A STUDY OF $PM_{2.5}$ EMITTED FROM COOKING ACTIVITIES IN INDOOR ENVIRONMENT

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ABSTRACT

Cooking activities has the potential to cause adverse health effects and are strongly dependence on cooking parameters. The objective of this thesis is to quantify the emission from the cooking activities and identify the parameter that affect the particle generation the most in order to predict the associated health impacts towards chefs and kitchen workers. Counterbalanced measure design was employed to test the variables (i.e. cooking stove and temperature) and $PM_{2.5}$ number concentration was measured in a controlled domestic kitchen with no mechanical ventilation by using a particle counter. The air change rate was measured using CO_2 tracer gas injection method using an IAQ meter. Based on a mass balance model, the emission rates of $PM_{2.5}$ are calculated using the concentration decay rate derived from the measured concentration changing curve with time. The calculated rate is then used to quantify the particle decay rate, intake fraction and health impact. The difference and the relationship of stove and temperature are established by graph analysis and comparison. From the results obtained, the concentration emitted ranged from 0.31×10^2 particles/cm^3 to 1.53×10^4 particles/cm^3. High $PM_{2.5}$ concentration was observed during high temperature on electric stove. Type of stove used shows a relatively lower affects in particle emission than the cooking temperature use during experiment. The results show deviation from the existing studies due to the inconsistent performance of gas stove and the amount of chicken being cooked. This study significantly implied that high temperature cooking emitted the highest $PM_{2.5}$ concentration and produce highest health impact. Recommendations were made according to hierarchy of control to correspond to the health impacts of the cooking emission.

ABSTRAK

Aktiviti memasak berpotensi untuk membawa kesan pada kesihatan dan amat bergantung kepada keadaan memasak. Objektif kajian ini adalah untuk mengaji pelepasan partikel $PM_{2.5}$ daripada aktiviti memasak dan mengenal pasti parameter yang melepaskan zarahan $PM_{2.5}$ yang paling tinggi agar impak kesihatan pada tukang masak serta pekerja dapur dapat diramalkan. Reka bentuk langkah balas telah digunakan untuk menguji pembolehubah (jenis dapur memasak dan suhu) dan kepekatan jumlah $PM_{2.5}$ telah diukur dengan menggunakan alat *Particle Counter* di dapur domestik terkawal tanpa pengudaraan mekanikal. Di samping itu, kadar perubahan udara diukur mengaplikasikan kaedah suntikan gas penyurih CO_2 menggunakan IAQ meter. Berdasarkan model keseimbangan jisim, kadar pelepasan $PM_{2.5}$ telah dikira menggunakan kadar pereputan kepekatan yang diperolehi daripada kepekatan kadar pereputan yang ditambah keluk dengan berubah dengan masa. Kadar yang dikira kemudiannya digunakan untuk mengukur kadar pereputan zarahanan, *individual intake* dan *health impact.* Analisis pada graf menunjukkan perbezaan yang ketara dalam hubungan dapur dan suhu. Daripada keputusan yang diperolehi , kepekatan yang dipancarkan ialah di antara 0.31×10^2 zarahan/cm^3 dan 1.53×10^4 zarahan/cm^3. Kepekatan $PM_{2.5}$ yang tinggi telah diperhatikan apabila memasak pada suhu yang tinggi dengan dapur elektrik. Jenis dapur yang digunakan menunjukkan kesan yang lebih rendah daripada suhu memasak semasa eksperimen dijalankan Kesisihan keputusan kajian ini daripada kajian yang sedia ada berpunca daripada fungsi dapur gas yang tidak konsisten dan amaun ayam yang dimasak. Walau bagaimanapun, kajian ini ketara tersirat bahawa memasak dengan suhu yang tinggi melepaskan zarahan bersaiz 2.5µm yang tertinggi dan bakal mendatangan impak kesihatan yang negatif. Cadangan yang berpandukan hierarki kawalan telah dibuatkan untuk mengurangkan kesan negatif daripada pelepasan partikel.

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LIST OF SYMBOLS

μm	Micrometer
h	Hour
λ	Air change rate
C_0	Gas concentration at time t=0
$C_i(t = t_i)$	Gas concentration at time t_i
$t_{i+1} - t_i$	Time interval between two measurements
Δt	Time difference between initial and peak concentration
C_t	Concentrations of the gas at times t
μg	Microgram
m	Meter
$°C$	Degree celcius
C_{out}	Particle concentrations outside the kitchen
C_{in}	Particle concentrations inside the kitchen
Q_s	Emission rate
P	Penetration efficacy
k	Deposition rate
V	Efficient volume of the kitchen
$\lambda+k$	Average total removal rate
$\overline{C_{in}}$	The average value of particle concentrations between the initial background and peak
iF	Intake fraction
Q_B	Average volumetric breathing rate
E	Number of individuals exposed
ER	Emission rate
D_p	Particle diameter

LIST OF ABBREVATIONS

ACR	Air Change Rate
AHSRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
APS	Aerodynamic Particle Sizer
CO	Carbon Monoxide
CPC	Condensation Particle Counter
DEC	Departments of Environmental Conservation
DOH	Departments of Health
DOSH	Department of Occupational Safety and Health
EF	Emission Factor
EH	Cooking on electric stove at high temperature
EL	Cooking on electric stove at low temperature
Eq	Equation
FET	Forced Expiratory Time
GH	Cooking on gas stove at high temperature
GL	Cooking on gas stove at low temperature
HCHO	Formaldehyde
HR-ToF-AMS	High-Resolution Time-Of-Flight Aerosol Mass Spectrometer
iF	Intake Fraction
M	Mass
N	Number
nDMA	Nano Differential Mobility Analyzer
NIST	National Institute Of Standards And Technology
NO_2	Nitrogen Dioxide
OA	Organic Aerosol
PAH	Polycyclic Aromatic Hydrocarbon
PM	Particulate Matter
ROS	Reactive Oxygen Species
S	Surface Area
SMPS	Scanning Mobility Particle Sizing
TEM	Transmission Electron Microscopy
UFP	Ultrafine Particle
VOC	Volatile Organic Compound

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter serves as an introductory chapter to this study on the particle emission from cooking activities in indoor environment. The elements included in this chapter are: background of study, research objectives, research hypothesis, and significance of study and scope of study. It is hope that readers can have a brief idea on the conduct of this study.

1.2 STUDY BACKGROUND

Cooking, a common but indispensable activity in our daily life is often being overlooked on its influence in terms of exposure and its corresponding consequences, especially when it comes to occupational exposure to kitchen workers, for example chefs and kitchen workers. The revolution in living and work habits in the industrial countries causes us to stay more than 90% of the time everyday inside buildings (Fromme, H. 2012). Being the paramount particle generating activities in indoor environment (Dennekamp et al., 2001 and Wallace et al., 2004), cooking is one of the most important sources of indoor particulate matter, including coarse (PM_{10}, aerodynamic diameter <10 μm), fine ($PM_{2.5}$, aerodynamic diameter <2.5 μm) and ultrafine particles (UFP, aerodynamic diameter <0.1 μm) (Abt et al. 2000; Dennekamp et al., 2001; Kamens et al., 1991 and Long et al. 2000). Wallace et al. (2004) found that cooking is capable of generating up to 10 fold of particle number concentration observed when compared to non-cooking periods.

Cooking emissions is subjected strongly to a variety of parameters. Numerous cooking emission-related scientific experiments were conducted in controlled laboratories, test rooms, and kitchenettes under controlled environmental conditions (Dennekamp et al., 2001; Glytsos et al., 2010; Li et al., 1993; See and Balasubramanian, 2006a and Yeung and To, 2008). These experiments shared the same outcomes that the number concentration of the cooking emitted particles depend strongly on particular parameters such as the type of stove used (Dennekamp et al., 2001 and Yeung and To, 2008), the type of the food that was used (Li et al., 1993) and the cooking temperature (Yeung and To, 2008).

Exposure to cooking emitted particles can occur in occupational or residential settings. Occupational exposure may be higher due to more frequent and longer cooking and exposure duration. Abundant of epidemiological studies also allied these effects with particle number concentration, including $PM_{2.5}$ (Pope, 2000) and PM_{10} (Loomis, 2000), as well as ultrafine particle (UFP) number concentration (Hauser et al., 2001) and overall exposure rate (Siegmann and Siegmann, 1998). A study conducted by Kreyling et al. (2006) established the associations between $PM_{2.5}$ and the parallel adverse effects on human health. Anastasio and Martin (2001) also suggest that health effects from $PM_{2.5}$ are strongly associated with co-exposure to other airborne pollutants.

Airborne pollutants are mainly inhalable particles but not all gases. Inhalation of these airborne ultrafine particles which occurs in outdoor and indoor environments has adverse effects on human health. The health implications of $PM_{2.5}$ are still under intensive study, however, the existing studies still managed to show various adverse health effects have been associated with exposure to $PM_{2.5}$. Reading across the studies on cooking emission and the associated health impacts, it is found that the development of cardiorespiratory ailments are due mainly to long term exposure as $PM_{2.5}$. $PM_{2.5}$ is a respirable dust that is able to penetrate into the airways and lungs, and when deposited, they may yield harmful health effects such as the cardiovascular effects (i.e. heart attacks and strokes) and respiratory effects (i.e. asthma attacks, coughing and breath shortness) (USEPA, 2007).

With the growth in the field of nanotechnology, the health effects due to exposure to nanomaterial have become an important concern. Certain styles of cooking have been associated with an elevated risk of lung cancer. A study has shown that women in Taiwan that cooked using a wok had a higher risk of developing lung cancer (Ko et al., 2000). The women would heat the cooking oil until it was smoking before adding the ingredients. The authors concluded that modifying the cooking methods and using a well-designed fume extractor could significantly lower the risks. A study in Shanghai has shown that using rapeseed oil as opposed to soybean or peanut oil in cooking increased the risk of lung cancer in non-smoking women (Zhong et al., 1999). To sum up, cooking activities, even common, but are attributable to cause adverse effect to human health due to long term exposure to $PM_{2.5}$. This motivated the conduct of this research to identify to what extent the effects of cooking stove and cooking temperature on the emission of $PM_{2.5}$ and predict the associated health impacts.

1.3 PROBLEM STATEMENT

Particulate matter is classified according to its size. $PM_{2.5}$ is defined as the concentration of particulate matter that has aerodynamic diameters of 2.5 μm or less. They have the ability to penetrate into the airways and lungs, and when deposited, they may yield harmful health effects such as the deteriorating of heart and lung illnesses (Nemmar et al., 2002). This particulate source has been specifically associated with respiratory ailments and lung cancer (Hoelscher et al., 2000; Ko et al., 2000), which is thought to be due to fine particles emitted from gas cooking (Dennekamp et al., 2001; Wallace et al., 2004). Many outdoor sources have already been targeted and efforts at reducing emissions are in progress. However, indoor sources may be more important because much of human activity occurs indoors and people are typically closer to the source of PM in indoor microenvironments. One important source of indoor PM is cooking. Cooking activities occur in both occupational and residential settings, in which the exposed groups are mainly chefs and kitchen workers. People closest to the source (the stove) are exposed to the highest concentration of PM.

Food cooking usually uses a high temperature heat source, such as a stove to prepare food. During cooking activities, gases, vapours and PM are emitted from the cooking process and by the stove. Numerous studies have been conducted to investigate the characteristics of the pollutants emitted during cooking activities (Li et al., 1993; Dennekamp et al., 2001; He et al., 2004; Wallace et al., 2004 and Hussein et al., 2006). Some have also characterized the pollutants emitted when using gas fuel, or solid fuel combustion stoves (Raiyani et al,. 1993; Benner et al., 1995; and Dasgupta et al., 2006). Epidemiological studies have shown an increased risk of lung cancer in women exposed to pollutants from Chinese style cooking (Zhong et al., 1999 and Ko et al., 2000). It has also been shown that cooking oil fumes contain carcinogenic and mutagenic PAHs (Shields et al., 1995 and Chiang et al., 1999). However, only a few studies have investigated in detail the emissions from electric stoves.

The focus of this study is to examine the effects of cooking stove and cooking temperature on the emission of $PM_{2.5}$ from the cooking activities. By identifying the factor that determine the generation of $PM_{2.5}$, we will be able to understand the emission of the particle concerned from cooking activities. A second focus of this project is to predict the concentration of $PM_{2.5}$ emitted and the health impacts that might be caused by calculating the individual intake of $PM_{2.5}$ and the associated health impact value from the emission $PM_{2.5}$ from cooking in the indoor environment.

1.4 RESEARCH OBJECTIVES

1.4.1 General Objectives

- To assess the level of the $PM_{2.5}$ emission during cooking event and the effect of varied cooking conditions on the particle emission. The data collected is then used to predict the health impacts value of the particle emission.

1.4.2 Specific Objectives

The objectives of this research are as follows:

I. To investigate the effect of the type of stove used on the $PM_{2.5}$ emission during cooking activities.

II. To investigate the effect of the cooking temperature on the $PM_{2.5}$ emission during cooking activities.

III. To predict occupational health impact value due to the generation of $PM_{2.5}$.

1.5 RESEARCH QUESTIONS

From the above research objectives, the following research questions are formulated:

I. What are the parameters that affect $PM_{2.5}$ emission the most during cooking activities in the indoor environment?

II. To what extent the type of stove used affect the $PM_{2.5}$ emission?

III. To what extent the cooking temperature affect the $PM_{2.5}$ emission?

IV. What are the health impacts predictable upon the emission of the $PM_{2.5}$ during cooking process?

1.6 RESEARCH HYPOTHESIS

In view of the above research questions, these hypotheses were formulated by referring to the results by Zhang et al. (2010):

I. Gas stove emits more $PM_{2.5}$ particles than electric stove during cooking activities

II. High stove power cooking emits more $PM_{2.5}$ than low stove power during cooking activities.

1.7 DEFINITION OF VARIABLES

1.7.1 Operational Definitions of Variables

I. Cooking Stove Type

Cooking stoves apply two main principles to generate heat, one is to combust fuel and the other is to use electrical power. Natural gas is the most commonly used fuels for a combustion stove in developed countries. Whereas, electric stoves use the heat emitted by electrical resistance through a metal to cook. Health studies in the past have looked at emissions from gas cooking stoves, but have focused mainly on NOx and CO emissions. For electric stove, it is not clear how the particles are emitted in this process but it is assumed that contaminants on the heating element get vaporized and then condense into particles as they are cooled in the air.

II. Cooking Temperature

Cooking temperature refers to the temperature applied during cooking, the level is set to 'High' and 'Low' which is the setting on the dial of stove power to full and low power. The temperature settings are varied with the power settings on the stove: high power and low power. No measurement was taken on the temperature resulted from the stove as until now, no appropriate methodology is designed and applied in cooking emission study. Emissions from high temperature frying have been classified as 'probably carcinogenic to humans (Group 2A)' by IARC (IARC 2010). Thus, it is one of the factors influencing the emission.

1.7.2 Operational Definitions of Environmental Parameters

I. Decay Rate

The decay rate refers to the time of total particle number concentration to decay to its background level. Decay rate is applied to achieve the calculation of air change rate (ACR) via CO_2 decay method reported by Laussman and Helm (2011) and He et al. (2004) as well as to get the decay rate of $PM_{2.5}$ during the cooking events. The decay rate is determined by the using the equation derived from the steady-state solution of the mass balance equation.

II. Particle Number Concentration

Particle mass concentration is dominated by larger particles, most of the number of particles is in the ultrafine size range (particle diameter $D_p < 100$ nm), and can reach and deposit in the alveoli region of the lung (Jaques and Kim 2000). Therefore, it has been suggested that particle number concentration could be used to better reflect the adverse health effect of the PM (Seaton et al., 1995). Particle number concentration is measured measured with a Six-Channel Hybrid Handheld Particle Counter (HPC; HPC600).

III. Particle Emission

Particle emission refers to the rate of emission of the particle number concentration of $PM_{2.5}$ in this study. The information about the particle emission are obtained from experimental and mathematical approach, the steady-state solution of the mass balance equation, is used to get the emission rate, air exchange rate and particle decay rate in the cooking particle emission study (Torkmahalleh et al.,2012 and He et al. 2007).

IV. Individual Intake Fraction

Individual intake is defined as the pollutant inhaled by an individual (Nazaroff, 2008). Individual intake fraction is the ratio of the individual intake to the total emissions from the source (Adams et al., 1993; Bennett et al., 2002 and Nazaroff, 2008). For cooking activities, individual intake of particles can be calculated as intake fraction as it provides a more direct association of the emission source to its corresponding human exposure of the air pollutant (i.e. $PM_{2.5}$).

Marshall and Nazaroff (2006) suggested the mathematical calculation of health impact when intake fraction, emissions and toxicity are known to enable the condition with the higher health impact value will be prioritized for control to be taken.

1.8 CONCEPTUAL FRAMEWORK

Figure 1.1 is the conceptual framework of this study which is interested in examining the effect of cooking parameters (i.e. cooking stove and temperature) in influencing the emission of $PM_{2.5}$ in indoor environment and predicts the health impacts associated.

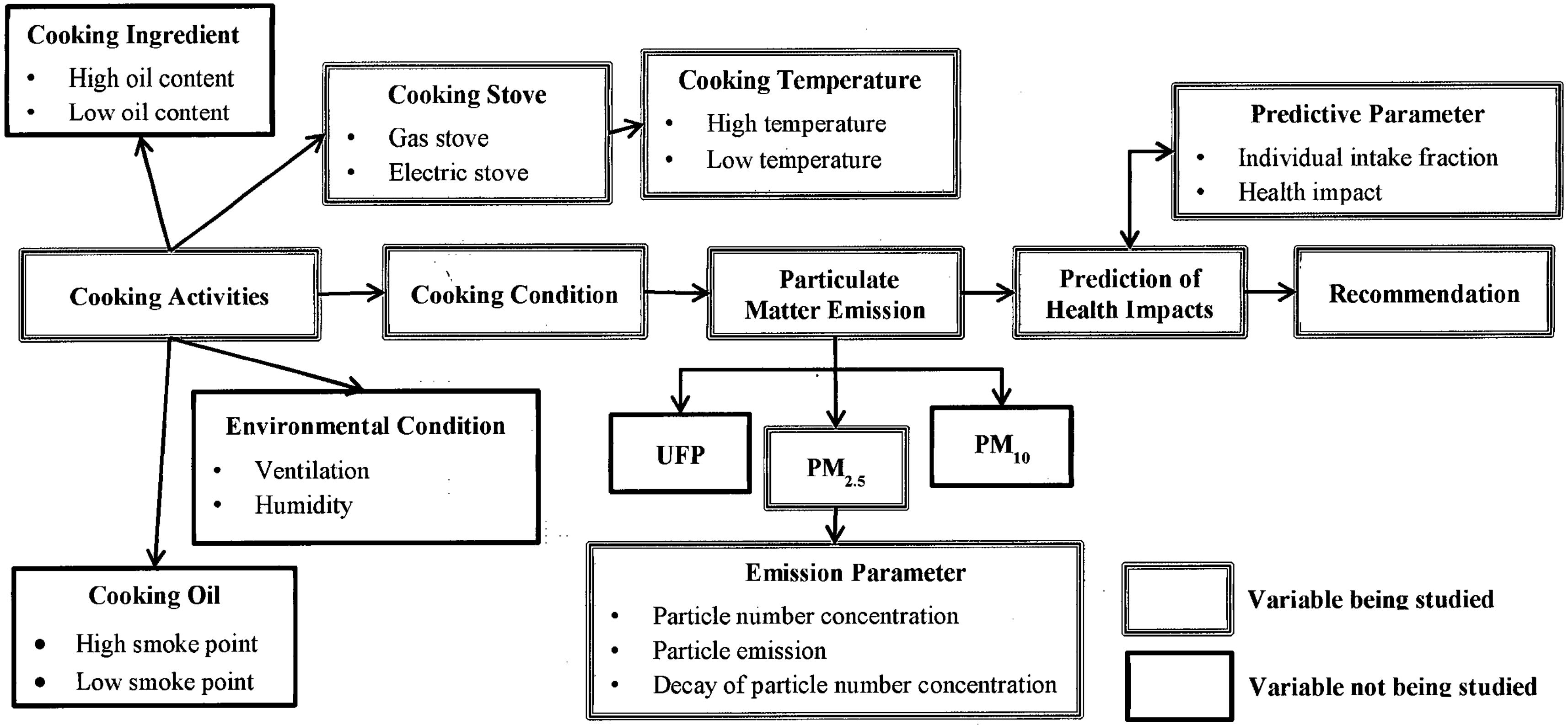

Figure 1.1: Conceptual framework of study

1.9 SIGNIFICANCE OF STUDY

Cooking is a process involving high temperature (i.e. stove power) heat sources that can generate high concentrations of air pollutants. In a non-smoking indoor background, cooking denotes one of the most noteworthy particles generating activities (Buonanno et al., 2009; Lai et al., 2010; Siegmann and Sattler, 1996; See and Balasubramanian, 2008; Wan et al., 2011 and Yeung and To, 2008). Researches have investigated the health impacts of fine particulate matter ($PM_{2.5}$, particulate matter with an aerodynamic diameter less than or equal to 2.5 μm). Particulate matter emitted from cooking oil fume has been associated with the development of respiratory problems, lung cancer and cardiopulmonary deaths, as proven by Boldo et al. (2006) and Pope and Dockery (2006).

The significant adverse impacts of the emissions of airborne particles from cooking activities have been reported in many former studies. Kelly (2001) concluded that residential cooking activities produce considerable elevation in particles and gaseous species in indoor air. Wallace et al. (2004) determined that cooking was associated with both an increase of a factor of 10 in the concentration of UFP and an increase of a factor of 3 in $PM_{2.5}$. Similarly, Li et al. (1993) observed a 10-fold increase in submicron particles when frying chicken on gas stoves.

Exposure to particles emitted by cooking activities may be responsible for a variety of respiratory health effects. However, the relationship between these exposures and their subsequent effects on health cannot be evaluated without understanding the main parameters that influence particle emissions during cooking. The exposure often occurs in occupational or residential settings, but may be higher in occupation environment due to more frequent and longer cooking periods. The health impacts that might be brought due to the cooking emitted PM are easily ignored as the effects are only detectable after a long duration of exposure and might be confused with the other confounding factor to cause the similar symptoms. Thus, this encourages the study on the emission and the implication of health impacts to raise the awareness that health aspects of kitchen workers should be well taken care of by fitting suitable adjustment and changes to control the emission of $PM_{2.5}$.

1.10 SCOPE OF STUDY

This is an experimental research in order to study the parameters that influence particle emissions during cooking and then predict the subsequent health impacts. This study was conducted in a controlled kitchen to simulate the emission. The parameters (i.e. cooking temperature and cooking stove type) are assessed to study their effects on the particle emission from the cooking activities. To predict the health impacts from the emission, particle emission, individual intake fraction and decay of particle number concentration will be measured to demonstrate the exposure level of the particles to the exposed worker.

In this study, the effects of cooking conditions were assessed during the pan frying of chicken. Pan frying activities were chosen as to represent cooking activity in all experiments to exclude the variability in emissions caused by differences in cooking styles. Ventilation was designed to be with minimal air movement where no windows and door were opened and no fan was turning on. The cooking ingredient and the duration were kept constant to avoid addition of manipulating factors. Stove type and cooking temperature were varied to assess the factors affecting cooking emissions and exposures. The data collected are then substitute into equations to generate air change rate, emission rate, particle decay rate, individual intake fraction and health impacts. Each parameter is studied to compare the difference between the variables concerned in this study to fulfil the hypothesis testing.

By studying the emission of particles from cooking activities, it is hope that this study will demonstrate the concern and understanding on the level of $PM_{2.5}$ emission from specific cooking condition and the associated health impacts during cooking activities. The health impact predicted is hoped to raise awareness on the adverse effect $PM_{2.5}$ emission from cooking. Appropriate recommendations are outlined in chapter 5 to ensure that the emission and exposure can be reduced by having them practised.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the review of previous researches and studies that display understanding and studies on $PM_{2.5}$ emission from the cooking activities in indoor environment. Besides that, this chapter serves to demonstrate the paramount concern on the cause and effect relationship of the cooking conditions (i.e. stove type and cooking temperature) and the $PM_{2.5}$ emission during cooking activities. Exposure to particles emitted by cooking activities may be responsible for a variety of respiratory health effects. The review on the occupational impacts of particle emission will be written in this chapter to show the possible health impacts caused by the particle emission from cooking activities

2.2 PARTICULATE MATTER AND $PM_{2.5}$

Aerosol is a disperse system of the suspended small liquid or solid particles in a gas, usually air. There is a wide range of phenomena categorized under aerosol: fume, smoke, fog, mist, haze, smog and dust. Particle size is the key parameter to characterize the aerosol behaviour. The understanding of the properties of aerosols is important as it determine the generation, movement and the fate of these atmospheric airborne pollutants. Aerosols are found to be one of the leading pollutants that determine the status of air quality in urban areas, especially in the local and regional atmosphere (Hu et al., 2010). Fine aerosol particles exposure tends to threaten on the environment and to be of concern in health-related effects (Grazia et al., 2001).

Particulate matter (PM) is defined as the mass of a mixture of solid particles and liquid droplets of various sizes (range from a few nanometres to tens of micrometres) suspended in a volume of air which represent a broad class of chemically and physically diverse substances. Particulate matter is classified according to its size, thus PM_{10} is defined as the concentration of particulate matter with aerodynamic diameter of 10 micrometres or less, while $PM_{2.5}$ is defined as the concentration of particulate matter that has aerodynamic diameters of 2.5 μm or less.

Particulate matter often featured by its morphological difference and non-spherical shape, thus there exists several of terminologies that define the particle size. Aerodynamic diameter is one of the most widely used terms. Aerodynamic diameter is defined as the diameter of a unit density sphere (density = $1 g/cm^3$) having the same settling velocity as the particle. This implies that particles, if their settling velocity is the same, will exhibit the same aerodynamic diameter, regardless their size and density. The aerodynamic property is the key properties to determine the respiratory deposition of inhales particles in the region of respiratory tract.

The American Conference of Governmental Industrial Hygienists (ACGIH) categorizes the particle size fractions in a different convention: inhalable, thoracic, and respirable (ACGIH, 2001). Inhalable particles, having 100μm in aerodynamic diameter can enter any part of the human respiratory tract upon inhalation. Thoracic particles are <25μm in aerodynamic diameter that is able to pass through larynx into the thorax, whereas respirable particles can penetrate through the breathing airways to the pulmonary region of the lung and are <10μm in aerodynamic diameter. Particles are classified according to aerodynamic diameter as ultrafine, coarse, and super coarse fraction by the US Environmental Protection Agency.

Understanding of the exposure means of $PM_{2.5}$ at home, especially during cooking events, provides a basic concept of the generation and for the quantification of potential health risks (Wan et al., 2011). Fine particulate matter, $PM_{2.5}$, an air pollutant that is a concern for human health when it exists at high exposure rate. $PM_{2.5}$ is tiny particles that float in the air. Its presence reduces visibility and causes the air appears to be hazy when levels are raised. Outdoor $PM_{2.5}$ levels are most likely to be elevated during daytime with little or no wind or air mixing. The New York State Departments of Health (DOH) and Environmental Conservation (DEC) alert the public by issuing a $PM_{2.5}$ Health Advisory when the outdoor $PM_{2.5}$ concentrations level in are estimated to be unhealthy for certain sensitive groups (i.e. elderly and asthma patient).

Table 2.1: Particle Classification by EPA.

Particle Type	**Aerodynamic Diameter**
Ultrafine	<0.1 μm
Fine	0.1 – 2.5 μm
Coarse	2.5 – 10 μm
Super coarse	>10 μm

Adapted from: USEPA 1996.

2.3 PARTICLE NUMBER CONCENTRATION

Particle number concentration, according to IUPAC (1997), refers to number of entities of a constituent divided by the volume of the mixture. The measurement of number concentration and size distribution of particles emitted during cooking activities has been the primary task in order to have a better understanding of the relationship between particulate emission and cooking activities (Li et al., 1993; Dennekamp et al., 2001; Hussein et al., 2005; He et al., 2004; See and Balasubramanian, 2006a, b; Wallace et al., 2004 and Yeung and To, 2008). Particle mass concentration is dominated by larger particles; most of the number of particles is in the ultrafine size range (particle diameter. D_p < 100 nm), and can reach and deposit in the alveoli region of the lung (Jaques and Kim, 2000). Therefore, it has been suggested that particle number concentration could be used to better reflect the adverse health effect of the PM.

In recent years, results from several researches (He et al., 2004; Wallace et al., 2004; Wallace, 2006 and Buonanno et al., 2009) recognized the relationship of indoor particle concentration and source emission factors of cooking activities in predicting the particle generation. They found the source strengths by the concentration decay rate from the natural logarithm of measured concentration and its linear regression using the