ and lung function among exposed group
5. There is significant association between personal exposure to UFP and lung function among exposed group
6. There is a significant association between duration of work and lung function among exposed group.

1.7 Definition of variables

1.7.1 Conceptual definition

a) Fine particles

Particles that has aerodynamics less than or equal to 2.5 μm in diameter. When breathed, these particles can accumulate in the respiratory system and are associated with numerous health effects. (EPA, 2011)

b) Ultrafine particle

Particles with a diameter of less than 0.1 μm are considered as the ultrafine particle fraction (UFP) and contain the majority (in numbers) of the ambient particles and an appreciable portion of total surface area (Ibald-Mulli et al., 2002).

c) Forced Vital Capacity (FVC)

FVC is the maximal volume of air exhaled with maximally forced effort from a maximal inspiration, i.e. vital capacity performed with a maximally forced expiratory effort, expressed in litres at body temperature and ambient pressure saturated with water vapour (BPTS) (ATS, 2005).

d) Forced Expiratory Volume in One second ($FEV_{1)}$

Forced Expiratory in One Second is the maximal volume of air exhaled in the first second of a forced expiration from a position of full inspiration, expressed in litres at BTPS (ATS, 2005).

e) Chronic cough

Cough experienced for at least 4 days in a week for 3 consecutive months in 1 year/more (ATS, 1978).

f) Chronic phlegm

Having phlegm that cough up from the chest for at least 4 days in one week for at least 3 consecutive months during the year (ATS, 1978).

g) Chect tightness

A combination of cough or phlegm or increase of cough or phlegm in cases where the subject cough or having phlegm continously (ATS, 1978).

h) Wheezing

A rasper whistle sound during breathing. Having wheezing or whistling sound in braeting associated with breathlessness on most days or nights (ATS, 1978).

1.5.2 Operational definition

a) Fine particles

Monitoring the personal exposure to the $PM_{2.5}$ photocopiers workers working area using the Personal Aerosol Monitor (Model TSI AM510).

b) Ultrafine particle

Exposure to ultrafine particles is monitored by using P-Trak Ultrafine Particles Counter. The sensitivity of P-Trak is from 0.02mm to greater than 1mm. This instrument can detect in the range from 0 to 500 000 particles/cm^3.

c) Forced Vital Capacity

The measurement of maximally and forcefully exhales the volumes of air by using spirometer (Spirolab II Model) expressed in liters.

d) Forced Expiratory Volume in One second ($FEV_{1)}$

The measurement of maximal volume of air exhaled in 1 second of forced vital capacity by using spirometer (Spirolab II Model) expressed in liters.

e) FVC % predictd

A calculation to determine a normal variable value of FVC of lung function among the respondents based on value for Malaysian in normal population group.

FVC % Predicted = (FVC measured / FVC predicted) x 100

f) FEV_1 % predicted

A calculation to determine a normal variable value of FEV_1 of lung function among the respondents based on value for Malaysian in normal population group.

FEV_1 % Predicted = (FEV_1 measured / FEV_1 predicted) x 100

g) Chronic cough

Chronic cough symptoms is determine from the study questionnaire based on ATS (1978).

h) Chronic phlegm

Chronic phlegm symptoms is determine from the study questionnaire based on ATS (1978)

i) Chest tightness

Chest tightness symptoms is determine from the study questionnaire based on ATS (1978).

j) Wheezing

Wheezing symptoms is determined from the study questionnaire based on ATS (1978).

CHAPTER 2

LITERATURE REVIEW

2.1 The photocopiers

According to Occupational Safety & Health Guidelines (2001), there are four types of photocopying methods which are blueprinting or whiteprinting, thermography, electrostatic photocopying and xerography. Blueprinting or whiteprinting method copying is used for large and high quality copies of architectural and engineering plans and drawings. In this process, light is shone through the original document onto a chemically treated paper which is then exposed to an alkaline agent before a copy image is formed. Ammonia vapour emitted in this process is a hazard. Even though, its health risk can be controlled.

In thermography method, the original document absorbs heat energy from infra-red light and transfers it to a special copy paper to form the image. While electrostatic photocopying includes of two methods which are wet methods and dry

methods or called as xerography. In wet methods, it requires the handling of liquid chemicals which are liable to spillage and lead to skin contact. They pose a higher health risk to operators and emit more volatile chemicals. Therefore, these copiers are nowadays replaced by xerography, a dry process using heat and it is widely used in today (OS & H Guidelines, 2001).

Based on the source from Community and Public Sector Union of Victoria (2011), in the xerography process, the photocopiers have a light sensitive drum or belt called the photo conductor. An electrical image of the original document is recorded on the drum or belt. Very small quantities of the chemical coasting of this part of the machine can be released during normal operation. Tests have shown that even under the worst ventilation conditions, the buildup of very low levels of these chemicals near the machine does not pose a significant health risk to workers.

In this photocopying process of xerography also used toner which transferring toner onto plain paper in the right amounts and in the right places prints the image. The toner contains carbon black which is the fine particles. The particles of carbon black come in a coating of plastic. As the copy comes out of the machine the plastic is melted into the paper by heat and/or pressure, so that a black print is fixed onto the paper. Carbon black has been a cause for concern in the past because of certain chemical impurities which are suspected of being carcinogens, agents which can cause cancer. The suspect chemical is nitropyrene (Community and Public Sector Union Victoria, 2011).

The xerography or dry method involves high electrical voltages that emit significantly higher number of particulate matter besides of the VOC and ozone which can cause breathing problems. The most particulates can be emitted by malfunctioning photocopiers is UFP after the fine particles. Besides that, dry process photocopy machine also can emit nitrous oxide gas and carbon monoxide gas. Light, heat and noise also associated with the process can also cause nuisance and discomfort (OS & H Guidelines, 2001).

The hazard of these particles emitted from the photocopiers has been proved by the study conducted by Adetunji *et al.*, (2009) which has investigate the nano-particle count in a room emitted by the photocopiers. The investigation has showed that the nano-scale particle count in the room increased by approximately 5 times when the photocopier was in use as compared to when there was no activity in the room. Besides that, the size distribution showed a probable correlation with the size distribution of the photocopier toner and thus has suggested that the photocopier as the main source for the increased nano-particle count in the room.

2.2 Fine and ultrafine particles

The categories of particulate matter with a diameter less than 10 micrometers but greater than 2.5 micrometers are known as Particulate Matter 10 micron fraction (PM_{10}), particulate matter with a diameter less than 2.5 but greater than 0.1 micrometers is known as Particulate Matter 2.5 micron fraction ($PM_{2.5}$), and

particles with a diameter of less than 0.1 micrometers are considered as the ultrafine particle fraction (UFP) (Ibald-Mulli *et al.*, 2002).

Fine particles have an aerodynamic diameter less than 2.5 μm ($PM_{2.5}$). They differ from PM_{10} in origin and chemistry. These particles are formed from gas and condensation of high-temperature vapors during combustion, and they are composed of various combinations of sulfate compounds, nitrate compounds, carbon compounds, ammonium, hydrogen ion, organic compounds, metals (Pb, Cd, V, Ni, Cu, Zn, Mn, and Fe), and particle bound water. Their lifetime is from days to weeks and travel distance ranges from 100s to >1000s km (Fierro, 2000).

Ultrafine particle are composed of both primary and secondary particulate matter (Xiong, 2001). The primary fraction is generally between 50 and 100 nm which is typically the dominating concentration (Wahlin *et al.*, 2001). This fraction of UFP, emitted directly from the emission source, often includes aggregates of smaller particles (Xiong, 2001). The primary fraction is generally believed to be the product of diesel engines and automobiles which initially emitted at around the 50nm diameter size (the so called nucleation mode) and later coagulate into the larger fraction of the ultrafine mode.

The secondary component is composed of particulate matter formed in the atmosphere, including sulfuric acid and sulfates, and organic reaction products of low volatility (Xiong, 2001). This size fraction is generally between 100 and 200 nm

which is partially distinguishable from other directly anthropogenic sources. These changes involve photoreactions of oxides of nitrogen (NOx), and sulfur dioxide (SO2). Both of which are products of combustion. There is also a component of secondary particle chemistry that result in production of ammonium sulphates, nitrates, and chlorides, but these materials are thought to have less toxicological significance (Donaldson *et al.,* 2003)

2.3 Formation of fine and ultrafine particles from photocopy machine

There are different mechanisms might contribute to the formation of fine and ultrafine particles during photocopying (Lee *et al.,* 2007). The first possible formation mechanism of these particles is the nucleation/condensation of low vapor pressure substances, which were vaporized at high temperature and condensed at low temperature to form particles. Some substances from the heated toner or paper were vaporized during the fusing stage, in which the fuser temperature reached around 200°C, and their concentrations exceeded their saturation vapor concentration. Therefore, particles may form when the saturated vapour condense at a lower temperature.

The second possible mechanism of ultrafine particles formation during photocopying is the oxidation of indoor VOCs. The byproducts of corona charging during photocopying, such as ozone, NOx and OH-radicals, are both strong oxidants for the oxidations of emitted VOCs (Lee *et al.,* 2007).

There is also study has demonstrated that photo-oxidation products of aromatic hydrocarbons can undergo various reactions to produce secondary organic aerosols (SOA) in the presence of O3, OH radicals, and NOx (Jang, 2001). The microenvironment inside the photocopier is very similar to a photochemical smog chamber that contains a light source and higher concentrations of reaction agents. Therefore, SOA formation inside photocopiers might be an important source of indoor ultrafine particles during photocopying.

The third possible mechanism is ion-induced nucleation of organic vapours. Ions, which are generated by corona devices during photocopying, may play a role in the formation of ultrafine particles by ion-induced nucleation of organic vapors. Ion-induced nucleation is the gasto-particle process causing supersaturated vapors to condense on ions (Lee *et al.*, 2007).

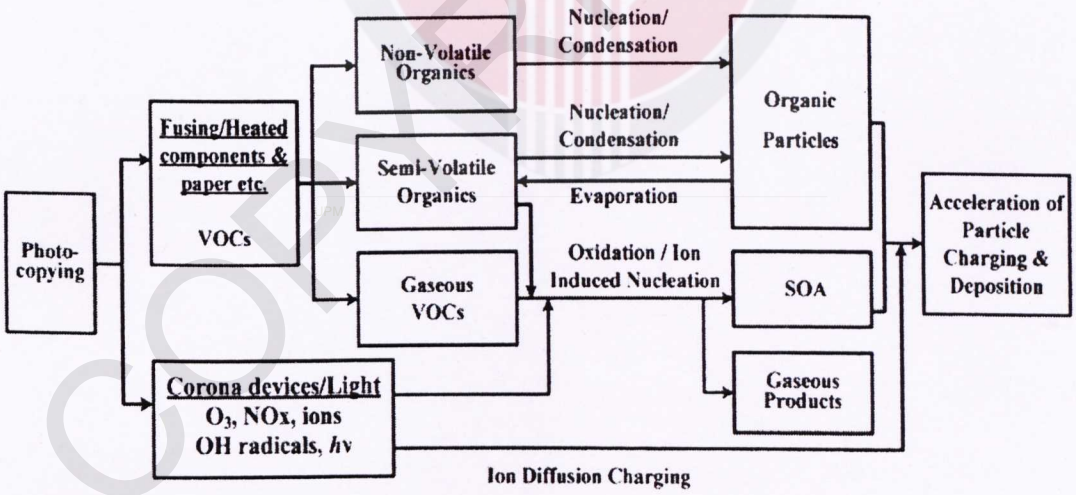

Figure 2.1: Conceptual model of indoor air chemistry and particle formation and removal during photocopying (Sources: Lee *et al.*, 2007).

2.4 Respiratory system

The human respiratory system consists of the lungs and tubes associated with the lungs. It is located in the thorax or chest. The thorax is surrounded by the ribs. The diaphragm forms the base of the thorax. Contractions of the diaphragm and the intercostals muscle change the size of the thorax and, thus, cause air to move in and out of the lungs. The main job of the respiratory system is to get oxygen into the body and get waste gases out of the body. It is the function of the respiratory system to transport gases to and from the circulatory system (Leaving Certificate Biology, 2011).

The human respiratory system consists of the nose, nasal cavity, pharynx, larynx, trachea, smaller conducting passageways which are bronchi bronchioles, and lungs as shown in figure 1. As air passes through the nasal cavities it is warmed and humidified, so that air that reaches the lungs is warmed and moist. The nasal airways are lined with cilia and kept moist by mucous secretions. The combination of cilia and mucous will helps to filter out solid particles from the air (Leaving Certificate Biology, 2011).

The trachea is made of muscle and elastic fibers with rings of cartilage. The cartilage prevents the tubes of the trachea from collapsing. The trachea is divided or branched into bronchi and then into smaller bronchioles. The bronchioles branch off into alveoli. These tubes are lined with mucous-secreting cells and tiny hairs called cilia. The mucous traps bacteria, dust and viruses. The cilia beat and create an

upward current. This moves the mucous up and into the esophagus. Here it goes to the stomach. When we clear our throats we force the mucous away from our vocal cords. This is often called coughing. It is used to get rid of irritants and excess mucous from our respiratory system (Leaving Certificate Biology, 2011).

The lungs are spongy structure where the exchange of gases takes place. Each lung is surrounded by a pair of pleural membranes. Between the membranes is pleural fluid, which reduces friction while breathing. The bronchi are divided into about a million bronchioles. The ends of the bronchioles are hollow air sacs called alveoli. There are over 700 million alveoli in the lungs. This greatly increases the surface area through which gas exchange occurs. Surrounding the alveoli are capillaries (Leaving Certificate Biology, 2011).

The lungs give up their oxygen to the capillaries through the alveoli. Likewise, carbon dioxide is taken from the capillaries and into the alveoli. Body cells use the inhaled oxygen gotten from the alveoli of the lungs. In turn, they produce carbon dioxide and water, which is taken to the alveoli and then exhaled. These exchanges occur as a result of diffusion. In each case the materials move from an area of high concentration to an area of lower concentration (Leaving Certificate Biology, 2011).

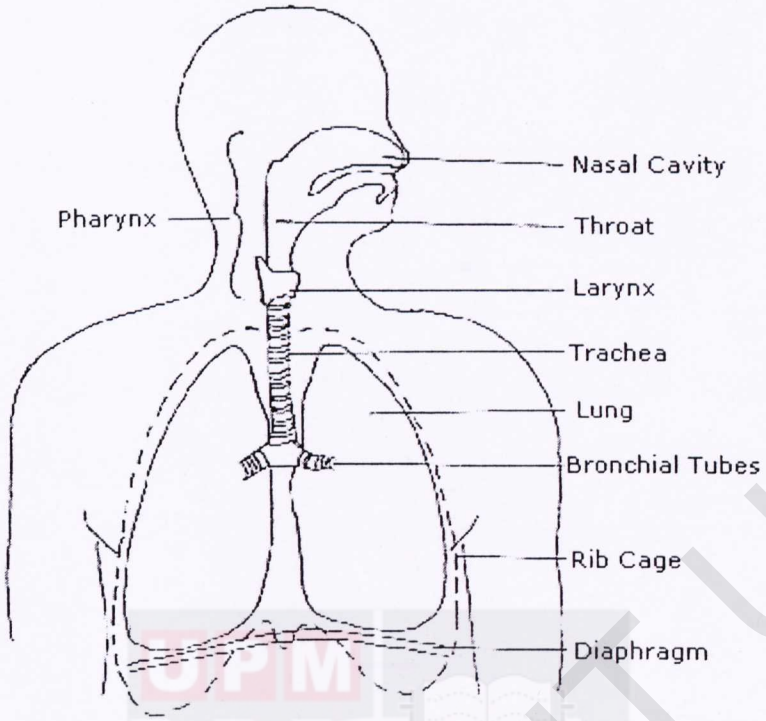

Figure 2.2: Human respiratory system (Source: BrianMac, 2011)

2.5 Particle deposition of particulate matter in respiratory system

The capacity of particulate matter to produce adverse health effects in humans depends on its deposition in the respiratory tract. Particle size, shape, and density affect deposition rates. The most important characteristics influencing the deposition of particles in the respiratory system are size and aerodynamic properties. The aerodynamic diameter of a particle is the diameter of a unit density sphere having the same settling velocity as the particle in question, whatever its size, shape or density (Fierro, 2000).

Particles between 2.5 and 10μm in aerodynamic diameters correspond to the inhalable particles capable to be deposited, in the upper respiratory tract. Particles with aerodynamic diameter smaller than 2.5μm or fine particles correspond to the respirable particle fraction capable of penetrating the alveolar region of the lung. Inhaled particles come in contact with surface of the respiratory system. These particles pass the proximal airway (throat and larynx) of the respiratory tract, and deposit in the tracheobronchial conductive airway of the lungs (bronchial and bronchiolar airway) or in the gas exchange region (respiratory bronchioles, alveolar ducts, and alveoli of the lung parenchyma (Fierro, 2000).

There are five mechanisms that influence particle deposition within the respiratory tract. The primary mechanisms are gravitational settling, impaction, and Brownian diffusion. Secondary mechanisms are electrostatic attraction and interception. These last two processes have minimal importance for inhalation and deposition of particulate matter (Fierro, 2000).

Deposition by gravitational settling occurs as a result of the influence of gravity on particles suspended in the air. The settling rate of particles is directly proportional to particle size. This process is most important in the distal region of the bronchial airway and in proximal portions of the gas exchange region (Fierro, 2000). Another mechanism of particle deposition is impaction. It occurs when particles are suspended which they tend to travel alongside their original course. When a bend

appears in the airways, for example, many particles do not spin, but rather crash or attach to a surface along their initial course. Impaction probability depends on air velocity and particle mass. This mechanism occurs primarily in the throat and larynx with particles larger than 3μm and increases with increasing particle size (Politis *et al.,* 2008).

Brownian diffusion involves collision between gas molecules and micrometer-sized particles, which push the particle in an irregular manner. It depends on the diffusive or thermodynamic diameter of the airborne particle rather than on the aerodynamic diameter. Due to this, Brownian diffusion increases with decreasing particle size. This mechanism is predominant in the gas exchange alveolar region of the lung for particles smaller than 0.5μm (Fierro, 2000).

A particle deposition by interception occurs when it moves so close to the airway surface that the edge of the particle touches the surface. This deposition method is the main method for fibres such as asbestos. The length of the fibre determines the point where the particle will be intercepted and deposit. For example, fibres of 1μm diameter and 200μm length will be deposited in the bronchial tree (Politis *et al.,* 2008).

There are other factors that also influence particle deposition, including mode of breathing (oral breathing permit the passage of particles greater than 10μm to the lung), physical activity (exercise), age, lung diseases (chronic obstructive lung

disease), and ambient conditions (increase in temperature or the presence of other pollutants) (Fierro, 2000).

2.6 Mechanism defense for clearance of particles from lung

The ability of the lung trying to protect itself against inhaled particles, clearance, will determine the adverse health effects of particulate matter. There are two clearance mechanisms: the mucociliary system and the alveolar macrophages. Particles deposited in the ciliated region of the tracheo bronchial airway, rise on the mucociliary ladder to be expelled by coughing or swallowing. Particles deposited on the terminal bronchioles are cleared by lung macrophages (Fierro, 2000).

The main clearance mechanism for insoluble particles deposited in the conducting airways is via the mucociliary escalator. Soluble particles are cleared mainly by diffusional and pinocytotic processes from this region, depending on their lipo- or hydrophilicity. The main clearance mechanism for insoluble particles in the alveolar region is based on the function of the alveolar macrophages that effectively phagocytize deposited particles and transport them toward the mucociliary escalator (Oberdorster, 1993).

Soluble compounds deposited in the alveolar region will mainly be cleared by diffusional and pinocytotic processes via inter- or transcellular pathways where lipophilicity, hydrophilicity, and molecular size play an important role. Using inhaled

particles as carriers for other chemical compounds or modulating uptake mechanisms should also be considered as a means for increasing the pulmonary retention of otherwise rapidly cleared compounds. Lung clearance and retention processes of inhaled particulate compounds may be significantly altered in the diseased lung (Oberdorster, 1993).

Ultrafine particles could also be cleared in the alveolar region by alveolar macrophages, through phagocytosis of deposited particles followed by gradual movement of the macrophages with internalized particles toward the mucociliary system. However due to difference in primary particles size and to degree of particles aggregation, ultrafine particles may escape phagocytosis, or the cascade of events leading to alveolar macrophage-mediated clearance may be more or less effective (Nemmar, 2002).

2.7 Health effect exposure to fine particles and ultrafine particles

Based on a study conducted in Germany on daily mortality shows that comparable and independent increases in mortality in association with fine and ultrafine particles. The mortality data suggest that fine particles have immediate health effects whereas ultrafine particles have more delayed effects. Immediate effects seem to be attributable to respiratory disease mortality whereas delayed effects are based on an increase in cardiovascular disease mortality (Morawska *et al.*, 2004).

Numerous epidemiological studies in the past 30 years found a strong exposure-response relationship between particulates and long-term or cumulative health effects as lung cancer, together with cardiopulmonary morbidity and mortality (Pope, 2009). These effects are stronger for fine and ultrafine particles because they can penetrate deeper into the airways of the respiratory tract and can reach the alveoli in which almost 50% are retained in the lung parenchyma, where exert genotoxicity and carcinogenic mechanisms (Schwarze *et al.*, 2006).

As explained previously, once deposited deeply into the lung, ultrafine particles which is in contrast to larger sized particles are appear to access to the blood circulation by different transfer routes and mechanisms, resulting in distribution throughout the body. The liver is the major distribution site via uptake by Kupffer cells, followed by the spleen and bone marrow as other organs of the reticuloendothelial system. Once accessed the blood circulation, ultrafine particles are so translocated to other organs including the liver, the spleen, the kidneys, the heart and the brain, where they may be deposited (Peters, 2006).

2.8 Mechanism effect exposure of fine particles and ultrafine particles to respiratory system

The particulate matter damage to lung defenses manifests itself in the form of health effects such as acute respiratory infection (both upper and lower respiratory tract infections), chronic obstructive lung disease (especially bronchitis), asthma

attacks, cardiovascular disease, and lung cancer (United Nations Environment Programme, 2011). It has been suggested that the high number of particles below 0.1 μm in diameter (UFPs) may be responsible for the adverse respiratory effects of particulate air pollution and be more strongly associated with decrease in lung function in asthmatic patients (Pekkanen, 1997).

Once the ultrafine particles been inhaled, it is not filtered out by nose and bronchioles and their size allows them to be breathed deeply into the lungs where they are able to penetrate alveolar epithelium and enter the pulmonary interstitium and vascular space to be absorbed directly into the blood stream (Terzano, 2010).

Besides, ultrafine particles have a soluble component and release transition metals or organics as their primary pro-inflammation even though the different types of ultrafine particles have differ physicochemical properties. Independently of their chemical composition, the inflammatory properties of ultrafine particles are mediated by their large numbers, small size and high penetration rate into the interstitium, as they are not readily and easily phagocytized by alveolar macrophages (Ferin, 1992).

Thus the adverse effects of ultrafine particles may be mediated in part by their ability to inhibit phagocytosis, allowing ultrafine particles and other particles that deposit along with them to persist unphagocytosed in the lung, and stimulating inflammatory responses, damaging epithelial cells and potentially gaining access to the interstitial (Terzano, 2010). Besides that, chronic exposure to ultrafine particles

can produce deleterious effects on the lung leading to chronic obstructive pulmonary disease (COPD) (David, 1998).

2.9 Lung function test and lung abnormalities

Lung function test or called as pulmonary function tests (PFT's) are breathing tests to find out how well the movement of air in and out of the lungs and how well oxygen enters the body. The most common PFT's are spirometry, diffusion studies and body plethysmography. Lung function tests can be used to:

- Compare lung function with known standards that show how well the lungs should be working.
- Measure the effect of chronic diseases like asthma, chronic obstructive lung disease (COPD), or cystic fibrosis on lung function.
- Identify early changes in lung function that might show a need for a change in treatment.
- Detect narrowing in the airways
- Decide if a medicine (such as a bronchodilator) could be helpful to use.
- Show whether exposure to substances in home or workplace have harmed the lungs.
- Determine the ability to tolerate surgery and medical procedures.

Spirometry is one of the most commonly ordered lung function tests. The spirometer measures how much air that a subject can breathe into the lungs and how

much air that can he quickly blow out of the lungs. This test is done by having a subject to take in a deep breath and then, as fast as can, blow out the air that they inhale. The subject will be blowing into a tube connected to a machine which is called spirometer (ATS, 2005).

The most common of spirometry value are the forced vital capacity (FVC), which is the volume delivered during an expiration made as forcefully and completely as possible starting from full inspiration, and the forced expiratory volume (FEV) in one second, which is the volume delivered in the first second of an FVC manoeuvre (ATS, 2005).

Lung function abnormality can be grouped into two main categories which are obstructive and restrictive defects. This grouping is based on the facts that the routine spirogram, as the centerpiece of lung function test, measures two basic components which are flow and volume. The abnormality is obstructive if expiratory flow is below normal and if lung volume is reduced, a restrictive disease probably presents (Sheldon, 2000).

An obstructive can occur in the upper airways (larynx, trachea, right or left bronchus), large airways (those greater than 2 mm in diameter) and small airways (less than 2 mm). upper airways obstruction will reduce flow rate in the initial 25% of a Forced Expiratory Vital Volume maneuver. Obstruction in the smaller airways

will reduce flow rates in the later position of the exhaled volume (Sheldon, 2000; Parkes, 1994)

A restrictive defect is present when lungs volume is reduced to less than 80% of predicted levels. This category of disease includes chest wall dysfunction, neurological disease resulting in paralysis of muscles of inspiration, dysfunction of the diaphragm, deficient lung tissue, and scaring of the lungs as with interstitial lung disease. Certain disease like severe emphysema can result in both obstructive and restrictive defects (Sheldon, 2000; Parkes, 1994).

Based on Encyclopedia Surgery (2011), common causes of an obstructive pattern are cystic fibrosis, asthma, bronchiectasis, bronchitis, and emphysema. Chronic bronchitis, emphysema, and asthma result in dyspnea (difficulty breathing) and ventilation deficiency, a condition known as chronic obstructive pulmonary disease (COPD). COPD is the fourth leading cause of death among Americans. Common causes of a restrictive pattern are pneumonia, heart disease, pregnancy, lung fibrosis, pneumothorax (collapsed lung), and pleural effusion (compression caused by chest fluid).

Obstructive and restrictive patterns can be identified on spirogram using both a "y" and "x" axis. Volume (liters) is plotted on the y-axis versus time (seconds) on the x-axis. A restrictive pattern is characterized by a normal shape showing reduced volumes for all parameters. The reduction in volumes indicates the severity of the

disease. An obstructive pattern produces a spirogram with an abnormal shape as shown in figure below. Inspiration volume is reduced. The volume of air expelled is normal but the air flow rate is slower, causing an elongated tail to the FVC (Encyclopedia Surgery, 2011).

Figures 2.3(a) - 2.3(e) show the spirogram patterns which are based on ATS, (2005) and Table 2.1 illustrated the lung function abnormalities based on the ATS, (1991).

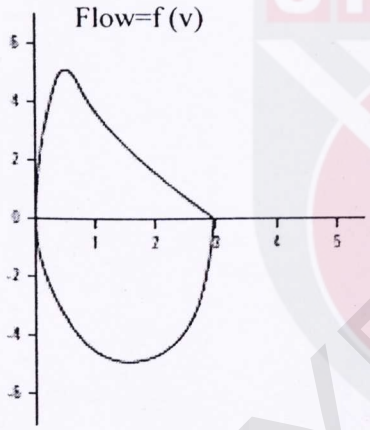

Figure 2.3(a): A normal spirometry

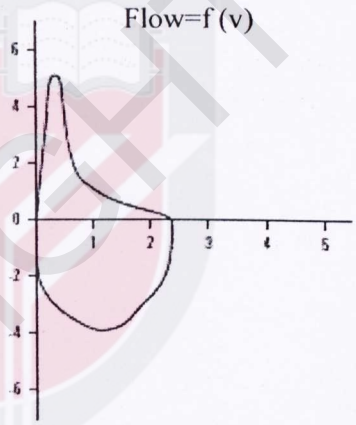

Figure 2.3(b): A mild obstructive

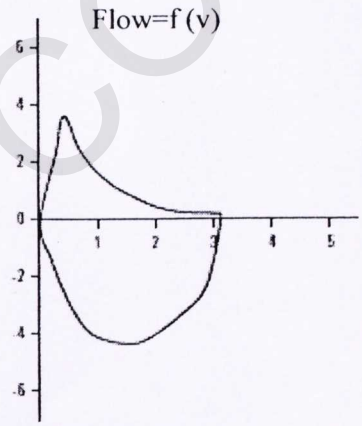

Figure 2.3(c): A severe obstructive

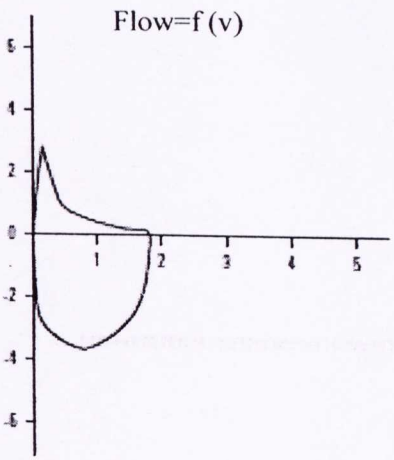

Figure 2.3(d): A mild restrictive

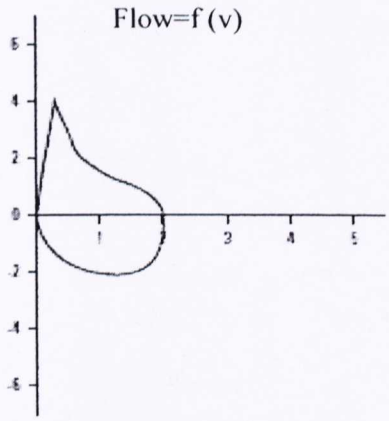

Figure 2.3(e): A severe restrictive spirometry

Table 2.1: Lung function abnormalities

Obstructive disease	**FEV_1% predicted**
Normal	≥80
Mild	79-70
Moderate	70-60
Severe	<60
Restrictive disease	**FVC % predicted**
Normal	≥80
Mild	79-70
Moderate	70-60
Severe	<60

(Sources: *ATS*, 1991)

2.10 Factors that influencing outcomes of lung function test

There are factors that will affect lung function test. Among those factors are height, age, gender, and race of the subjects. For example, taller people has higher lung function compared to those who are shorter. From gender prospective, women have been found to have lower lung function than men even though both genders have the same height, age and race. (Parkers, 1994)

Other fact identified in affecting lung function is the health status of the individual who undergone the test. If a individual has lung function like asthma and bronchitis, the result will show slightly lower than those who are disease free. Besides, smoking habit will affect lung function due to mucociliary structures damage which functions to remove precipitated particles. This condition disrupts the air passage and cause extended coughing. Besides, FEV_1 values will decrease about 0.003 liter per year for healthy person starting at the age 21 to 27 years old (Parkers, 1994).

In lung function test, several basic variables may have an impact on lung function results and must be considered in the testing process. According to Sheldon (2000), these follows factors may influence the lung function of the subjects:

1) Height

Height is the most important factor because it influencing lung size and predicted values. Generally, the tallest the person, the larger the size and predicted lung volumes.

2) Gender

Some measurements in lung function vary with the sex of the individual. When individuals are matched for height and weight, male patients normally have larger lungs than female patients.

3) Age

The Forced Vital Capacity (FVC) that is maximal amount of air that can be exhale after a maximal inspiration effort, increase in a person until the middle twenties. Lung size begins to decrease as the person ages past the twenties. An average twenty years old has predicted FVC slightly over 5 liter. By the age of 70, the same person of FVC predicted will have to fallen to approximately 4 liters.

4) Exposure to occupational pollution

Exposure to occupational pollution including dusts, chemicals, and gases may induce acute and chronic changes in lung function.

5) Post and present health status

Lung function at any one point in time reflects not only the present health of individual but also the sum of all the insults and injuries the lung. Lung function has sustained in the past health history including those from parental and immediate postnatal periods.

6) Other poorly defined of lung function may include race, rate of exercise, geographic factors such as altitude and socioeconomic status.

A proper technique and participation of the subjects can also determine the accuracy of lung function tests results using spirometry. Therefore, correct steps and procedures should be taken to run the test such as specification as recommended by American Thoracic Society and other standard operation procedures. Proper using of instruments is also important to ensure accurate readings and instruments.

2.11 Measurement level of UFP and health effect

Various studies about measuring UFP have been conducted and been published on the particle number concentration at various setting. For example, there was a study conducted to measure personal exposure to UFP from common sources in various locations such as homes, cars and restaurant. Study was conducted by Wallace *et al.* (2011) suggested personal exposure to UFP can occur while people are

cooking, driving, smoking, operating small appliances such as hair dryers, or eating out in restaurants. However, cooking on gas or electric stoves and electric toaster ovens was a major source of UFP as the measurement level of UFP was high which is 144 000 particles/cm^3 – 223 000 particles/cm^3. Other common sources of high UFP exposures were cigarettes, a vented gas clothes dryer, an air popcorn popper, candles, an electric mixer, a toaster, a hair dryer, a curling iron, and a steam iron.

Besides, a cross sectional study was conducted by Kavita *et al.* (2011) showed concentration of personal exposure to particulate matter of PM_{10}, $PM_{2.5}$ and UFP among bus drivers in Klang Valley, Malaysia by using Dust Trak Aerosol Monitor, Side Pak AM510 Personal Aerosol Monitor and P-Trak Ultrafine Particle Counter. The study showed mean exposure levels UFP were significantly higher among the bus drivers compared to comparative group with the t value is 19.61 and p value less than 0.01. That study also has suggested that bus driver were at higher risk of getting respiratory illnesses compared to comparative group due to higher concentration of biomarkers induced by exposure to the particulate matter.

Other than that, a study conducted by Abraham *et al.* (2002) which have measured UFP number concentration in a variety of indoor, personal and mobile environment by using a P-Trak condensation particle counter (TSI model 8525) and have found that indoor UFP levels indicated influx of outdoor air plus indoor combustion sources such as toasting and cooking. While in a moving passenger car environment, there was observed of prolonged exposure to UFP concentrations >100

000 particles/cm^3 was related to heavy traffic especially diesel vehicles. Then, acute upper respiratory symptoms (headache, nasal/sinus congestion and rhinitis) were noted by both driver and passenger in the car at very high exposure levels which is >150000 particles/cm3.

However, the study on the measurement of personal exposure level to UFP and health effect is very limited besides most of them mainly focused on the UFP measurement of motor vehicle emission and indoor sources such as cooking. There are only a few studies that really emphasized on the UFP measurement from photocopiers workers. For instance is a study conducted by Massey *et al.* (2009) in Agra City to measure UFP size distribution and mass concentration at an interval of 10 minutes, in two periods at the 2 photocopier and printer centers during the business hours and background hours. The study also found that the particle number concentration was 3-7 times higher during operational hours than background values obtained before and after the machine was operational at both the centers. As the machines were nonoperational before the opening of the centers in morning and after the closing of the centers at night, there were significant decrease in the particulate numbers and mass concentrations from the working hours of the machine during the day. While during the working hours, the number of particulate and mass concentration kept on increasing during the first hour of hard copying

CHAPTER 3

METHODOLOGY

3.1 Study location

This study was conducted at Sri Serdang, Sri Kembangan, Kajang and Bangi where these locations have high number of photocopy shop due to present of educational institution.

3.2 Study Design

The study design used in this study was cross sectional comparative study. This study design was very suitable to be used in this study as this study was comparing the exposure level of ultrafine particle and $PM_{2.5}$ between exposed group and comparison group besides looking of the respiratory symptoms and level of exposure to ultrafine particle and $PM_{2.5}$.

3.3 Study population

The study population was comprised of photocopiers worker that work in photocopy shop as exposed group. Then, respondents from the administrative workers were selected as the comparative group.

3.4 Sampling method

The sampling method that was used to carry out in this study was purposive sampling method because this study has selected the respondents that only fulfill the inclusive criteria set in this study. The inclusive criteria were as follow:

- Healthy individual without lung/respiratory disease (e.g.: asthma) and history of chronic disease
- Age: 20-50 years old
- Female workers
- Non-smoker

Then, respondents who have fulfilled the above inclusive criteria were gone through the personal exposure monitoring to fine particles. Lung function was performed on them to determine the abnormality based on the FVC and FEV_1. The comparative group was selected based on the same criteria set for this study. Figure 3.1 below have illustrated the flow chart of sampling method in this study.

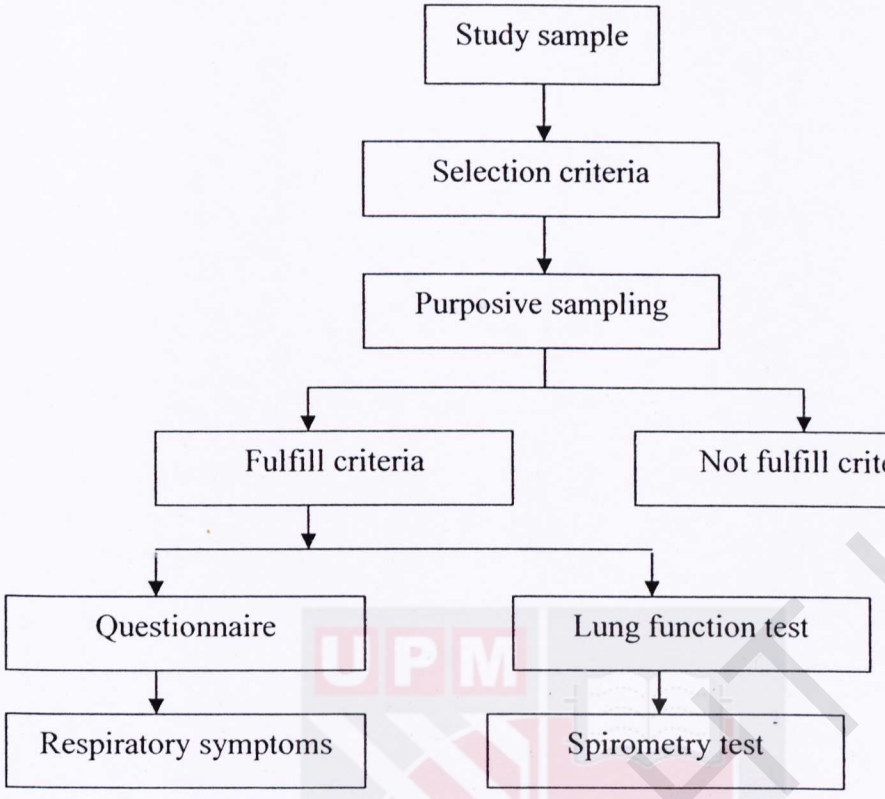

Figure 3.1 Sampling method

3.5 Sample size

In order to carry out this study, the sample was obtained for the data collection process. For that, the adequate sample is very essential to representative the study population. The determination of sample size is based on the formula of 'Rubinson & Nuetens' as follow:

$$N = (z/e)^2 (p) (1-p)$$

Where:

N = sample size

p= prevalence/ estimated proportion or incidence of cases in the population

e= standard error (0.10)

z= standard score corresponding to a given confidence level (1.96)

Based on (Salawati. 2002) the prevalence abnormality of lung function of moderate obstructive among 40 printing mill workers is 10%.

Hence,

$n = (1.96/0.10)^2 (0.10) (1 - 0.10)$

$= 35$ respondents

Total of 35 peoples were the amount that needed for the respondents in each group of exposed and comparative. However, in this study, only 30 respondents for each group were selected in this study. This amount of respondents in each group was much smaller compared to the sample size that has been determined earlier before conducting the study. This situation happens because of the restriction criteria of the photocopier workers participation to involve in this study.

3.6 Instrumentation

3.6.1 Questionnaire

The questionnaire was used to obtain some information directly from the respondents regarding of this study by interview session. This is purposely to avoid from the questionnaire bias. The questionnaire that was used as the instrument in this study is adapted from American Thoracic Society (ATS), 1978. It was consist of 8 part which have collected the information about respondent's background, socio-economics, previous disease especially related to the lung disease, current and previous working history related with exposure to particulate matter, respiratory symptoms that currently experienced by the respondents such as phlegm, cough, wheezing and chest tightness;, disease history among family, and smoking habit.

3.6.2 Anthropometry measurement equipments

a. SECA 206 BODYMETER SCALE

SECA 206 Body Meter Scale is an instrument that used to measure the height. It is only a single screw this band measure becomes a measuring station. The wall plate ensures stability and the recess permits convenient reading, even from below. The measuring range is 0 - 220 cm. This instrument was used to measure the height of respondents in this study with the nearest value to 0.5cm in bare footed and

standing in straight position. The instrument was calibrated each time before start the measurement.

Figure 3.2: SECA 206 Bodymeter Scale

a. SECA Weighing Machine

SECA Weighing Machine (Model Tanita) is used to measure the body weight. The capacity of measurement is 150kg with its weight is 4kg and accuracy of 0.1kg. This instrument was used to measure the weight of respondents in this study. The weighing scale was placed on the flat surface during measurement. The instrument was calibrated each time before start the measurement.

Figure 3.3: SECA Weighing Machine

3.6.3 P-Trak Ultrafine particle Counter Model 8525

P-Trak Ultrafine Particle Counter Model 8525 was used in this study to measure the level of the ultrafine particles (UFP). The P-Trak Ultrafine Particle Counter (UPC) measures ultrafine particle concentrations in real-time and also datalogs. These measurements were made in units of particles per cubic centimeter (pt/cm^3) versus traditional aerosol measurements of milligrams per cubic meter (mg/m^3) made by photometers. The P-Trak can see single ultrafine particles, making it far more sensitive than other technologies.

Particles were drawn through the P-Trak UPC using a built-in pump. Upon entering the instrument, particles passed through a saturator tube where they mix with an alcohol vapor. The particle/alcohol mixture then passes into a condenser tube where alcohol condenses onto the particles, causing them to grow into a larger

droplet. The droplets then pass through a focused laser beam, producing flashes of light which are sensed by a photo-detector.

The detail specification and the minimum sensitivities of the P-Trak are as follow:

- Aerosol concentration range from 0 to 5 x 10^5 particles/cm^3
- Particle size range from 0.02 to 1 micrometer (μm)
- Adjustable flow rate of 100 cm^3/min
- Operating temperature range from 0°C to 38°C

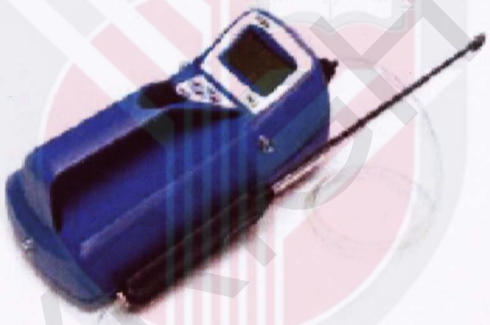

Figure 3.4: P-Trak Ultrafine Particle Counter Model 8525

3.6.4 Personal Aerosol Monitor

Personal Aerosol Monitor (model TSI AM510) was used to sample the fine particle ($PM_{2.5}$). This instrument is using light scattering technology to determine mass concentration in real time. An aerosol sample was drawn into the sensing

chamber in a continuous stream. One section of the aerosol stream was illuminated with a small beam of laser light. Particles in the aerosol stream scatter light in all directions. A lens at 90° to both the aerosol stream and laser beam collects some of the scattered light and focuses in onto a photodetector. The detection circuitry converts the light into a voltage. This voltage was proportional to the amount of light scattered which was, in-turn, proportional to the mass concentration of the aerosol. The voltage was read by the processor and multiplied by an internal calibration constant to yield mass concentration.

The detail specification and the minimum sensitivities of the sampling pump are as follow:

- Aerosol concentration range from 0.001 to 20 mg/cm^3
- Particle size range from 0.1 to 10 micrometer (μm)
- Minimum resolution of ± 0.001mg/cm^3
- Adjustable flow rate of 0.7-1.8 liters/min
- Operating temperature range from 0°C to 50°C

Figure 3.5: Personal Aerosol Monitor (model TSI AM510)

3.6.5 Spirometer

Spirometer was used in the lung function test which is purposely to measure the volume of air in the lungs and the volume that able to breathe out in one second. The function of this instrument is as follow:

- Measures air flow by electronic or mechanical displacement principles, and uses a microprocessor and recorder to calculate and plot air flow.
- records the amount and the rate of air that respondents breathe in and out over a period of time-spirogram. The recording, called a spirogram, shows the volume of air moved and the rate at which it travels into and out of the lungs.

For the purpose of this study, two parameters were performed which are Forced Vital Capacity (FVC) and Forced Expired Volume in one second (FEV_1). FVC is the maximal volume of air exhaled with maximally forced effort from a position of maximal inspirtaion expressed in liters. While FEV_1 is the volume expired in the first second of maximal expiration after a maximal inspiration and is a useful measurement of how quickly full lungs can be emptied.

The type of spirometer that was used in this study is Spirolab II Model. The data of respondents include age, gender, height (cm), weight (kg) and also date was recorded in the spirometer before spirometry test been handled. Spirometry maneuver was performed appropriately to produce good result. Below is the

maneuvers performance recommendations based on ATS (1995) that been followed while performing lung function tets:

i. Checked and calibrated the spirometer.

ii. Explained to respondents about the testing procedures and to get their fullest cooperation.

iii. Prepared the subjects. Ensure they do not have flu, cough allergt test and no intake of heavy meal.

iv. Instructed and demostrated the test procedures to subjects.

   a. Correct posture with head elevated and standing in straight position

   b. Inhale completely

   c. Position mouthpiece and exhale with maximal force

v. Performed manuever.

   a. Have subject assume correct posture

   b. Attach a nose clip (optional)

   c. Inhale completely; the inhalation should rapid but not forced

   d. Place mouthpiece in the mouth and close lips around mouthpiece

   e. Exhale maximally as soon as lips are sealed around mouthpiece. Prompt the subject to "blast,'' not just "blow," the air from their lungs, then continue to encourage subject to fully exhale.

vi. Performed a minimum of three acceptable FVC maneuvers. If subject shows large variabillity (FVC and/or FEV_1) between expiratory maneuvers (more than 0.2L) reproducibility criteria may require that up to but usually no more than eight maneuvers be performed.

Figure 3.6: Spirolab II Model

3.7 Data Collection

3.7.1 Questionnaire distribution

Questionnaire was distributed to all subjects that been selected prior of the exposure monitoring of air sampling. The questionnaire was interviewed to the respondents to avoid from bias.

Quality control:

- Pre-test was conducted on 10% of the sample size to determine validity and reliability of the questionnaire.

3.7.2 Ultrafine particle (UFP) sampling

In order for P-Trak collect the data, the telescoping sample probe was put at the photocopy machine area. This is because the source of ultrafine to be sampled is come from the photocopy machine. After P-Trak was correctly placed, the pump then was turned on. The logging time was set at 60 seconds. The duration of measurement was about 4 hour. This measurement of 4 hours was been taken because instrument of P-Trak used to measure UFP is using alcohol which after 6 hours, the particle count begins to drift continuously lower and eventually reads zero. At last, after the sampling is complete, the P-Trak was turned off.

3.7.3 Fine particle ($PM_{2.5}$) sampling

All the respondents in this study were gone through the personal exposure monitoring to fine particles during working hours. The personal exposure was measured using Personal Aerosol Monitor of Model TSI AM510. Before start the sampling, Personal Aerosol Monitor was zero calibrated prior to each test to ensure data collected from the respondent is accurate.

During measurement, the personal Aerosol Monitor was clipped to respondent's pants and clear plastic tubing attached to the inlet was put at the breathing zone of the respondents for 4 hours during the working hours. After everything was correctly placed, the Personal Aerosol Monitor was turned on. The

logging time was set at 60 seconds. Lastly, after the sampling completed, it was turned off and the data was transferred to computer to get the total reading after the measurement.

3.7.4 Lung function test /spirometry

a. Calibration

Prior of using the spirometer, it has been calibrated first. Calibration on the spirometer was performed based on the recommendations by ATS standardization of spirometry. Spirometer was calibrated by injecting 3 liters of air into the spirometer using a three liters syringe. Error that was allowed is in 3% or 50mL of air (ATS, 1995).

b. Pre-test spirometry

Before conduct the test, the measurement of height and weight of respondents was taken. The height and weight of respondents was recorded by measured using SECA weighing machine for measuring weight and SECA Bodymeter for measuring height. During the measurement, the respondents were ensured that all the things that can give error to the measurement such as the watch, hand phone, wallet and so on were removed from the body. Three times of measurements was obtained to get the accurate body weight and height of the respondents. Then, the value of the

measurement of height and weight of respondents was inserted into spirometer measurement.

c. Spirometry test

Spirometry test was performed to all respondents in this study which is 30 respondents for both exposed group and comparative group. Firstly, the important infromation such as identity card, date of test, age, gender and heaight and weight measurement of respondents was entered into spirometer equipment. Then, before performed the maneuver of the lung function test, the right explanation with simple language about the testing procedure was given to te respondents which emphasized them to get extra effort and get maximal results. Next, the respondents was instructed and demonstrated the test procedure include correct posture with head elevated and standing in straight position, inhale completely, showing proper mouthpiece position and exhale with maximal effort.

After that, the respondents was asked to performed the maneuver. The respondents was asked to stand during the examination and been sure the bench is positioned behind the respondents. The respondents also was asked to loosen any tight clothing and removed dentures (if not secure). Noseclip was placed on nose but it may be removed between trials. Then, respondents were asked to elevate the chin and extend neck slightly.When the ready signal was given, respondents inhale as deep as they can and then placed mouthpiece in the mouth and the respondents was

ensure that their lips tight properly around the mouthpiece. Lastly, they had blast the air into the tube as hard and fast as they can. This test was do for 3 trials and the highest of trials was used for evaluation of breathing.

d. Acceptance of spirometry test

American Thoracic Society have set standard to control the quality of spirometer in 1978. The result was valid if subject give a full cooperation during the test. At least 3 acceptable results were taken. Validity requirements depended on the subject that were not doing the activity of ccoughing, ccompleting the expiration too early, and obstruction of tongue or teeth.

e. Quality control of spirometry usage

American Thoracic Society has recommended some quality control for spirometry test. The quality controls are respondents have to loosen the tight attire, be in ready and standing posture and remove the false teeth if present before starting the test. Besides that, providing clear explanation of procedure was given to respondents. During the beginning of test, the respondents were asked to give the full maximal inspiration besides provide more time for the subjects to perform this test. Last but not least, ATS also required that the researcher to identify the unsatisfactory result and also take the maneuver for at least 3 acceptable maneuver.

The criteria of maneuver that was accepted in this test are the test is beginning after the maximal inspiration, with the maximal effort, continuous expression at least for 4 seconds, no coughing and only the best maneuver from the three valid and identical maneuvers being accepted.

f. Evaluation of spirometry test

The FVC and FEV_1 value was automatically corrected to body temperature (BTPS) by the spirometer. Evaluation process was done by comparing the observation spirometer value obtained from this test with the predicted value from study of Singh et al., (1993). This is because the value that was obtained was assumed to have similarity with the Malaysian`s population which consists of variety of race and economic status. The varieties of respondents in this study are including of body weight, height, environment and also altitude. The predicted value by study of Singh et al., is shown in table 3.1 below.

Table 3.1: Predicted value for study of Singh et al., (1993) (20-69 years old)

Lung function parameters	Predicted value
FVC	0.0312(height)-0.022(age)-1.64
FEV_1	0.0294(height)-0.0238(age)-1.609

Sources: Singh et al. (1993)

3.8 Statistical Analysis

Data collection in this study was analyzed using SPPS (Statistical Package for Social Science) which significant level used for evaluating the test of significance was set at 0.05.

3.8.1 Univariate analysis

The descriptive analysis was used to determine the characteristic of the data collected from the exposed group and comparative group

3.8.2 Bivariate analysis

a) Mann-Whitney U test

Mann-Whitney U test was used to compare the mean differences of the nominal and quantitative variable study of the not normally distributed data. It determined the mean of differences for the exposure level of ultrafine particle and $PM_{2.5}$ between exposed group and the comparative group. Besides that, it was also determine the mean of differences for age, physical measurement and duration of work between exposed group and the comparative group.

b) Chi –square Test

Chi –Square test was used to test the association of 2 dichotomous variables. It was used in this study to compare the prevalence of respiratory symptoms between exposed group and comparative group

c) Correlation Test

Spearman rho correlation test was used in this study to test the relationship between exposure to ultrafine particle, $PM_{2.5}$ and duration of work (years) with lung function among the exposed group. This test has been used because the data is continuous data and not normally distributed data.

3.9 Study limitation

There are same limitations in this study which are:

1. This study is a cross-sectional study which can only study the relationship between risk and outcomes of exposure and not to identify the cause and effect relationship.

2. There is very limited study on $PM_{2.5}$ and UFP exposure from photocopiers and lung function were found in the population. In fact, this is the first study

to relate personal exposure to $PM_{2.5}$ and UFP and lung function among photocopiers workers in Malaysia.

3. The sample size of the study is small which only involve 60 respondents consist of 30 exposed group and 30 comparative group due to rejection from participation of the subject in this study. Most of owner of the photocopy shop rejected to involve in this study as they have negative perception on this study that will give bad impact to them and their workers and then can disturb their business even though they have the awareness about health impact of the air pollution.

4. This study is only representative to the population on the personal exposure level to $PM_{2.5}$ and UFP and the health effects of their lung function.

3.10 Study Ethics

This study has obtained approval from Faculty of Medicine and Health Science Ethic Committee. Then, before conduct the measurement and assessment, it is essential that the subjects have full information about the study and therefore they have been given the information about the research topic. Besides that, the respondents also have been given written consent before participated in this study.

Information of the research that have been presented to the subjects include the content about what will happen, what is being asked, the right of subjects to agree or disagree to take part without adverse consequences, and right to withdraw at any time in this study. The information also have been given in clear language at a level that the subjects can understand, using visual aids such as photos for spirometry measurement and instrument for the air sampling. The subjects also have been ensured that they understand the procedures and instruction which they have to follow throughout the study being conducted. The privacy of all the information gathered in this study from the subjects also are guaranteed.

CHAPTER 4

RESULTS

4.1 Background

This study was conducted to determine the relationship between exposures to the particles emitted from photocopy machine ($PM_{2.5}$, and UFP) and respiratory health among the photocopiers workers. This study was conducted among the photocopiers workers whose work in photocopy shop in the area of Serdang, Bangi and Kajang.

A total number of 30 photocopiers were selected to involve in this study. For the comparative group, a total number of 30 staffs from administrative department were selected. These photocopiers were exposed to the particles emitted from photocopiers due to their nature of work as compared to the administrative staff.

This study involved the respondents who fulfilled the criteria based on the purposive sampling method. Both the exposed and comparison group were restricted

to age between 20 to 50 years old, female workers, non smokers and free of lung disease before working.

4.2 Response Rate

After screening for the inclusive criteria, the initial samples of respondents which have agreed to participate in this study and fulfilled the inclusive criteria were about 46 photocopiers workers. However, only 30 of them give full cooperation for the study. The rest of 16 respondents have rejected to participate in this study at last minute as they did not want to involve in lung function test, and give cooperation for air sampling monitoring as well as give information for the questionnaire. They have negative perception on this study that it will give bad impact to them and their workers and then it may interfere on their business even though they have the awareness about health impact of the air pollution. Besides that, they also give reason did not want to participate in this study is because they were too busy in the business. Therefore, the response rate of exposed group is 65%. For the comparative group, the initial sample of respondents which come from administrative is about 40 people. However, only 33 of them were fulfilled the inclusive criteria. Badly, out of 3 from 33 people rejected to participate in this study due to the reason of hustle of work. Therefore, only 30 of respondents participate in this study that representative for comparative group. This value represents 91% from the overall respondents in the comparative group.

4.3 Univariate Analysis

4.3.1 Ethnicity of the Respondents

Majority of the respondents were Malay background which is all the expose group (100%) were Malay and 93.3% of comparison group comprise of Malay background. The rest of the respondents in comparative group comprise of 1 Chinese and 1 Indians which contribute 3.3% for each race. The result ethnicity of the respondents had been summarized on the Table 4.2 below.

Table 4.1: Distribution of race of respondents

Variables	Percentage of Respondents (%)	
	Exposed (n=30)	Comparative (n=30)
Malay	30 (100.0)	28 (93.3)
Chinese	0 (0.0)	1 (3.3)
Indians	0 (0.0)	1 (3.3)
Others	0 (0.0)	0 (0)

4.3.2 Age and Physical Measurement of the Respondents

The age and physical measurement of height of respondents are presented in the table below. The median age and height of respondents among exposed group were 21.50 years old and 154.00 cm respectively. Then, for the comparative group, the median age and height of respondents were 25 years old and 155.00 cm

respectively. In this study, the age of respondents had been restricted between 20 to 50 years old. Therefore, the range of age among expose group and comparative group were between 20 to 41 years old and 20 to 40 years old respectively. From the Mann-Whitney U test that had been performed, there was no significant difference in term of age and height between exposed and comparative group. The result of respondent's age and height has been summarized in the table 4.2 below.

Table 4.2: Comparison of age and height between exposed and comparison

Variables	Exposed (n=30)			Comparative (n=30)				
	Median (IQR)	Range	Mean Rank	Median (IQR)	Range	Mean Rank	Z value	p value
Age (years)	21.50 (7)	20-41	20.38	25.00 (4)	20-40	40.62	- 1.865	0.062
Height (cm)	154.00 (7.25)	140-161	28.97	155.00 (9.25)	147-168	23.63	- 0.682	0.495

4.3.3 Education of the Respondents

Most of the respondents from exposed group were educated with STPM/Diploma which is about 56.7%. Same goes to the comparative group which most of the respondents had education level of STPM/Diploma which is 46.7%. Table 4.3 has summarized the distribution of education level based on group of study.

Table 4.3 distribution of educational level of respondents

Variables	Percentage of Respondents (%)	
	Exposed (n=30)	Comparative (n=30)
PMR	4 (13.3)	1 (3.3)
SPM	6 (20.0)	7 (23.3)
STPM/Diploma	17 (56.7)	14 (46.7)
Others	3 (10.0)	8 (26.7)

4.3.4 Duration of Work (years) & Working History

Table 4.4 shows the distribution of work duration among the respondents. The result shows that the median of work duration among expose group was 1.5 years. It is much lower compared to the comparative group which is the median of work duration was 5.00 years. After comparing the duration of work between both group of study by performing Mann-Whitney U test, it was found that there was a significant difference of work duration between exposed and comparative group as p value <0.001. Besides, from the analysis that have been done, it was found that 63.3% of respondents from exposed group and 70.0% of respondents from comparative group have working experience in other organization before migrate to the current work. However, all of the respondents have been selected never exposed to the dusty working experience or chemicals that can cause to the reduction of lung function. In this study, the workers that ever exposed to the factors above were not

selected as the respondents because past exposure can become the confounder. Table 4.5 below shows the distribution of working history among respondents.

Table 4.4: Duration of work among respondents

Variables	Exposed (n=30)			Comparative (n=30)			Z value	p value
	Median (IQR)	Range	Mean rank	Median (IQR)	Range	Mean rank		
Duration of work (years)	1.5 (1.58)	0.08-5.00	18.12	5.00 (3.25)	1.00-20.00	42.88	-5.485	**<0.001

**significant at P<0.001

Table 4.5: Distribution of working history among respondents

Variables	Percentage of Respondents (%)	
	Exposed (n=30)	Comparative (n=30)
Previously work in other organization	19 (63.3)	21 (70.0)
Previously not work in other organization	11 (36.7)	9 (30.0)

4.4 Bivariate Analysis

4.4.1 Comparison of Personal Exposure to UFP & $PM_{2.5}$

Personal monitoring to the exposure of UFP and $PM_{2.5}$ has been conducted in the work environment towards the 30 of respondent for both groups. From the normality test that have been run using SPSS, the distribution of UFP for exposed group was not normal distributed and for comparative group was normal distributed. Same also with the distribution of $PM_{2.5}$ which is not normal distributed for exposed group and normal distributed for comparative group. A mann-Whithey U test has been performed to compare personal exposure of both variables between the exposed and comparative group. Then the result shows that the median of personal exposure to $PM_{2.5}$ was 50.00 $\mu g/m^3$ (range 17.00-192.00) for exposed group and 13.00 $\mu g/m^3$ (range 3.00-25.00) for comparative group. This personal exposure was about 4 times more than comparative group. While, for the personal exposure to UFP among expose group and comparative group were 14520.00 pt/cc (range 5652-35081) and 3634.50 pt/cc (range 1359-5584) respectively. Figure 4.1(a) and 4.1(b) shows the distribution of the personal exposure to $PM_{2.5}$ among exposed and comparative group. While figure 4.1(c) and 4.1(d) shows the distribution of the personal exposure to UFP among exposed and comparative group.

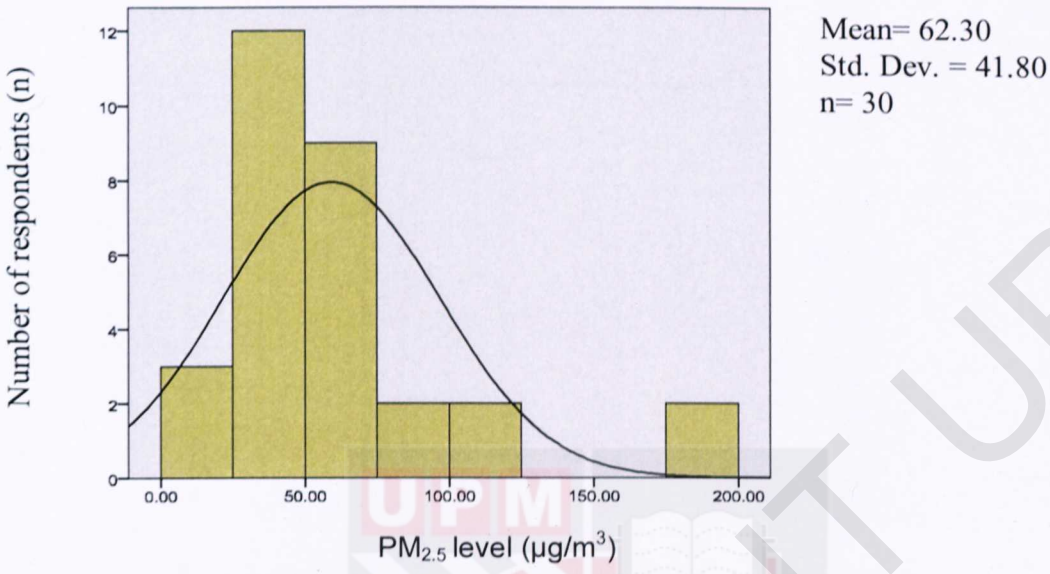

Figure 4.1(a): Distribution of personal exposure level to $PM_{2.5}$ among exposed group

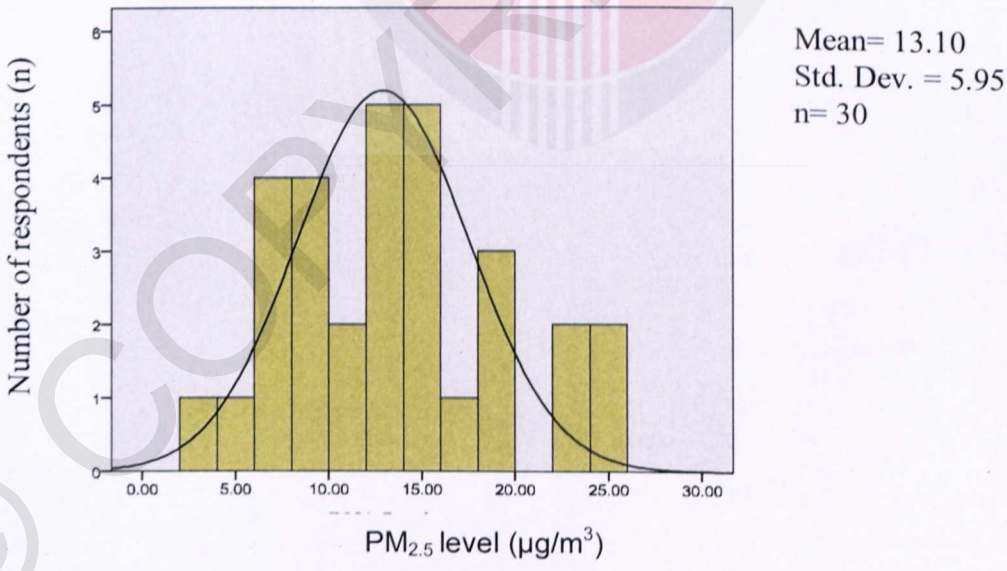

Figure 4.1(b): Distribution of personal exposure level to $PM_{2.5}$ among comparative group

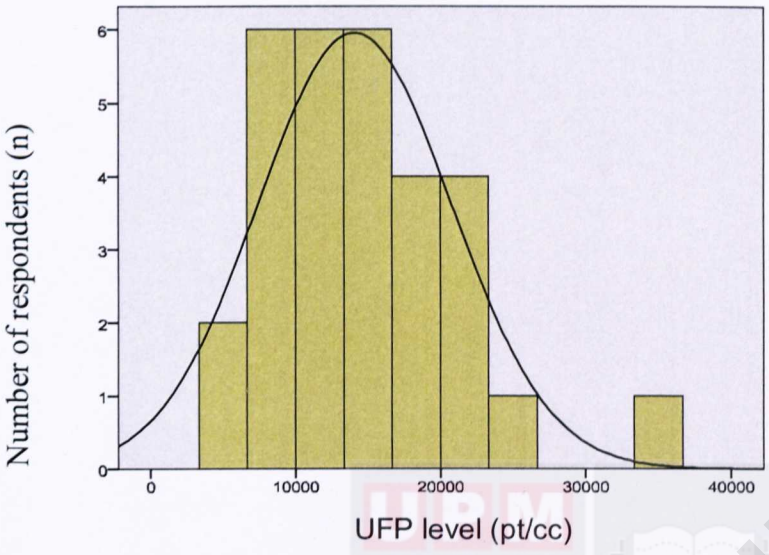

Figure 4.1(c): Distribution of personal exposure level to UFP among exposed group

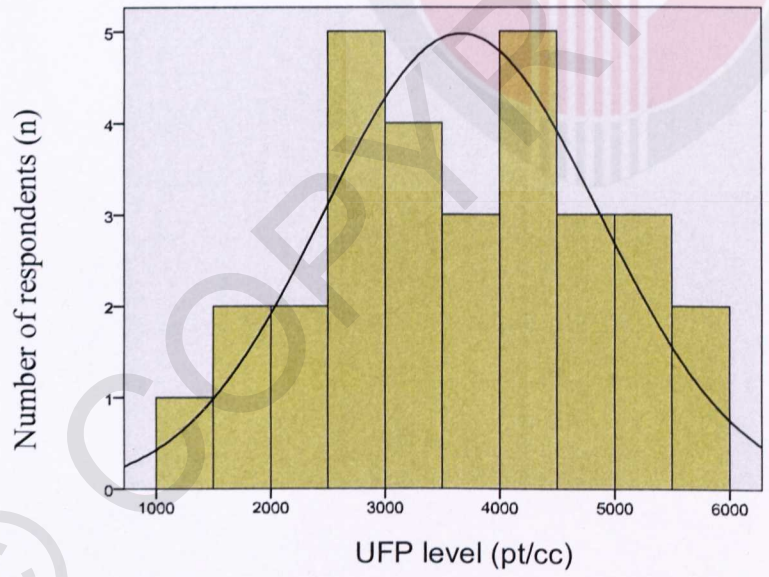

Figure 4.1(d): Distribution of personal exposure level to UFP among comparison group

Table 4.6: Comparison of UFP and $PM_{2.5}$ personal exposure between study groups

Variables	Exposed (n=30)			Comparative (n=30)			Z value	p value
	Median (IQR)	Range	Mean rank	Median (IQR)	Range	Mean rank		
$PM_{2.5}$ ($\mu g/m^3$)	50.00 (26.50)	17.00-192.00	44.40	13.00 (8.75)	3.00-25.00	16.60	-6.398	**<0.001
UFP (pt/cc)	14522.00 (10050)	5652-35081	45.50	3634.50 (1826)	1359-5584	15.50	-6.653	**<0.001

**significant at P<0.001

Table 4.6 showed the comparison of personal exposure to $PM_{2.5}$ and UFP between exposed group and comparative group by using Mann-Whitney U test. Then the result showed that there was a significant differences of personal exposure to $PM_{2.5}$ and UFP between both of the two groups as it was significasnt at P<0.001.

4.4.2 Comparison of Respiratory Symptoms

Based on the Table 4.7 below, it has been found that the exposed group has much higher percentage of reported respiratory symptoms such as cough, phlegm, chest tightness and wheezing compared to the comparative group. Based on the Chi Square test, all of the respiratory symptoms show no significant differences between

both of the two groups. Figure 4.2 below shows the reported respiratory symptoms between both groups of study.

Table 4.7: Comparison of respiratory symptoms among respondents

Respiratory symptoms		Percentage of Respondents (%)		χ^2 value	p value
		Exposed (n=30)	Comparative (n=30)		
Cough	Yes	8 (26.7)	3 (10.0)	2.783	0.095
	No	22 (73.3)	27 (90.0)		
Phlegm	Yes	5 (16.7)	0 (0.0)	-	#0.052
	No	25 (83.3)	30 (100.0)		
Chest tightness	Yes	1 (3.3)	0 (0.0)	-	#1.000
	No	29 (96.7)	30 (100.0)		
Wheezing	Yes	2 (6.7)	0 (0.0)	-	#0.492
	No	28 (93.3)	30 (100.0)		

*significant at P<0.05

#Fisher Exact Test

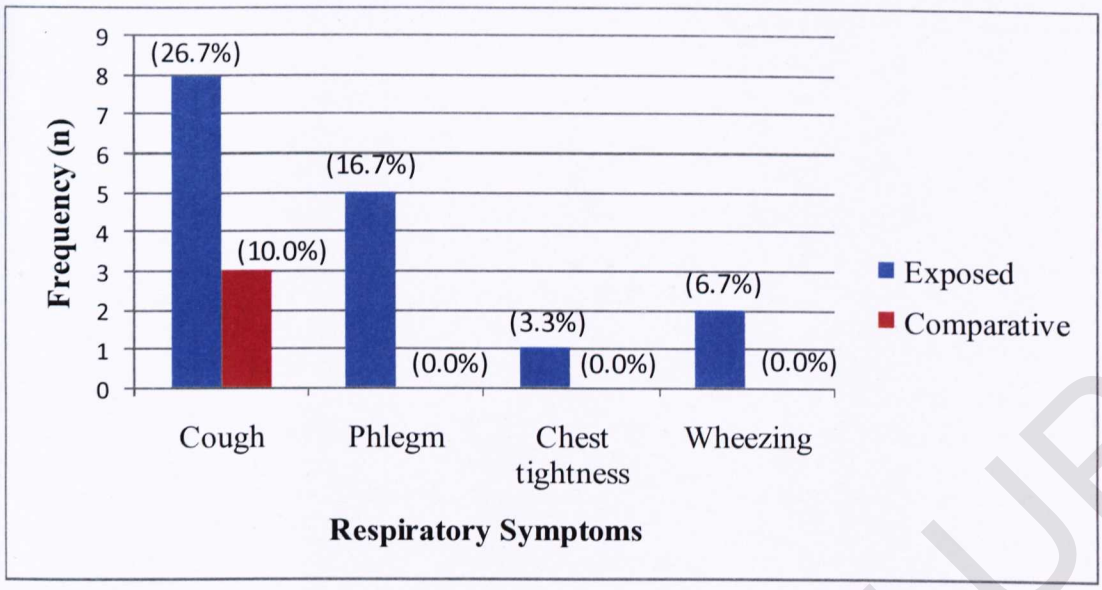

Figure 4.2: Prevalence of respiratory symptoms based on group of study

4.4.3 Comparison of Lung Function level of study group

Lung function test has been conducted among all of the respondents in the study. From the result it has been found that the median of the lung function level for FVC and FEV_1 (1/min) among the exposed group were 2.29 (range 1.35-3.98) and 2.08 (range 1.31-2.76) respectively. Whereas, for the comparative group, the median for the value of FVC was 2.59 (range 1.90-3.39) and FEV_1 was 2.29 (range 1.70-3.06). Result of the normality test that has been done shows that the distribution of the value of FVC and FEV_1 were normal distributed. Figure 4.1(a) and 4.1 (b) shows the distribution of the value of FVC for both group of exposed and comparative. While, figure 4.1(c) and 4.2(d) showed the distribution of FEV_1 value for both group.

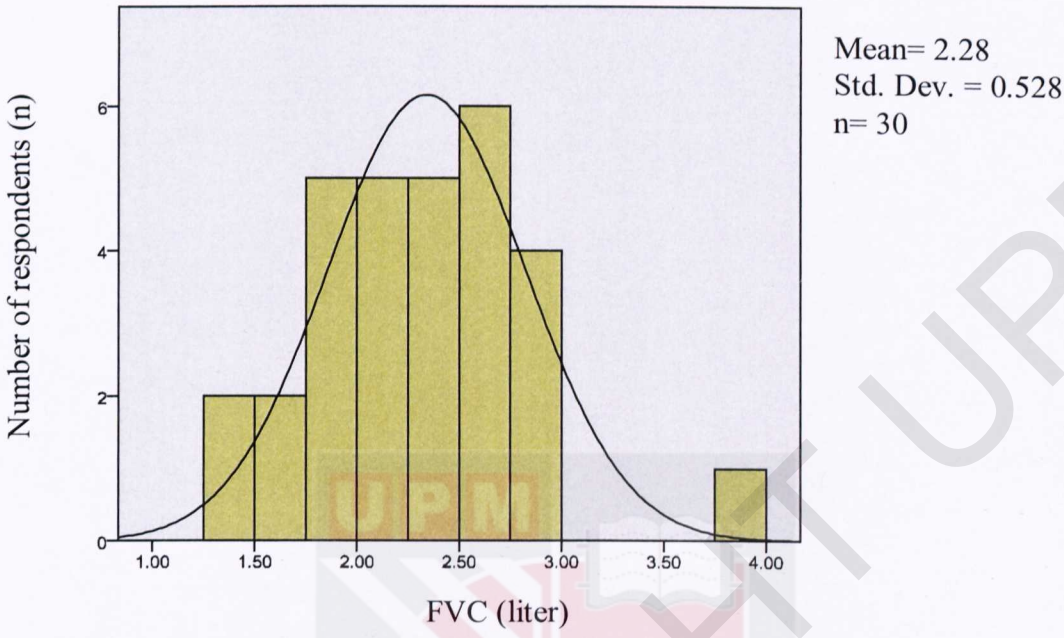

Figure 4.3(a): Distribution of FVC (liter) value for exposed group

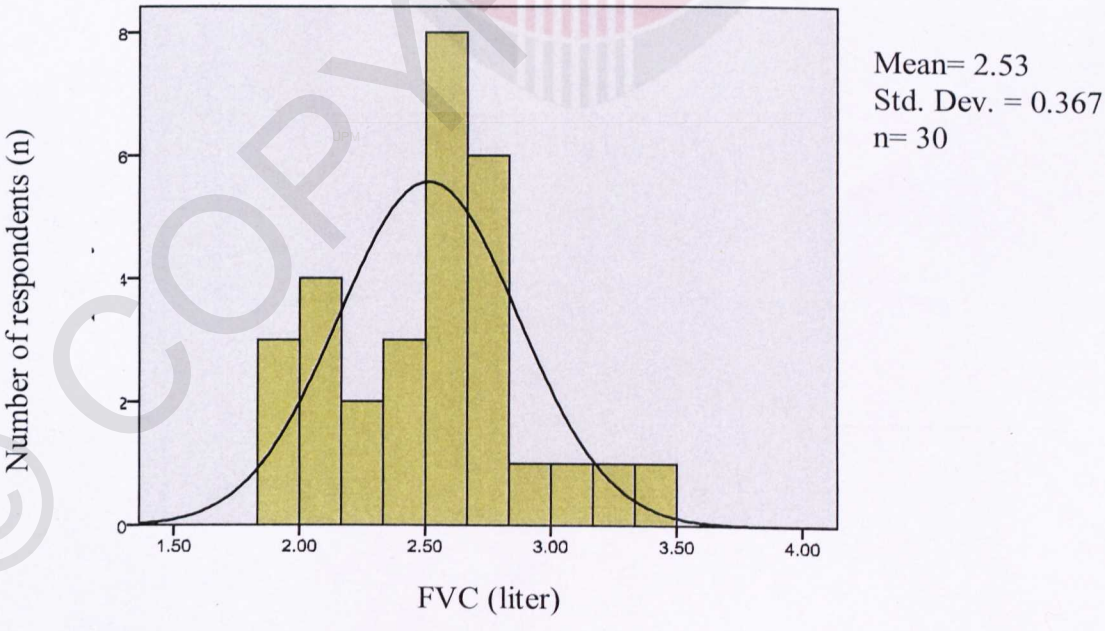

Figure 4.3(b): Distribution of FVC (liter) value for comparative group

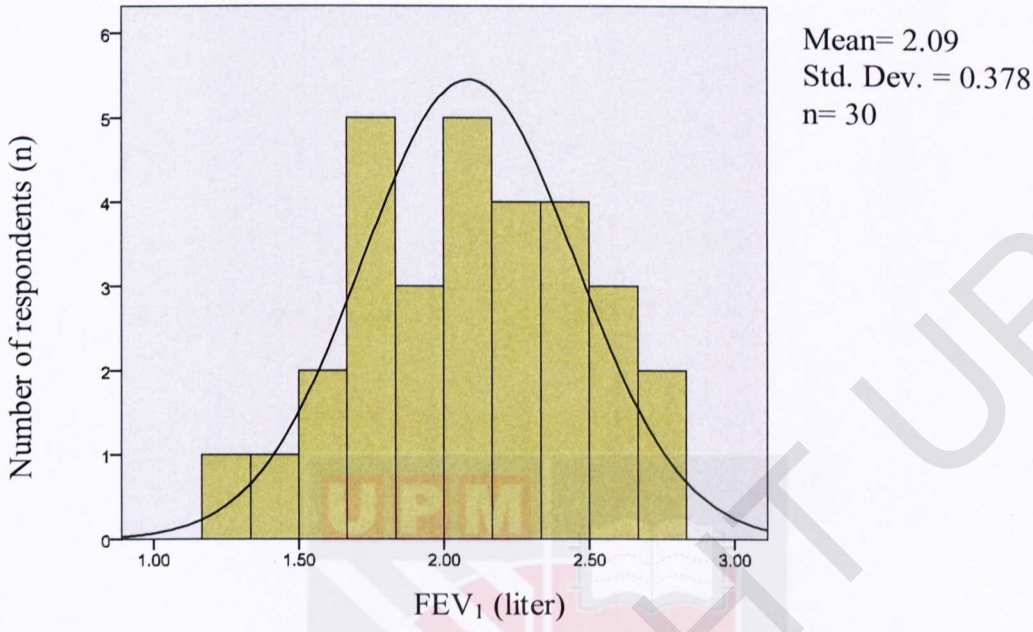

Figure 4.3(c): Distribution of FEV_1 (liter) value for exposed group

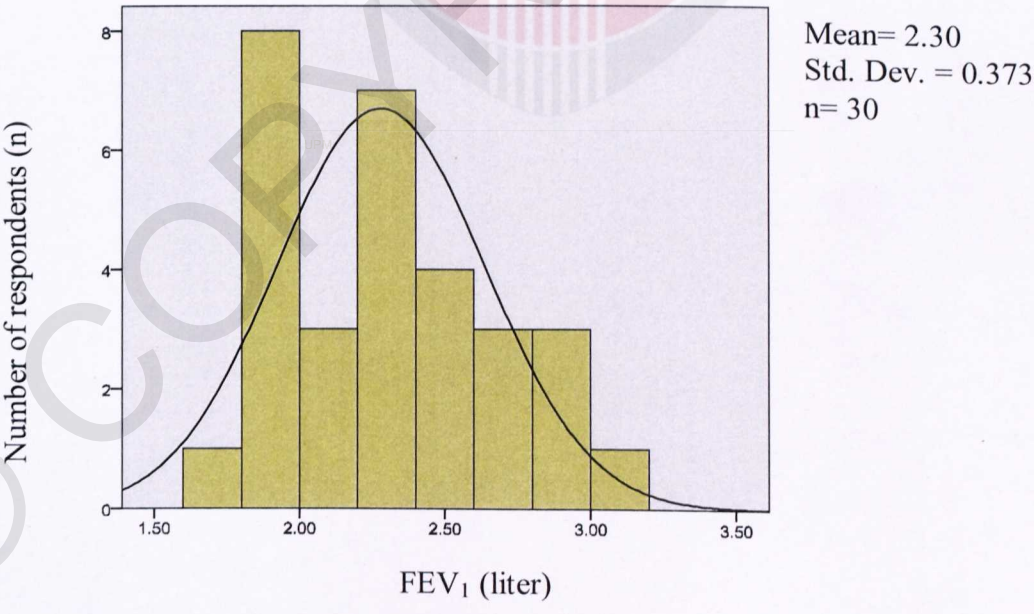

Figure 4.3(d): Distribution of FEV_1 (liter) value for comparative group

Table 4.8 shows the result of Mann – Whitney U test that has been performed to all the value of lung function that been studied. From that, it have been found that all the variables of lung function except FEV_1 shows significant differences between the two group of study, exposed and comparative which is the p value for the comparison of FVC % predicted and FEV_1 % predicted were <0.001 and FVC, FEV_1 / FVC % were <0.05. The lung function value was much lower in exposed group compared to the comparative group.

Table 4.8: Comparison of lung function level among respondents

Variables	Exposed (n=30)			Comparative (n=30)			Z value	p value
	Median (IQR)	Range	Mean rank	Median (IQR)	Range	Mean rank		
FVC (liter)	2.29 (0.68)	1.35-3.98	26.88	2.59 (0.57)	1.90-3.39	34.12	-2.225	*0.026
FEV_1 (liter)	2.08 (0.60)	1.31-2.76	27.65	2.29 (0.62)	1.70-3.06	33.35	-1.952	0.051
FVC % predicted	85.47 (27.01)	57.14-138.19	24.20	101.50 (13.25)	76.26-130.00	36.80	-3.490	**<0.001
FEV_1 % predicted	86.74 (21.70)	64.00-140.00	22.12	105.50 (15.27)	78.00-144.00	38.88	-4.399	**<0.001
FEV_1 / FVC % preidcted	110 (11.00)	60-150	35.10	100 (0.00)	75-110	25.90	-1.971	*0.049

*significant at P<0.05

**significant at P<0.001

4.4.4 Comparison of the Lung Function Abnormality among the Respondents

Lung function abnormality information of both exposed and comparative group has been summarized in the Table 4.9 below. From the result, it shows that the abnormal lung function of FVC % predicted, FEV_1 % predicted and FEV_1/FVC % predicted were much higher in exposed group compared to the comparative group. Then, after performing the Chi Square test, it have been found that two parameters of FVC % predicted and FEV_1 % predicted showed significantly difference between both group of study as p value <0.05. However, lung function of FEV_1/FVC % predicted was not significantly difference between both groups of study.

Table 4.9: Comparison prevalence of the lung function abnormality among the respondents

Variables	Lung Function Abnormality	Exposed (n=30) n (%)	Comparative (n=30) n (%)	χ^2 value	p value
FVC % predicted	Abnormal	11 (36.7)	1 (3.3)	10.417	*0.001
	Normal	19 (63.3)	29 (96.7)		
FEV_1 % predicted	Abnormal	11 (36.7)	1 (3.3)	10.417	*0.001
	Normal	19 (63.3)	29 (96.7)		
FEV_1/FVC % predicted	Abnormal	2 (6.7)	0 (0.0%)	-	#0.492
	Normal	28 (93.3)	30 (100%)		

#Fisher Exact Test

*significant at P<0.05

4.4.5 Association between Exposure to Fine Particles ($PM_{2.5}$) & Lung Function

In order to determine the association between the personal exposure to $PM_{2.5}$ with lung function levels among respondents, Spearman rho correlation test has been performed for value of FVC, FEV_1, FVC % predicted, FEV_1 % predicted, and FEV_1/FVC % with exposure to $PM_{2.5}$. From the result, it has been found that there was a significant association between personal exposure to $PM_{2.5}$ with lung function value of FVC and FVC % predicted among exposed group as p value are <0.05. Then, when considering total of 60 respondents, there was a significant association between personal exposure to $PM_{2.5}$ with all of the lung function value except for FEV_1. Table 4.10 below shows the association between personal exposure to $PM_{2.5}$ with lung function level among both group of study.

Table 4.10: Association between personal exposure to $PM_{2.5}$ & lung function

$PM_{2.5}$ ($\mu g/m^3$)	Exposed (n=30)		Total (n=60)	
	r-value	p-value	r-value	p-value
FVC (liter)	-0.398	*0.029	-0.355	*0.005
FEV_1 (Liter)	-0.332	0.073	-0.249	0.055
FVC % predicted	-0.404	*0.027	-0.589	**<0.001
FEV_1 % predicted	-0.267	0.154	-0.571	**<0.001
FEV_1/FVC % predicted	0.362	0.050	0.316	*0.014

*significant at P<0.05

**significant at P<0.001

4.4.6 Association between Personal Exposure to Ultrafine Particles (UFP) & Lung Function

Spearman rho correlation test have been performed for value of FVC, FEV_1, FVC % predicted, FEV_1 % predicted, and FEV_1/FVC % with exposure to UFP to determine the association between the personal exposures to UFP with lung function levels among respondents. From the result, it have been found that there was a significant association between personal exposure to UFP with lung function value of FEV_1 % predicted among expose group as p value <0.05. However, there was no significant association between FVC, FEV_1, FVC % predicted, and FEV_1/FVC % value among exposed group. Even though, when including exposed and comparative group, there was a significant association between personal exposures to UFP with all of lung function value except for FEV_1/FVC % value. Table 4.11 shows the

association between personal exposures to UFP with lung function level among both group of study.

Table 4.11: Association between personal exposure to UFP & lung function

UFP (pt/cc)	Exposed (n=30)		Total (n=60)	
	r-value	p-value	r-value	p-value
FVC (liter)	-0.260	0.166	-0.331	*0.010
FEV_1 (Liter)	-0.295	0.114	-0.275	*0.034
FVC % predicted	-0.274	0.143	-0.476	**<0.001
FEV_1 % predicted	-0.377	*0.040	-0.586	**<0.001
FEV_1/FVC % predicted	0.170	0.370	0.249	0.055

*significant at P<0.05

4.4.7 Association between Duration of Work with Lung Function among Respondents

A Spearman rho correlation test has been performed to determine the association between duration of work with lung function among respondents. The variables that have been tested were FVC, FEV_1, FVC % predicted, FEV_1 % predicted, and FEV_1/FVC % with duration of work which is total of years the respondents have working (Table 4.12). Outcome of the test shows that there was a significant association between duration of work with all of the value of lung function except for FEV_1/FVC % among exposed group. Then, among total of 60

respondents, there was also a significant association between duration of work with two of the lung function value which are and FVC % predicted and FEV_1 % predicted.

Table 4.12: Association between duration of work with lung function among respondents

Duration of Work (years)	Exposed (n=30)		Total (n=60)	
	r-value	p-value	r-value	p-value
FVC (liter)	-0.397	*0.030	0.007	0.955
FEV_1 (Liter)	-0.441	*0.015	0.010	0.942
FVC % predicted	-0.396	*0.030	0.261	*0.044
FEV_1 % predicted	-0.558	*0.001	0.319	*0.013
FEV_1/FVC % predicted	-0.061	0.747	-0.127	0.334

*significant at P<0.05

CHAPTER 5

DISCUSSION, CONCLUSION & RECOMMENDATION

5.1 Discussion

5.1.1 Background of respondents

Respondents from the exposed and comparative groups that have been selected were having the same socio-economic characteristics in order to ensure homogeneity of respondents and to eliminate the effects of confounder factors. According to Sheldon (2000), factors such as age, gender, and height are the important factors that can influence lung function parameters among the subjects. So, that is why in the methodologies on selecting the respondents were by purposive sampling method which is only restricted to the inclusive criteria such as age and gender.

Therefore, the selection of respondents was involved only female respondents which have participated in this study. As been mentioned earlier that this study had restricted for the respondents in the age range of 20 to 45 years old, therefore the

selection of respondents was involved in this study were consist of the age in the range of 20 to 41 years old for the exposed group and 20 to 40 years old for the comparative group. As comparing the factors such as age and height between two groups of study in chapter 4, there was no significant difference of age between exposed and comparative group.

For the physical characteristics of height, the respondents in exposed group and comparative group were in the height range of 140 to 161 cm and 147 to 168 cm respectively. As comparing this factor of height between two groups of study from table 4.2 of chapter 4, there was no significant difference between exposed and comparative group. In the aspect of race, all exposed group were comprise of Malay background. This is accordance to the observation toward photocopying shop in the area of Selangor that most of the photocopiers workers were dominated by Malay even though the owner of the photocopy shop were Chinese. For the comparative group, majority of them also comprise of Malay background.

Besides, for the duration of work, it is not restricted for how many years the respondents were working as working duration becomes one of the factors that were determined for the association with the lung function level of respondents in this study. So that, the range of working duration for exposed group and comparative group were 1 month to 5 years and 1 year to 20 years respectively. After comparing the working duration between both groups of study in the chapter 4 as shown in table 4.4, it is found that there was a significant difference between exposed and

comparative group. This is because, most of the respondents whose working as photocopiers were consist of those in the earlier age and they were working for that work as their part time job. Furthermore, several of them were still studying in educational institution. So that is why the duration of work for the exposed group was only in a short period of time.

Besides, the exposed group in this study which involve of photocopier workers were employed by the owner of the photocopy shop to handle the photocopiers and operate the photocopying process in order to fulfill the requirement of the customer for the photocopying services. Their task was included of the loading the paper into photocopiers, change the toner cartridges and refilling of consumable chemical. This nature of work has give exposure of hazardous to $PM_{2.5}$ and UFP towards them. Then, duration of work of the workers was not consistent and similar among them as their work duration per day was depending on the requirement of their employer. Several of them were working for 4 hours per day which their time was depend on their work shift and some of them also were working for 8 hours which is from 8 am until 5 pm with lunch break for 1 hour. Therefore, in order to get standardize period of measurement for the air sampling using Side Pak and P-Trak, the measurement in this study was taken for average 4 hours. By referring to the other previous study also had conducted of $PM_{2.5}$ and UFP measurement for 4 hours during the operation of photocopying process (Massey *et al.*, 2011).

5.1.2 Comparison of personal exposure to $PM_{2.5}$ & UFP

This study had conducted exposure assessment by monitoring personal exposure to $PM_{2.5}$ and UFP among respondents as long as 4 hours to get average exposure for 4 working hours and not for 8 working hours because majority of the photocopiers as the exposed group had maximum time working hours for only 4 hours as they were working in shift. Their work will be changed with next shift after enough for their 4 hours working time. Besides, measurement of UFP using P-Trak cannot be conducted for a long period of time because that instrument is using alcohol (isopropyl alcohol) in order to account UFP number particles concentration which after 6 hours, the particle count begins to drift continuously lower and eventually read zeros. Hence, the reasons above lead the researcher to take measurement exposure for 4 hours for both $PM_{2.5}$ and UFP assessment among each respondent.

From the table 4.4.1, the median of personal exposure to $PM_{2.5}$ & UFP among respondents in expose group were 50.00 $\mu g/m^3$ and 14522 pt/cc respectively which is the exposure concentration of $PM_{2.5}$ was in the range of 17 $\mu g/m^3$ to 192 $\mu g/m^3$ and exposure concentration of UFP was in the range of 5652 pt/cc-35081 pt/cc. Based on the National Ambient Air Quality Standards (NAAQS) (2006), US EPA had revised the level of the 24-hour $PM_{2.5}$ standard of 1997 from 65 $\mu g/m^3$ to 35 $\mu g/m^3$ in 2006. This revision of $PM_{2.5}$ level standard was much lower compared to the previous standard in 1997 as it is accordance to the objective of US EPA to provide increase

protection of public health and welfare. With regard to the personal exposure to $PM_{2.5}$ among exposed group in this study, it is much higher compared to the NAAQS (2006) for the $PM_{2.5}$ standard. Even though, the average measurement for $PM_{2.5}$ exposure in this study was 4 hours only, it is had exceeded the level of the 24-hour $PM_{2.5}$ standard. Therefore, this shows that personal exposure to $PM_{2.5}$ among photocopiers was very high.

The result of high concentration of PM_{25} exposure among photocopiers workers in this study also accordance with the previous study conducted by Massey *et.al* (2009) which has investigated the emission and formation of fine particles from hardcopy devices where the findings shows that mass concentration of particles in background air ranged from 0.87 to 9.13 $\mu g/m^3$ and during the hardcopier making they ranged from 8.33 to 80.16 $\mu g/m^3$. This study was clearly shows that the emission of fine particles in 250 to 1000 nano meters range from photocopiers were much higher compared to the background values and it is same with the findings of this study as the exposure concentration of $PM_{2.5}$ emitted from the photocopiers was much higher compared to comparison group that not exposed to the emission of particles from photocopiers.

Besides, findings of study conducted by Massey *et.al* (2009) also showed that particle number concentration obtained in photocopier centers were much higher compared to the background value. Thus, it is correspond to the findings in this study which shows that the particle number concentration of UFP exposed by the

photocopiers workers was much higher compared to the unexposed respondents. Based on Massey *et.al,* the particle number concentration was 3-7 times higher during operational hours than background values obtained before and after the machine was operational. During the operational mode of these hard copying machines the number concentration of the particulate varied from 82612/Lit to 2580941/Lit with an average of 1504133/Lit respectively. Increase in the particle number concentration of UFP in this study also seems to be in consistent with the results of studies which suggested that particulate matter emitted by hardcopiers are aerosolized toner powder (Lee *et al.,* 2007). That study shows that the background-corrected $PM_{2.5}$ values ranged from 10 to 83 $\mu g/m^3$with an average of 40 $\mu g/m^3$. Then, the particle number concentration increased as photocopying began and a high number concentration of UFP was found with a peak value of $>10^8$ particles cm^{-3} during photocopying.

The median of personal exposure level to $PM_{2.5}$ & UFP among respondent in comparative group were much lower compared to the exposed group which the median value were 44.40 (range, 17-192 $\mu g/m^3$) and 45.50 (range, 5651-35081 pt/cc) respectively. From the comparison test that has been performed, it was found that the personal exposure level to $PM_{2.5}$ & UFP between both groups of study were very significantly difference. This definitely shows that the $PM_{2.5}$ & UFP exposure were much higher in the group that exposed to the photocopiers compared to the unexposed respondents. Therefore, the first hypothesis of this study said that the

personal exposure level to $PM_{2.5}$ & UFP were significantly higher among exposed group compared to the comparative group was failed to be rejected.

5.1.3 Comparison of prevalence of respiratory symptoms among study group

In order to assess the respiratory symptoms among respondents, a set of questionnaire had been distributed for each of respondent. This questionnaire has been prepared based on the ATS questionnaire (1978). The respiratory symptoms that have been studied were cough, phlegm, chest tightness and wheezing. Based on the findings, the reported respiratory symptom among exposed group for cough was 26.7%, phlegm was 16.7%, chest tightness was 3.3% and wheezing was 6.7%. Then, for the comparative group the reported of respiratory symptoms for cough was 10.0% and there were no respondents that experienced the respiratory symptoms of phlegm (0.0%), chest tightness (0.0%) and wheezing (0.0%). It is clearly showed that all of the reported respiratory symptoms assessed in this study were much higher in exposed group compared to the comparative group.

It is corresponding to the study conducted by Salawati (2002) towards 40 printing mill workers showed that prevalence of respiratory symptoms of cough (52.5%), phlegm (67.5%), chest tightness (35.0%) and wheezing (20.0%) were much higher in exposed group that exposed to printing process than comparative group. That prevalence of respiratory symptoms among exposed group was much higher compared to the reported respiratory symptoms among exposed group in this study.

Based on the table 4.7, result of the Chi Square test that has been performed shows that all the respiratory symptoms was not significantly difference between exposed group and comparative group. This finding was against the study findings of Salawati (2002) on the significant difference of respiratory symptoms of cough ($p<0.001$), phlegm ($p=0.007$) and chest tightness ($p<0.001$) in two groups of study. It is possibly because study of Salawati (2002) was involved the respondents who smoke, which smoking confers a high risk of developing a number of respiratory symptoms and deterioration of the ventilatory function (Isabel, 2005) which then give the findings much more higher prevalence of respiratory symptoms compared to this present study. Otherwise, this present study did not involve respondents who smoke because smoking habit is the confounder for this study.

Besides, this study finding also correspond to a cross-sectional study conducted by Yang (2008) on respiratory symptoms and irritant health symptoms among 74 photocopier workers in Taiwan which has assessed symptoms of chronic cough, phlegm, wheezing, chronic bronchitis and dyspnea. He has found that there was no significant differences in the prevalence of chronic respiratory symptoms in the two groups of exposed and controls. Then, the study had concluded that occupational exposure to pollutants emitted from photocopiers was not significantly associated with an excess of chronic respiratory symptoms and acute irritative symptoms in photocopy employees. Similarly, to the findings of the study conducted by Penttinen *et al.,* (2001) on respiratory health among adult asthmatic in Helsinki, Finland due to exposure to UFP in urban air which has reported that no association

were observed with respiratory symptoms or medication use with the exposure to the particles number concentration of UFP.

The result of no significant difference of respiratory symptoms shows between exposed and comparative group in this study is due to unreported respiratory symptoms by the photocopiers workers as most of them were avoiding from giving right information on their health condition during interviewing of respiratory symptoms.Hence, the second hypothesis in this study said that the respiratory symptoms are significantly higher among exposed group compared to the comparative group was rejected.

5.1.4 Comparison of lung function between the study groups

From the lung function test result, it has been found that the value of FVC% predicted was 85.47, FEV_1 % predicted was 86.74 and FEV_1 / FVC % predicted was 110 among the expose group. Then, the value of FVC% predicted and FEV_1 % predicted among the comparative group were 101.50 and 105.50 respectively with the value of FEV_1 / FVC % predicted was 100. This clearly shows that lung function level among exposed group was much lower compared to the comparative group. Based on the table 4.8, it clearly shows that there was a significant difference in lung function level between both groups of study. It has been proved by Mann-Whitney U test which shows that there was a significant differences of FVC (l/min) ($z= -2.225$, $p= 0.026$), FVC % predicted ($z= -3.490$, $p= <0.001$), FEV_1 % predicted ($z= -4.399$,

p= <0.001) and FEV_1 / FVC % predicted (z= -1.971, p= 0.049) between exposed and comparative group.

This study finding on the comparison of lung function level is correspond to the study conducted by Salawati (2002) towards 40 workers of printing mill which shows that there was a significant reduction of lung function among the workers that exposed to the particle emitted from the process of printing mill. Hence, the third of hypothesis in this study said that lung function are significantly lower among exposed group compared to the comparative group were failed to be rejected.

This study findings on reduction of lung function is correspond to the study conducted by Suhairy (2007) which studied on the lung function and exposure to fine particles among highway toll operators. The findings of his study shows that there was a significant difference of FVC % predicted (z= -0.129, p= 0.898), FEV_1 % predicted (z= -6.424, p< 0.001), and FEV_1/FVC % predicted (z= -0.129, p= 0,898). Similarly, the findings of the study conducted by Aidil (2005) that has studied on lung function level of 50 bus drivers in Klang Valley which exposed to the diesel-exhaust combustion of fine particles shows that FVC % predicted (t= -6.815, p< 0.001) and FEV_1 % predicted (t= -4.901, p< 0.001). In this study also, the findings shows that the lung function abnormality among the photocopiers workers (FVC % predicted= 36.7%, FEV_1 % predicted= 36.7%, FEV_1/FVC= 6.7%) was much higher compared to the comparative group (FVC % predicted= 3.3%, FEV_1 % predicted=3.3%, FEV_1/FVC= 0.0%). Result of Chi Square test shows that the

abnormality of lung function of FVC % predicted and FEV_1 % predicted was significantly different between exposed group and comparative group.

This findings also was supported by the study conducted by Suhairy (2007) among 55 toll operators exposed to the $PM_{2.5}$ which has found that lung function abnormality status determination in the parameters of FVC % predicted (χ^2= 25.795, p< 0.005) and FEV_1 % predicted (χ^2= 16.042, p< 0.005) was significantly higher among the expose group compared to the comparative group. Other than that, Salawati (2002) has found that there was a significant difference (p< 0.05) for the lung function parameters of FVC, FVC % predicted and FEV_1 % predicted between exposed and comparative group. Findings from her study that has been conducted in printing mills also has reported that the prevalence of lung function abnormality were significantly higher among the exposed group compared to the comparative group for FVC % predicted (χ^2= 18.590, p< 0.001), FEV_1 % predicted (χ^2= 8.690, p= 0.013), and FEV_1/FVC % predicted (χ^2= 4.210, p= 0.040)

5.1.5 Association between personal exposures to $PM_{2.5}$ with lung function

In this study, the association between personal exposure to $PM_{2.5}$ with lung function was tested by using Spearman rho correlation test and the findings shows that there was a significant association between personal exposure to $PM_{2.5}$ with lung function parameters of FVC (r= -0.398, p= 0.029) and FVC% predicted (r= -0.404, p= <0.001) among photocopiers workers. Therefore the exposure to the $PM_{2.5}$ can

cause decrement to the lung function level. This findings was supported by a study that have been conducted by Carol A. *et al.,* (2006) to assessed the associations between change in lung function (FEV_1 or PEF) and personal, indoor, outdoor, and central site $PM_{2.5}$ among 57 adults which include of 24 with COPD and 33 without COPD. In that study also, personal, indoor, and outdoor monitoring was conducted for all subjects which is $PM_{2.5}$ and PM_{10} gravimetric 24-h measurements were obtained inside and outside subjects' residences whereby the subjects wore personal exposure monitors for 10 consecutive 24-h periods, and PM was also measured at a central outdoor location. Then, the researcher also has assessed the within-subject effect of particulate exposure on FEV_1 and peak expiratory flow (PEF). As a result, the findings shows that FEV_1 decrements were associated with 1-day lagged central site PM < 2.5 μm in diameter ($PM_{2.5}$) in adult subjects with COPD besides had observe strong correlations (r= 0.70) between home outdoor and central site $PM_{2.5}$ measurements. Hence, the fifth hypothesis in this study said that there is a significant association between personal exposure to $PM_{2.5}$ and lung function among photocopiers workers as the exposed group were failed to be rejected.

In explanation, the photocopiers workers which participated in this study has work directly with the photocopiers when they want to make the copies and this lead to the exposure of particles emitted from that machine. As been mentioned and discussed before, photocopiers are the sources which can produce fine particles and ultrafine particles whereby the workers that operate the machine will inhale the particles and then that particles enter deeply to the lung through their respiratory

tract. Furthermore, according to the result showed in chapter 4 (Table 4.6), the median of personal exposure level to $PM_{2.5}$ among exposed group was 50.00 $\mu g/m^3$ (range 17- 192 $\mu g/m^3$) that is much higher compared to the $PM_{2.5}$ personal exposure level among comparative group (median= 13.00 $\mu g/m^3$, range 3.00-25.00). Thus, it was strongly proved that the photocopier workers was exposed heavily to fine particles as the findings on comparison of $PM_{2.5}$ personal exposure between expose group and comparative group shows that the personal exposure to $PM_{2.5}$ was significantly higher ($z= -6.398$, $p=<0.001$) among exposed group compared to the comparative group.

The exposure to the $PM_{2.5}$ was said to be heavily exposed due to the comparison with the National Ambient Air Quality Standards (NAAQS) US EPA (2006) which have set the 24-hour $PM_{2.5}$ standard of 35 $\mu g/m^3$. Instead, in this study, the measurement of $PM_{2.5}$ personal exposure level within 4 hours among the photocopiers had exceeded the 24-hour $PM_{2.5}$ standard. Thus, this heavily exposure to the $PM_{2.5}$ had influence the lung function level among the photocopiers workers as the findings shows that there was a significant association between personal exposure to $PM_{2.5}$ with lung function among the photocopier workers.

In nature of work, photocopiers workers were work directly with photocopiers when they want to make copies and operate machine during changing the toner cartridges of photocopiers. According to Fogarty (2004), carbon black of photocopiers toner cartridge was the source of such fine particles and ultrafine

particles. Others study by Adentunji *et al.,* (2009) has said that photocopiers as the main source for the increased nano-particles count in a room. Thus, this exposure to fine particles and UFP will lead to lung function impairment as the recent research found that direct and continuous exposure to $PM_{2.5}$ increased the prevalence of bronchitis and decrease lung function (EPA, 1998). According to EPA, exposure to fine particles can promote adverse health effects to lung and may develop diseases such as asthma. This is correlated to the findings of present study which shows the association between exposures to $PM_{2.5}$ and lung function.

5.1.6 Association between personal exposures to UFP with lung function

This study has analyzed the association between personal exposure to UFP with lung function (FVC, FEV_1, FVC % predicted, FEV_1 % predicted, FEV_1/FVC % predicted) by using Spearman rho correlation test. Then, the findings from the test shows that there was a significant association between personal exposure to UFP with lung function parameter of FEV_1 % predicted ($r= -0.377$, $p= 0.040$) among photocopier workers. This association of exposure to UFP and lung function also has been seen in the study conducted by Peters *et al.*, (1997) on exposure to $PM_{2.5}$ and UFP and respiratory health among 27 adults with history of asthma which shows that an elevated level of fine and ultrafine particle pollution were associated with decreases in peak expiratory flow (PEF) among the subjects. Hence, the fourth hypothesis in this study said that there is a significant association between personal exposure to UFP and lung function among exposed group were failed to be rejected.

Theoretically, exposure to the UFP has potential to cause decrement of the lung function. This is based on the Donaldosn *et al.,* (2001) which has said that UFP can adversely affect the ability of macrophages to phagocytose by inhibit phagocytosis. Then, this failure of macrophages clearance may increase oxidative stress from the large surface area of ultrafine particles. This leads to pro-inflammatory cytokine production by macrophages because of oxidative stress from the surface of the ultrafine particles and chemokine production by the epithelium. Therefore, it will increase the respiratory illness and lead to the reduction of lung function.

This fact is also supported by a cross-sectional study conducted by Kavitha *et al.,* (2011) that has measured particulate matters of PM_{10}, $PM_{2.5}$, and UFP and the biological indicator of inflammation in the lung which is Interleukin-6 (IL-6) among 62 bus drivers as exposed group and 62 administrative staff as comparative group. That study was based on the facts that particulate exposures can lead to the activation of alveolar macrophages for clearance mechanism followed by inflammation. Findings of the study showed that mean exposure level to $PM_{2.5}$ ($t = 9.95$, $p<0.01$) and UFP ($t = 19.61$, $p<0.01$) were significantly higher among the bus drivers compared to comparative group and bus drivers showed higher concentration of IL-6 compared to the comparative group. That study also has suggested that the bus driver that exposed to the particulates matter (PM_{10}, $PM_{2.5}$, and UFP) were at higher risk of getting respiratory illnesses and lung disease compared to comparative group as the

findings also shows there was a positive correlations between the exposure level of PM and concentration of biomarkers.

5.1.7 Association between duration of work with lung function

The last hypothesis in this study is association between duration of work with lung function among respondents which has been tested by using Spearman rho correlation test and then the results shows that there was a significant association between duration of work with lung function parameters of FVC (r= -0.397, p= -0.030), FEV_1 (r= -0.441, p= 0.015), FVC % predicted (r= -0.396, p= 0.030), and FEV_1 % predicted (r= -0.558, p <0.001) among photocopiers workers. This significant showed negatively association between duration of work with the lung function level which means that increase in duration of work that the workers exposed to, more reduce the lung function value. As been measured in this study, the work duration of the photocopier workers was range from 1 month to 5 years. Therefore, the workers who had work for a long duration had shown the reduction in lung function and vice versa. This is the best explanation as the long term exposure to the particles can cause chronic effect which is decrement in lung function level.

As been mentioned before, the nature of work of the photocopiers workers have required them to work directly with the machine. They have to change the toner cartridges and handling chemicals frequently besides make the copies everyday and this frequent task will great the exposure to the hazardous particles emitted from the

photocopiers. Thus, their lung function will be affected when they have working for that workplace for long time duration. In an earlier comprehensive literature review for the Australian Government Department of Environment and Heritage, Morawska *et al.,* (2004) has mentioned that effects due to inflammation in the lungs do not occur immediately but develop over hours or days. Cumulative effects over five days appear to be stronger than same-day effects. Besides, the mortality data suggest that fine particles have immediate health effects whereas UFP have more delayed effect (Morawska *et al.,* 2004). Chronic exposure (long-term exposure) to UFP can produce deleterious effects on the lung leading to chronic obstructive pulmonary diseases (COPD) which is disease associated with airflow obstruction (David, 1998).

According to Hnizdo *et al.,* (2004), airflow obstruction was defined as FEV1/FVC<75% and FEV_1<80% predicted and regard to the table 7, it shows that there was an association between UFP and lung function of FEV_1 % predicted. It proved that there was a possibility that the photocopiers workers who continuously exposed in a long-term period to the UFP emitted from the photocopiers have decrement in lung function as the result of this present study also shows inverse association between exposure to UFP with lung function of FVC, FEV_1, FVC % predicted, and FEV_1 % predicted which means that increase in duration of work (years), more reduce the lung function level. Hence, the last hypothesis said that there is a significant association between duration of work and lung function was failed to be rejected.

5.2 Conclusion

From the findings of this study, it is concluded that photocopiers workers have higher personal exposure to $PM_{2.5}$ and UFP compared to the comparative group. Besides that, the reported of respiratory symptoms was much higher among photocopiers workers compared to the comparative group even though there result shows that there was no significant difference of respiratory symptoms between the exposed group and comparative group. The level of lung function in parameters of FVC, FEV_1, FVC % predicted, FEV_1 % predicted, FEV1/FVC % predicted. Then, there was also significant association between personal exposure to $PM_{2.5}$, UFP and duration of work with lung function among exposed group.

Hence, the present study has successfully answered to the research hypothesis as followed:

- The personal exposure to UFP and $PM_{2.5}$ is significantly higher among exposed group compared to comparative group
- Lung function (FVC, FEV_1) are significantly lower among exposed group compared to comparative group.
- There is significant association between personal exposure to UFP and lung function among exposed group
- There is a significant association between personal exposure to $PM_{2.5}$ and lung function among exposed group

- There is a significant association between duration of work and lung function among exposed group.

5.3 Recommendation

The recommendation to improve the indoor air quality and reduce the exposure to the particulate matter of $PM_{2.5}$ and UFP in the photocopy shop can be done by take into look on some factors. This is because there are many factors that can influence the exposure to the $PM_{2.5}$ and UFP emitted from the photocopiers. Here are the factors that influence the exposure to these particles and the solution:

1. Photocopying environment

As the been discussed before that photocopying can generate particulate matter, ozone and vapours, and other nuisance such as noise, light, heat, which can worst adverse health effect to the operators or those whose working nearby, the shop can isolate the photocopying area with an insulation board to reduce its impact on the shop environment. Besides, it is important to ensure the shop is well ventilated. Extra exhaust fans and fresh air inlets can improve ventilation in the photocopying area. Because of the photocopiers can generate heat and combine with the frequent and continuous photocopying will increase the room temperature which may cause discomfort to those workers. Thus it is advisable that the photocopying shop has

independent air-conditioning controls or is equipped with exhaust fans to keep the temperature down.

2. Machine design

Modern xerography machines have many automatic functions which can reduce the workload and shorten the length of time the user workers with the machine. By using these functions, the degree, duration and frequency of exposure of the user to $PM_{2.5,}$ UFP and other hazard produced by the photocopiers can be reduced. Therefore, the owner of the photocopy shop should consider for the alteration of new model of photocopiers.

3. Daily operation

Daily use of photocopiers can increase the exposure to the particulate matter as frequent use of that machine can generate much heat and hazardous gases and particles. Then, the health risks may exist if the room is poorly ventilated, and may be increased if only one worker is employed to the do the photocopying job because of extended duration working in the photocopying shop. Therefore, the solution for this situation is besides the shop is well ventilated, if possible the owner of photocopying shop should rearranged the worker's duties that he or she can spend less time with the photocopiers. This is possible if the owner applies work rotation or work shift among their workers. Besides that, the owner also may possible to explore

the ways of reducing photocopying and shortening the time in the photocopying shop.

Other than that, particulate matter of $PM_{2.5}$, UFP emitted from photocopiers may cause discomfort of the eye and respiratory symptoms such as cough, phlegm, chest tightness and wheezing as been discussed before. Besides that, irritant gases and vapours can cause sore eyes and a sore nose, headaches and breathing problems. Therefore, the owner of the photocopiers should aware and realize these health problems among their workers. The owner should also give awareness about this kind of health risk to their workers by practicing them to immediately get medical examination if they have experienced the respiratory symptoms or other irritation. Then, the owner also should take follow-up action immediately in order to recover this problem in his or her shop. For that, every possibility to this health complaint should be explored in their shop to find the source of the problem and remedial actions should be implemented. The remedial actions to be taken may include improving ventilation, changing the photocopying process, reducing the amount of photocopying and proper maintenance of photocopiers.

4. Instruction and training

Hazards associated with photocopying include those of physical, chemical and ergonomic origins and the hazardous one is the particles, chemical and gases. For that, proper control of the hazards requires co-operation and participation of

employees. Therefore, to control the exposure to these hazards, the workers should be well informed of such hazards, adverse health effects and control measures required. For that, adequate training should be provided by the owner to the employers including changing of toner cartridges and refilling of consumable chemicals even though modern photocopier models are user-friendly, but the workers should follow the instruction to use the photocopiers appropriately. This is because, untrained workers may come into contact with and exposed to the hazardous particles and chemicals and this can consequently to the illnesses such as respiratory symptoms.

Besides that, the workers also may have skin contact with or inhale harmful substances in changing toner cartridges and handling chemicals. For that, the owner should provide employees with appropriate protective equipment such as mask and impervious gloves besides ensure the protective equipment is kept in good condition. The owner also has to provide adequate training to the employees on when and how to use the protective equipment.

5. Maintenance

Lastly, and the most important thing to control and reduce the exposure to the hazardous particles and other tpes of hazard produce by the photocopiers is the regularly serviced of the machine by the competent maintenance technicians. Faulty photocopiers should be checked and fixed by competent maintenance technicians and

avoid from being handled or checked by the workers that not expert. Then, if the machine problems cannot be fixed, the owner should consider buying a new copier as keep use the faulty photocopiers is probably can increase the problem of release of the hazard.

Besides that, the researcher also has some recommendation for future researchers. As regard to the limited study on respiratory symptoms in particular lung function level among photocopier workers due to exposure to $PM_{2.5}$ and UFP emitted from photocopiers, it is recommended that more detail and comprehensive studies should be performed to determine the risk and health effect between exposures to particles emitted from photocopiers among the workers. Then, future studies also may involve bigger sample size and to include more health effect variables related to the particulate matter exposure. Beside of the lung function parameters, future researcher may take biological sample of blood or biomarkers of exposure for a better and more representative data and more accurate result could be concluded.

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APPENDIX 1

Respondent Information Sheet

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SELANGOR, MALAYSIA

PENERANGAN KEPADA PESERTA

TAJUK KAJIAN: PENDEDAHAN PARTIKEL HALUS DAN ULTRA PARTIKEL DAN FUNGSI PARU-PARU DI KALANGAN PEKERJA KEDAI PENCETAK

PENYELIDIK : NUR AYUNI BT BAHRUDDIN

Apakah kajian ini?

Sejak kebelakangan ini, peningkatan penggunaan mesin fotokopi adalah semakin tinggi disebabkan oleh peningkatan permintaan perkhidmatan fotokopi oleh orang ramai terutamanya golongan pelajar. Bebrapa kajian telah dijalankan yang telah membuktikan bahawa terdapat pencemaran partikel halus dan ultra partikel oleh mesin fotokopi. Partikel halus dan ultra partikel boleh memberikan kesan buruk kepada kesihatan pernafasan manusia termasuklah paru-paru. Pendedahan kepada partikel halus boleh memberikan kesan kesihatan jangka pendek seperti iritasi mata, hidung, tekak dan paru-paru. Ini adalah kerana partikel ini mampu bergerak jauh ke dalam saluran pernafasan dan sampai ke paru-paru. Oleh itu, pendedahan kepada partikel halus dan ultra partikel boleh mengurangkan fungsi pernafasan dan meningkatkan simptom-simptom serta penggunaan ubat-ubatan.

Apakah tujuan kajian ini?

Kajian ini adalah bertujuan untuk mengenalpasti hubungan antara pendedahan kepada partikel halus dan ultra partikel dengan fungsi paru-paru di kalangan pekerja kedai fotokopi.

Siapakah yang perlu terlibat dalam kajian ini?

Pekerja wanita sahaja yang bekerja di kedai fotokopi

Apakah jenis ujian yang akan dijalankan?

Satu set borang soal kaji selidik akan diberikan kepada setiap responden untuk diisi. Selain daripada itu, pengukuran berat badan, ketinggian, dan fungsi paru-paru akan diambil untuk menetahui tahap fungsi paru-paru pekerja kedai fotokopi. Selain itu, tahap partikel halus dan ultra partikel yang dibebaskan oleh mesin fotokopi akan diukur dengan menggunakan alat.

Adakah bayaran dikenakan?

Pengkaji akan menanggung segala pembiayaan ujian yang akan dijalankan dan tiada sebarang bayaran dikenakan terhadap setiap responden.

Apakah faedah daripada kajian ini?

a) Kepada anda sebagai peserta

Dapat mengetahui keadaan fungsi paru-paru setelah terdedah dengan partikel halus dan ultra partikel dariapda proses fotoskopi yang boleh memberikan kesan buruk kepada paru-paru.

Dapat mengambil langkah pencegahan bagi mereka yang terlibat dengan proses fotokopi hasil daripada keputusan kajian untuk mengurangkan risiko pendedahan kepada partikel halus dan ultra partikel.

b) Kepada penyelidik

Memberikan pengetahuan baru mengenai hubungan antara partikel halus dan ultra partikle terhasil daripada proses fotokopi dengan fungsi paru-paru

Adakah maklumat dijamin sulit?

Semua maklumat yang diberikan oleh responden di dalam borang kaji selidik adalah dijamin sulit. Tiada huraian individu akan dibuat pada mana-mana bahagian di dalam kajian atau penerbitan.

Adakah hak anda?

Kajian ini melibatkan anda secara sukarela. Oleh itu, peserta mempunyai hak untuk menarik diri dari penyertaan dalam kajian ini pada bila-bila masa sekiranya peserta merasa tidak selesa untuk memberikan maklumat kepada pengkaji.

Apakah yang harus anda lakukan?

Anda dikehendaki menandatangani borang penyertaan responden yang menyatakan minat anda untuk menyertai kajian ini. Ianya boleh dilakukan setelah anda membaca dan

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memahami isi kandungan penerangan ini. Borang penyertaan responden haruslah dikembalikan kepada penyelidik sebelum ujian dijalankan. Sekiranya anda mempunyai sebarang kemusykilan, penyelidik akan membantu untuk memberi maklumat yang selanjutnya.

Terima kasih atas kerjasama dan bantuan anda.

NUR AYUNI BT BAHRUDDIN
Penyelidik
B. Sc. Kesihatan Persekitaran dan Pekerjaan
Unit Kesihatan Persekitaran dan Pekerjaan
Jabatan Kesihatan komuniti
Fakulti Perubatan dan Sains Kesihatan
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APPENDIX 2

Consent Letter

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BORANG PERSETUJUAN RESPONDEN

TAJUK KAJIAN: PENDEDAHAN PARTIKEL HALUS DAN ULTRA PARTIKEL DAN FUNGSI PARU-PARU DI KALANGAN PEKERJA KEDAI PENCETAK

PENYELIDIK : NUR AYUNI BT BAHRUDDIN

Saya……..... No.K/P: .....……

alamat……

…….. ……..dengan ini secara sukarela bersetuju untuk mengambil bahagian dalam penyelidikan yang dinyatakan di atas. Saya telah dimaklumkan mengenai latar belakang penyelidikan ini dari segi kaedah, kemungkinan kesan buruk dan komplikasi(rujuk kepada risalah maklumat). Saya faham bahawa saya mempunyai hak untuk menarik diri dari kajian ini pada bila-bila masa tanpa memberikan apa jua sebab. Saya juga faham bahawa kajian ini adalah sulit dan semua maklumat yang diberikan mengenai identiti saya adalah sulit dan persendirian.

Saya ingin *tahu/tidak ingin mengetahui keputusan ujian yang dijalankan ke atas sampel saya.

* potong mana yang tidak berkaitan

Tandatangan……..…… Tandatangan……..……
(*Responden*) *(Saksi)*

Tarikh :…….. Nama :……..…..

No.K/P :……..…..

Saya mengesahkan bahawa saya telah menjelaskan kepada responden latar belakang dan tujuan penyelidikan di atas.

Tarikh ……..…… Tandatangan……..……
(Penyelidik)

APPENDIX 3

Questionnaire

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BORANG KAJI SELIDIK

PENDEDAHAN PARTIKEL HALUS DAN ULTRA PARTIKEL DAN FUNGSI PARU-PARU DI KALANGAN PEKERJA MESIN PENCETAK

Dengan ini, sukacita dimaklumkan bahawa pihak tuan telah disenaraikan sebagai salah seorang responden dalam satu kajian penyelidikan yang mengkaji pendedahan kepada partikel halus dan ultra partikel dan hubungannya dengan fungsi paru-paru. Oleh yang demikian, saya memohon jasa baik pihak tuan untuk menjawab soalan-soalan yang terdapat dalam borang soal selidik ini secara tepat dan jujur. Segala maklumat kajian yang diterima akan dirahsiakan. Kerjasama dari pihak tuan amatlah dihargai.

No Responden: ☐☐☐☐☐☐

Tarikh: ☐☐☐☐☐☐

No Telefon: ☐☐☐ - ☐☐☐☐☐☐☐

Tandatangan: _____

SULIT

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A. LATAR BELAKANG RESPONDEN

1. Nama: _____
2. Alamat: _____

   _____
3. No. telefon: _____
4. Pekerjaan: _____
5. Umur: _____tahun Tarikh Lahir: _____
6. No kad pengenalan: _____
7. Jantina: lelaki / perempuan
8. Tinggi: _____cm Berat: _____kg
9. Bangsa:

   ☐ Melayu
   ☐ Cina
   ☐ India
   ☐ Lain-lain: _____

10. Warganegara: _____
11. Tahap pendidikan:

    ☐ PMR/ Tingkatan 3
    ☐ SPM/ Tingkatan 5
    ☐ STPM/ Diploma
    ☐ Ijazah

12. Status perkahwinan:

    ☐ Bujang
    ☐ Berkahwin
    ☐ Duda/Janda

13. Jumlah pendapatan: RM _____

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B. SEJARAH PERUBATAN

14. Adakah anda mengalami masalah paru-paru sebelum masuk bekerja?

- ☐ Ya
- ☐ Tidak

15. Pernahkah anda mengalami sebarang penyakit berikut?

- ☐ Bronkitis kronik
- ☐ Pneumonia
- ☐ Asma / lelah
- ☐ TB

16. Adakah penyakit yang tersebut di atas disahkan oleh doktor?

- ☐ Ya
- ☐ Tidak
- ☐ Tidak berkenaan

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C. BUTIR-BUTIR PEKERJAAN

17. Pekerjaan sekarang: _____ Tempoh bekerja: _____

    tahun

18. Pekerjaan dahulu: _____ Tempoh bekerja: _____

    tahun

19. Di bahagian mana anda bekerja:

    ☐ Pentadbiran
    ☐ Pengeluaran
    ☐ Lain-lain: _____

20. Adakah anda terdedah kepada debu/habuk semasa bekerja?

    ☐ Ya
    ☐ Tidak

    Jika 'Ya', berapa lama anda terdedah dalam sehari? _____ Jam

21. Apakah tahap pendedahan kepada habuk di tempat kerja anda?

    ☐ Kurang
    ☐ Sederhana
    ☐ Teruk

22. Adakah anda selesa bekerja di tempat ini?

    ☐ Ya
    ☐ Tidak

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D. SEJARAH PENYAKIT

Bahagian ini mengandungi soalan yang berkaitan dengan sejarah penyakit yang pernah dialami. Sila tandakan (√) pada petak yang berkenaan. Sekiranya anda tidak pasti, sila tandakan di petak "TIDAK".

	YA	TIDAK
1. Pernahkah mengalami masalah pernafasan?		
2. Apakah penyakit berkenaan?		
I. Asma		
II. Emfisema		
III. Pleurisy		
IV. Barah paru-paru		
3. Masih mengidap penyakit tersebut?		
4. Adakah penyakit anda disahkan oleh doktor?		
5. Bila penyakit bermula?		
6. Adakah mendapat tawatan untuk penyakit tersebut?		
7. Adakah anda masih mendapat rawatan?		

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E. BATUK, KAHAK, KESESAKAN NAFAS, DAN NAFAS BERBUNYI BATUK

Bahagian ini mengandungi soalan yang berkaitan dengan masalah kesihatan di bahagian dada. Sila tandakan (√) pada petak yang berkenaan. Sekiranya anda tidak pasti, sila tandakan di petak "TIDAK".

	YA	TIDAK
1. Adakah anda selalu mengalami batuk?		
2. Berapa kalikah anda mengalami batuk dalam sehari? _____kali sehari		
3. Adakah anda mengalami batuk pada waktu siang atau waktu malam?		
4. Adakah anda mengalami batuk semasa bangun daripada tidur atau pagi-pagi?		
5. Adakah anda mengalami batuk hampir setiap bulan untuk 3 bulan berturut-turut dalam setahun?		
6. Berapa lamakah anda mengalami masalah sebegini? 7. _____bulan/tahun		
8. Adakah anda mengikuti rawatan?		

KAHAK (PHLEGM)

	YA	TIDAK
1. Adakah anda selalu mengalami batuk berkahak?		
2. Adakah anda mengalami batuk berkahak pada waktu siang atau waktu malam?		
3. Adakah anda mengalami batuk berkahak semasa bangun daripada tidur atau pagi-pagi?		
4. Adakah anda mengalami batuk 2 kali sehari atau 4 kali atau lebih dalam seminggu?		
5. Adakah anda mengalami masalah batuk berkahak untuk 3 bulan atau lebih secara berturut-turut?		

KESESAKAN NAFAS

	YA	TIDAK
1. Adakah anda selalu mengalami kesesakan nafas atau dada apabila batuk?		
2. Adakah anda mengalami masalah ini ketika bekerja?		
3. Adakah anda mendapat rawatan doktor?		
4. Adakah anda telah menjalani unian X-ray?		

NAFAS BERBUNYI (WHEEZING)

	YA	TIDAK
1. Pernahkah anda terasa nafas anda berbunyi seperti wisel?		
2. Berapa lamakah dada berbunyi ini berterusan? _____bulan		
3. Adakah anda mendapat rawatan doctor untuk masalah ini?		

F: SEJARAH PENYAKIT KELUARGA

Bahagian ini mengandungi soalan berkaitan dengan sejarah penyakit dan masalah kesihatan keluarga. Sila tandakan (√) pada petak yang berkenaan. Sekiranya anda tidak pasti, sila tandakan di petak "TIDAK"

	YA	TIDAK
1. Bronchitis kronik		
2. Emfiseme		
3. Asma		
4. Barah paru-paru		
5. Lain-lain penyakit 6. _____		

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G. TABIAT MEROKOK

23. Adakah anda masih menghisap rokok?

☐ Ya

☐ Tidak

24. Berapa batang rokok anda hisap dalam sehari?

_____ batang

SEKIAN, TERIMA KASIH.