CHAPTER 1

Introduction

1.1 Problem Statement

Air pollution is one of the most important environmental issues to be addressed, as atmospheric pollution and global warming issues are increasingly becoming major environmental concerns (Sen et al., 2014; Tawfiq et al., 2015). The air pollution is defined as contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere (WHO, 2017), air pollution is also defined as one or more chemicals or substances in high enough concentrations in the air to harm humans, other animals, vegetation, or materials. Such chemicals or physical conditions (i.e. excess heat or noise) are called air pollutants (US EPA, 2016).

Various extreme events recorded over the world have been recognized as scientific-based evidence for possible, air pollution, climate changes and variability (Kanabkaew, 2013), household combustion devices, motor vehicles, industrial facilities, agricultural residues deposals (open burning) and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide. Outdoor and indoor air pollution causes respiratory and other diseases, which can be fatal (WHO, 2017). Particularly, increasing mass concentration of particulate matter in the atmosphere could have an adverse impact on human health (Qiu et al., 2016).

Over the past decades, increasing international attention had been paid to fine particles released as a consequence of open biomass burning (agricultural waste, sugarcane, maize, rice straw, and other crops) prior to the harvest season, normally performed to clean land quickly before the next crop cycle (Pongpiachan et al., 2017). At global scale, fire emissions are dominated by biomass burning in tropics (Reddington et al., 2016; Werf et al., 2004).

Biomass burning is producing toxic gaseous pollutants, PAH and heavy metals (Pb, Cu, Fe, Zn, and Hg, etc) many of which can adversely affect human health. Biogeochemical cycles of trace elements in tropical regions may also be changing due to biomass burning emissions. Emission of heavy metals can cause local and regional pollution of the atmosphere (Hasan et al., 2009), therefore BB emitted pollutants are harmful for human health and also have effects on the climate change (Arbex et al., 2007). Globally biomass burning estimated to cause 3.5 million premature deaths per year, around one million of which are attributed to acute respiratory infections in young children, pneumonia in children under five, lund concer, tubercloses (Ielpo et al., 2016) and chronic pulmonary (Kurmi, et al., 2010).

Urban air pollution is a greater risk factor in middle-income countries than in high-income countries because of substantial progress by the latter in controlling this risk through public health policies. Increasing exposure to these emerging risks is not inevitable; it is amenable to public health intervention (WHO, 2016). According to 2010 and 2013 Global Burden of diseases (GBD) reports, air pollution is ranked in the top 10 causes of death in the world. Specifically, Asia is under the highest threat from air pollution. Two third of the world’s air pollution related casualties occur in Asia (GBD, 2013).

Emission of air pollutants in the Asian region are increasing rapidly (Chantara et al., 2012). Biomass burning (agricultural burning and forest fires) in Southeast Asia produces high levels of haze, especially in the dry season (Reid et al., 2013). The smoke-haze episode in the Southeast Asia (SEA) region for the past three decades has been an almost annual transbounadry pollution problem affecting several countries in the region. Atmospheric aerosols emitted by the biomass in SEA is the dominant pollutant causing exceedances of ambient air quality threshold on a regional scale (Dotse et al., 2016).

Hence, air Pollution is a serious environmental problem (Zhang et al., 2011) in southeast Asia, and the previous studies have highlighted the worsening of air pollution in Northern Thailand over recent years, due to the effects of unintentional burning of biomass, and burning of agricultural waste (Pongpiachan et al., 2015), burning of grassland and forest fires (Chantara, et al., 2012) .

Thailand is predominantly an agriculture-based country (TOTA, 2011) and produces plenty of stubbles remaining after harvesting. Open burning is frequently used to remove agro-residues because of its simplicity and economical sound but releasing a significant amount of air pollutants. In addition, in Northern Thailand, agricultural activities such as biomass burning and forest fires were shown to be closely correlated to the ambient Particulate Matter (PM) concentration (Phairuang et al., 2017). Biomass open burning in Northern Thailand and neighboring countries has been considered as essential sources of high concentration of PM during the dry season (Kanabkaew, 2013). Fire is one of the significant sources of pollutant gases released into the atmosphere; and tropical biomass fires contribute greatly to the PM emission (Tawfiq et al., 2015). Chiang Mai province, as well as other provinces in upper Northern Thailand has been annually facing air pollution almost every dry season (Sillapapiromsuk et al., 2013), evenutally biomass open burning is main cause of air pollution problem in Northern Thailand, underneath biomass burning is beifly introduced.

1.2 Biomass Burning and its Impact (on environment and health)

The spatial and temporal distribution of fire depends on the climate, vegetation and human activities. At global scale, fire emissions are dominated by burning in tropics (Reddington et al., 2016; Werf et al., 2004), and biomass burning is a problem of long standing in tropical areas. Huge amounts of air pollution are produced worldwide by the annual burning of 3 billion metric tons of biomass such as wood, leaves, trees, grass and trash. Biomass burning represents the largest source of air pollution in many rural areas of the developed and developing world. Biomass burning is used create heat, to clear forests, to dispose of leaves, crop stubble, trash and wood. Globally, biomass burning is estimated to produce 40 percent of the carbon dioxide, 32 percent of the carbon monoxide, 20 percent of the particulates, and 50 percent of the highly carcinogenic poly-aromatic hydrocarbons produced by all sources (Curtis, 2002).

Biomass burning includes the open burning of crop residues, forest fires and grassland fires and it’s largely source of many trace gases and fine particles (Reddington et al., 2016; Tian et al., 2015; Wiriya et al., 2016). PM emitted from sources such as biomass burning, incomplete combustion of fossil fuels and traffic-related suspension of road, soil, dust, sea salt and biological materials (Chantara et al., 2009). Open biomass burning is an important sources of trace gases and Particulate Matter (PM), and PM from biomass burning can substantially degrade regional air quality (Tippayawong & Lee, 2006), while emissions from biomass combustion are a major source of indoor and outdoor air pollution (Chakraborty et al., 2014; Rastogi et al., 2014). Particularly, increasing mass concentration of PM in the atmosphere could have an adverse impact on human health (Qiu et al., 2016; Tao et al., 2013), this adverse effect on human health leading to mortality of adults and children, it is estimated to cause millions of premature deaths worldwide annually (Tao et al., 2013; Tippayawong & Lee, 2006).

Biomass is biological material derived from living or dead organisms (Notte et al., 2017). Biomass is contemporaneous (non-fossil) and complex biogenic organic–inorganic solid product generated by natural and anthropogenic (techno-genic) processes (Vassilev, et al., 2010). The components of biomass include cellulose, hemicelluloses, lignin, lipids, proteins, simple sugars, starches, water, hydrocarbon, ash, and other compounds. The concentration of each class of compound varies depending on species, type of plant tissue, stage of growth, and growing conditions (Sillapapiromsuk et al., 2013), and biomasses are highly enriched in heavy metals such as Fe, Mn, Al, K, Na, Ca, Mg (Vassilev, et al., 2010) and Poly Aromatic Hydrocarbons (PAHs) (Ielpo, et al*.,* 2016).

1.2.1 Air pollution and its environmental impacts

During the recent decades, due to the dramatically increasing emission of air pollutants at the same time, in the absence of environmental protection technologies, several acute air pollution episodes were formed in some countries.

Each pollutant emitted to the atmosphere can affect directly or indirectly the human health. Along with harming human health, air pollution can cause a variety of environmental effects, such us acid rain, eutrophication, effects on wildlife, ozone depletion, crop and forest damages, global climate change.

Some pollutants can also play important role in weather situations (e.g. reduction of visibility, forming of clouds and precipitation, modification of radiation budget etc). At the same time, the state of the atmosphere is also affects the degree of air pollution through several processes (e.g. photochemical activity, transport and deposition processes etc).

1.2.2 Air Pollution and its health impact

Many particulates and gas compounds that come from biomass burning are known as hazardous to human health (Sillapapiromsuk, et al., 2013). Typ of pollutants and amount of pollutants emitted from biomass open burning depend to properties of biomass and condition of biomass burning. Biomass burning of different types of agricultural products, for instance rice, wheat, sugar cane and other crops have a variety of emissions, such as soot and particles, carbon monoxide, methane, and volatile organic compounds (Amaral et al., 2016). Typically pollutants emitted from biomass burning are various and can be classified into gases (such as CO) and solid particles (black carbon and PMs) and fine particulate mater ($PM_{2.5}$) that contains various elements including heavy metals , PAH, ions and toxic and non-t and toxic. Futhermore, can penetrate deeply into the alveolar sacks of lung and cause lung diseases , thus, this study is focusing on fine particulate mater.

Fine particles contain toxic trace metals such as copper and chromium; inhalation can result in cancer, for every 1 in 200 people. Each 10 µg m^{-3} increase in particulate matter is associated with increased lung cancer risk by 8%. $PM_{2.5}$ particles are also miniscule enough to penetrate the lungs deeply, increasing risk of respiratory-related diseases such as bronchitis and asthma. Indeed, inhalation accounts for 70% of $PM_{2.5}$ in the lungs (Figure 1.1). All in all, haze is associated with respiratory disease, associated hospital admissions, risk of cancer, eye conditions, as well as death (Islam et al., 2016).

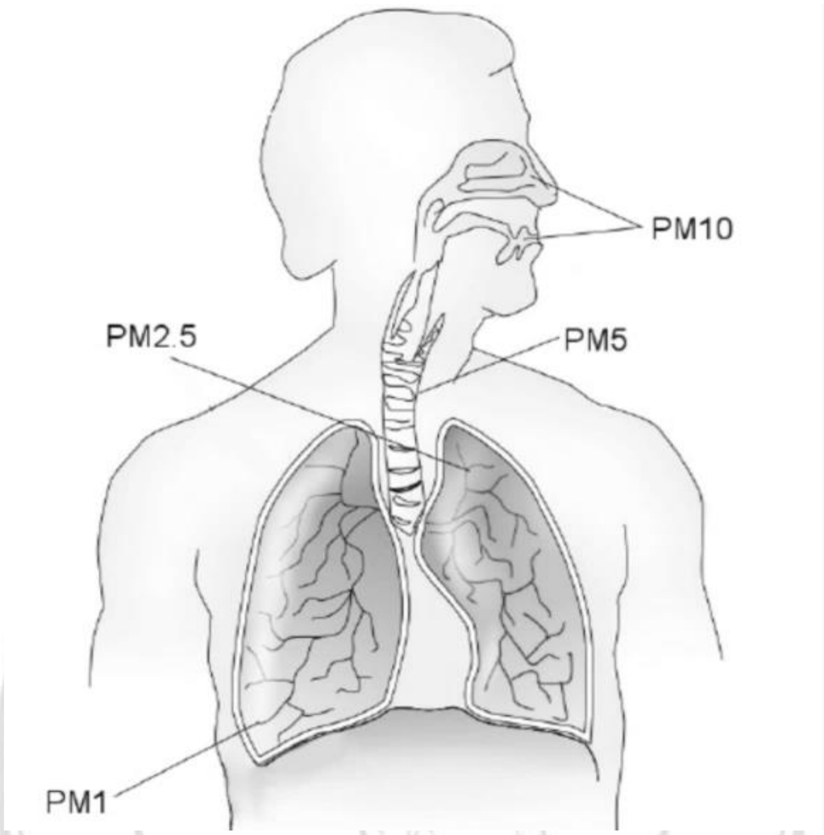

Figure 1.1 Particle deposition in the lunch based on their size, (Pražnikar & Pražnikar, 2012)

It is estimated that approximately 3% of cardiopulmonary and 5% of lung cancer deaths are attributable to PM globally, in the European Region; this proportion is 1–3% and 2–5%, respectively, in various sub regions. Results emerging from a recent study indicate that the burden of disease related to ambient air pollution may be even higher. This study estimates that in 2010, ambient air pollution, as annual $PM_{2.5}$, accounted for 3.1 million deaths and around 3.1% of global disability-adjusted life years. Exposure to $PM_{2.5}$ reduces the life expectancy of the population of the Region by about 8.6 months on average. Results from the scientific project Improving Knowledge and Communication for Decision-making on Air Pollution and Health in Europe (Aphekom, WHO 2011), which uses traditional health impact assessment methods, indicate that average life expectancy in the most polluted cities could be increased by approximately 20 months if the long-term $PM_{2.5}$ concentration was reduced to the WHO standard (WHO, 2017).

1.3 Air Pollutants

Air pollutants are a heterogeneous mixture of gaseous and particulate matter (PM). The main gaseous components of air pollution include NO_2, SO_2, CO, O_3, NH_3, carbonyl compounds, and organic solvents. On the other hand, PM is made of solid and liquid particles from traffic, industry, domestic heating and various natural sources (Pražnikar & Pražnikar, 2012). Later species of mentioned pollutants is introduced as following.

1.3.1 Particulate matters

Particles in the atmosphere arise from natural sources, such as wind-borne dust, sea spray, volcanoes, and from anthropogenic activities, such as combustion of fuels, emitted directly as particles (primary aerosol) or formed in the atmosphere by gas-to-particle conversion processes (secondary aerosol) (Austin et al., 2002).

PM stands for particulate matter (also called particle pollution), and is the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot or smoke, are large or dark enough to be seen with the naked eye, while others are so small they can only be detected using an electron microscope (US EPA, 2016). Particles are often non-spherical, there are many definition of particle size. The most widely used definition is the aerodynamic diameter. The studies around the world have consistently demonstrated that particles with an aerodynamic diameter < 10 µm (PM_{10}) and most recently < 2.5 µm ($PM_{2.5}$) (Chaichana, 2011), 2011). $PM_{2.5}$ are also known as fine particles, find particulate matter ($PM_{2.5}$ can be made up of hundreds of different chemicals (Dai et al., 2013).

Fine particulate mater are complex in compostion which include verious elements, organic and inorganic counpound. Trace elements are the important constituents of fine atmospheric particles (Rungratanaubon, et al., 2008) emitted from BB. Furthermore, common chemical constituents of PM include sulfates, nitrates, ammonium, other inorganic ions such as ions of sodium, potassium, calcium, magnesium and chlorine, organic and elemental carbon, crustal material, particle-bound water, metals (including cadmium, copper, nickel, vanadium and zinc) and polycyclic aromatic hydrocarbons (PAH). In addition, biological components such as allergens and microbial compounds are found in PM (WHO, 2017). Consequently, exposure to particulate matter, especially fine PM, is associated with a wide range of diseases, including respiratory infection, lung cancer and bronchus (Shen et al., 2010).

Inhaled PM particles penetrate to the lung and the smaller they are more deeply they can penetrate to the lung and cause more serious health impacts, thus $PM_{2.5}$ can pose greater risk to human comparing to PM_{10}. Think about a single hair from your head. The average human hair is about 70 micrometers in diameter making it 30 times larger than the largest fine particle, Figure 1.2 illustrates this comparison.

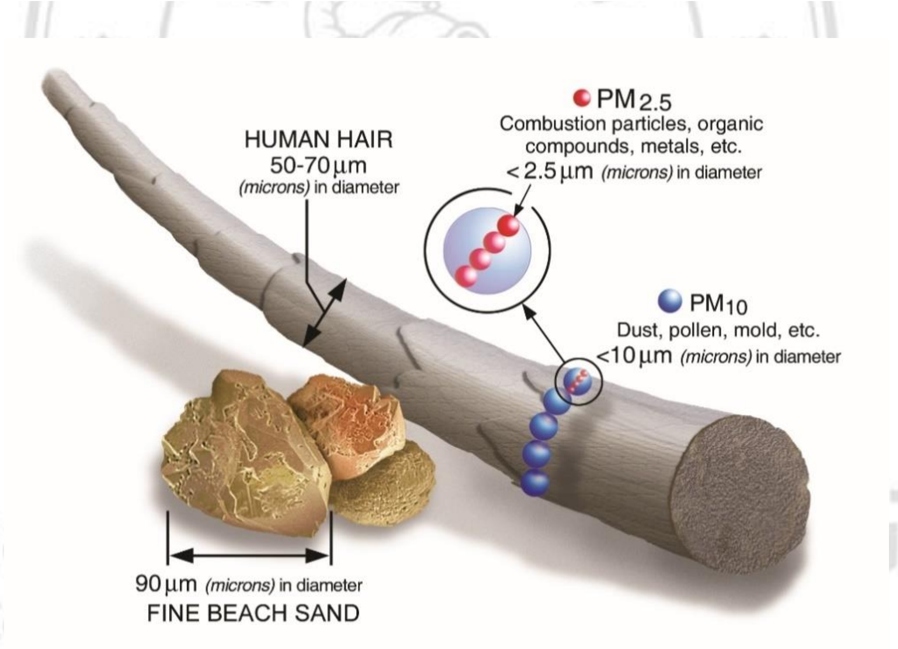

Figure 1.2 Size comparison for PM particles (https://www.epa.gov/pm-pollution/particulate-matter-pm-basics).

1.4 Literature Review

1.4.1 Chemical composition of $PM_{2.5}$

Biomass open burning of agricultural residual is the main source of air pollutants in Northern Thailand. Researches have been conducted to study effects of biomass burning on air pollution. Beneath some relevant precious studies have been reviewed.

Khamkaew et al. (2016) investigated biomass burning component over Northern SEA. The $PM_{2.5}$ samples were collected from Doi Ang Khang and Chiang Mai University during dry season (March to mid-April) 2014 and analyzed for concentrations of ions, metals and levoglucosan using Ion Chromatography, Inductive Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and Gas Chromatograph-Mass Spectroscopy (GC-MS), respectively. The study determined that concentrations of levoglucosan and K^+ (BB tracers) were well correlated. Therefore, $PM_{2.5}$ detected in these areas was mainly influenced by BB activity. Elemental analysis showed that the most abundant elements at both sampling sites were K (49–50% of total elements), Al (26–31%), Mg (16%) and Zn (4–7%). Most abundant ions according to IC results were SO_4^{2-} (30–38%), NO_3^- (13–20%), Na^+ (16–20%) and NH_4^+ (14–15%), whereas the overall result showed that the concentration of $PM_{2.5}$ at DAK and CMU were 80.8–83.3 and 90.7–93.1μg m^{-3}, respectively. which were very high comparing to WHO guideline daily (25 μg m^{-3}) and annual (10 μg m^{-3}) (WHO, 2016), and Thailand National Air Quality Standard daily (50 μg m^{-3}) and annual (25 μg m^{-3}) (PCD, 2017). Emissions from biomass open burning causing smog and haze in the cities. Trace metals in air particulate matter (TSP & $PM_{2.5}$) during biomass burning haze episode in Malaysia have been studied by (Ahmed, et al., 2016). Leading trace metals in PM were Al, Zn, Pb, Cd, and Cr. During the haze period, the highest mass concentration of TSP and $PM_{2.5}$ were 313 mg/m^3 and 191 mg/m^3, respectively. Those can pose high health impact for human health.

Furthermore, ash produced by biomass open burning is source of some particulate matters with variety of size and composition contributing to air pollution. Lanzerstorfer (Lanzerstorfer, 2015) studied the Cyclone fly ash from a grate-fired biomass combustion plant. Laboratory classification flying ashes from biomass combustion was conducted using air classifier and measurement of particles size by using laser diffraction instrument (HELOS/RODOS, Sympatec's Laser Diffraction Sensor) with dry sample dispersion. Microscopic images of particles from the various particle classes were taken with a scanning electron microscope (TESCAN, type VEGALM) and elemental analysis of metals (Al, As, B, Ba, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Sr, Ti, V and Zn) were done by ICP-OES. Results showed that particle size classes were with diameters of 2.0, 4.3, 9.1, 18 and 43 μm. A considerable increase in the concentration with decreasing particle size was found for K, and for the heavy metals Bi, Cd, Cu, Hg, Pb and Zn as well as for Cl^-, NO_3^- and SO_4^{2-} ions. The metals Al, As, Ba, Fe, Si, Ti and V showed the opposite behavior with lower concentrations in the fine particle classes. Biomass open burning is a significant source of trace gases and particulate pollutants on a global scale and plays an important role in both atmospheric chemistry and climate change studied (Tian et al., 2015). To determine the emission characteristics and to acquire multi-pollutant emission rates and source profiles of biomass, various combustion chambers were established to identify and define pollutant and PMs from biomass open burning.

1.4.2 Combustion chamber for biomass burning simulation

Many chambers have been designed and applied to simulate emission from biomass open burning. Limitation such as amount of biomass used for burning (Wiriya, et al., 2016; Li, et al., 2016) in some previously applied chambers and/or closed system (Wiriya, et al., 2016; Amaral, et al., 2014; Zhang, et al., 2011) of the combustion chamber restricted their results. For efficiency open burning process, all factors such amount biomass used for open burning simulation and burning condition to comply with real open burning are considered by environmental chemistry research laboratory (ECRL) for designing and constructing open system combustion chamber.

Sillapapiromsuk, et al., (2012), studied emission factor of PM_{10} and PM_{10}-bounded ions from rice straw, maize residue and leaf litter using closed system combustion chamber constructed on stainless steel with two main connecting parts in a cylindrical shape (Fig 1.3), which consist of a burning chamber and a storage chamber. The burning chamber has a diameter of 0.50 m and a height of 1.20 m, while the storage chamber has a diameter of 0.85 m and a height of 2.00 m. The volume of the two sections of the chamber was approximately 1.4 m^3. The burning section was equipped with a temperature sensor, while the storage section was equipped with a Minivol Portable Air Sampler (Airmetrics, USA), gas analyzer (350-XL, Testo, Germany) and vacuum pump (FY-1.5B, Mizu, Thailand). The burning of each fuel type took about 1 min for approximately 20 mg biomass. The pollutants emitted from the biomass burning were drawn into the storage chamber. Gases including CO, NO, NO_2 and SO_2 were continuously measured for approximately 5 min using a gas analyzer. After that, the air inside the storage chamber was drawn out using an air sampler at a flow rate of 5 L/min and PM_{10} were collected on a pure quartz fiber filter (£ 47 mm, Whatman, UK) for 5 h. The results showed that the burning of leaf litter emitted the highest PM_{10} (1.52 ± 0.65 g kg^{-1}). The PM_{10}-bound ions emitted from the burning of rice straw and maize residue showed the same trend, which was $K^+ > Cl^- > SO_4^{-2} > NH_4^+ > NO_3^-$. However, the emissions of ions from maize residue burning were 1.5–2.0 times higher than those from the rice straw burning and concentration of K^+ and Cl^- ions from agricultural biomass 2-4 times higher than leaf litter biomass.

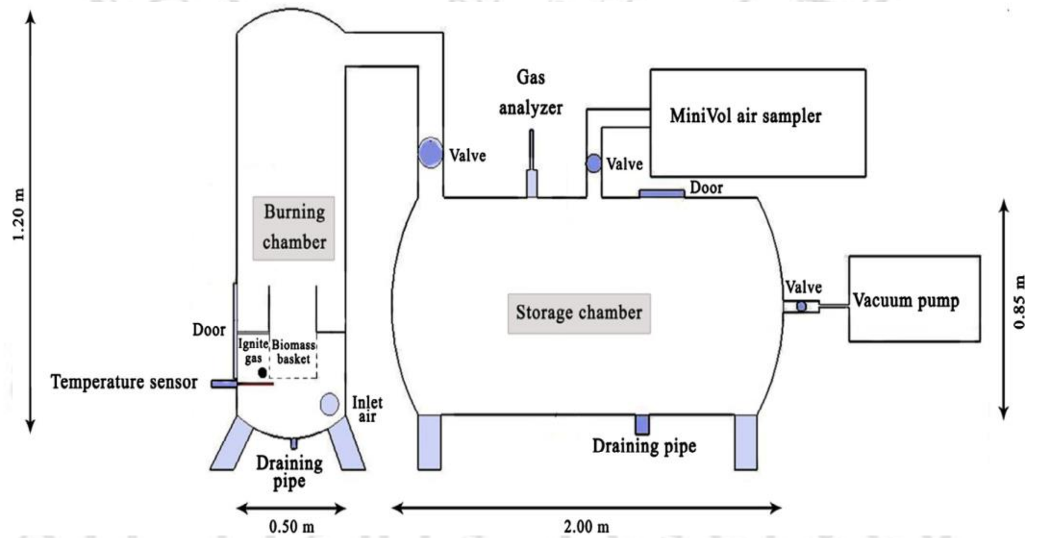

Figure 1.3 Diagram of stainless-steel chamber (Sillapapiromsuk, et al., 2012; Wiriya, *et al.*, 2016).

Zhang et al., (2011) investigated particle size distribution and polycyclic aromatic hydrocarbons (PAHs) emissions from agricultural crop residue burning. The Particle sampling was carried out using a self-designed combustion stove and a stainless-steel environmental aerosol chamber equipped with a set of sampling instruments. The volume of the aerosol chamber was 4.50 m^3 with a mixing fan at the bottom. The inner temperature and relative humidity of aerosol chamber was measured by a hygroclip monitor (Figure 1.4). Three types of biomass (rice, wheat, and corn straws) which account for 78% of the total yield of agricultural residues in China were chosen as representatives of agricultural crop residues. The agricultural crop residues were collected and dried for 24 h at 100 ^{0}C in an oven and weighed on an analytical balance before each burning experiment and measurement. The result indicates that the emissions from the burning of rice, wheat, and corn straws were dominated by fine particles (< 2.5 μm), and PAHs emission factors of rice, wheat, and corn were 5.26, 1.37, and 1.74 mg kg^{-1}, respectively.

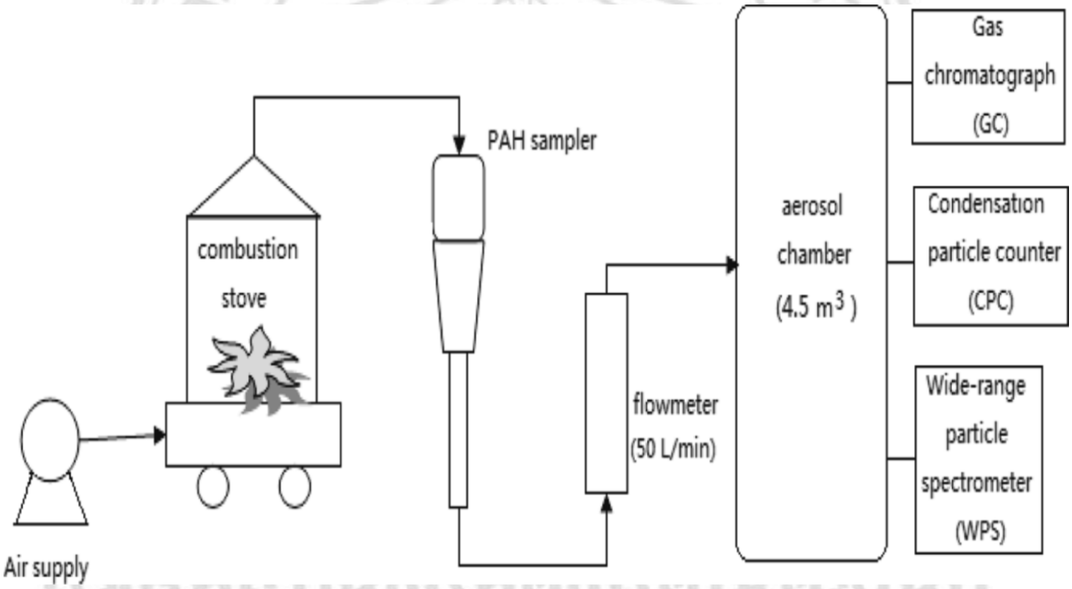

Figure 1.4 Schematic view of Self-designed combustion stove constructed by Zhang, et al., (2011).

Likewise, (Amaral et al., 2014) conducted a research on comparative study for hardwood and softwood forest biomass: chemical characterization, combustion phases and gas and particulate matter emissions. In this research, for each combustion experiment approximately 1.5 kg of mixed different species of biomasses from the Amazon rain forest, and Araucaria were burned in combustion chamber, which is basically consisting a burning tray placed in the center of a container directly under a hood connected to a chimney, an axial exhaust fan generated vertical airflow in the chimney outlet by convection, a temperature sensor, a Pitot tube, and absolute and differential pressure transducers. The measurements taken were transmitted to a mass flow controller that calculated air flow through the biomass on the tray during the burning experiments. It was also equipped with gas analyzer and PM impactors. The findings indicate that Araucaria biomass emitted a higher concentration of particles with an average of $PM_{2.5}$ emissions factor of 5.66 ± 1.03 g kg^{-1}, which was higher than emission factor from Amazon rain forest (3.18 ± 1.35 g kg^{-1}). Also Araucaria biomass had a higher lignin content (34.9%), which may have contributed to higher generation of CO_2 than Amazon biomass (23.3%). Lignin content seemed to exert influence on CO_2 and CO emission factors (Figure 1.5).

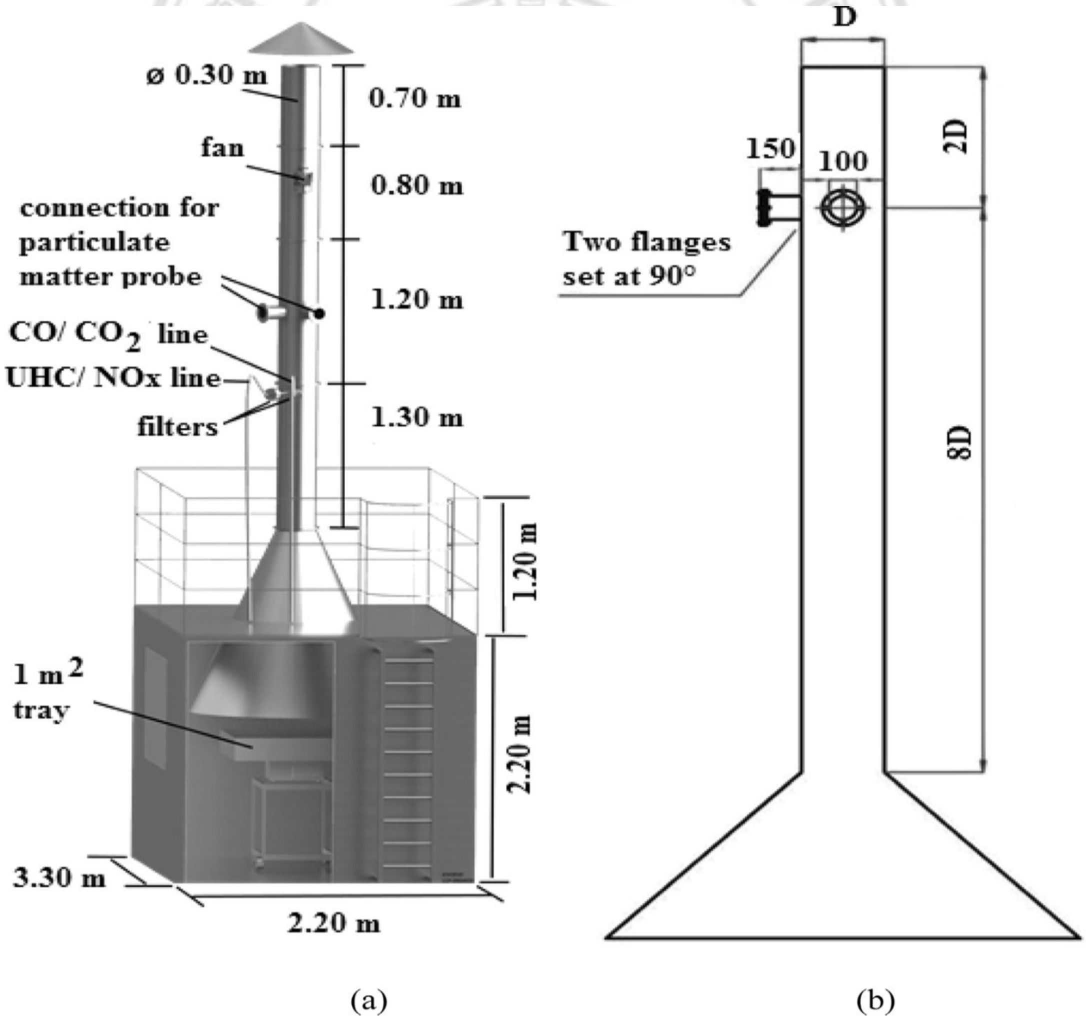

Figure 1.5 Diagram of combustion chamber for BB and sampling of PM constructed by Amaral et al., (2014)

Li et al., (2016) used an aerosol chamber system to study the physiochemical properties of carbonaceous aerosol from agricultural residue burning: density, volatility, and hygroscopicity, the dark aerosol chamber system is capsule-like stainless tank of 4.5 m^3 with 0.3 mm Teflon coating at the inner face. The biomass fuels used for this investigation included wheat, corn, rice, soybean, and cotton residues which represent major agricultural residues in China. Ten grams (10.0 g) of each fuel were burned in combustion stove. The emissions were aspirated into the chamber till room pressure. Temperature and relative humidity (RH) in the chamber were maintained within 19.5-23.5 ºC and 55-65% RH, which were tracked using a hygroclip monitor

Four tests for each agricultural fuel burning were repeated. The finding revealed that effective density of fresh smoke particles varies from 1.1 to 1.4 g cm^{-3}, and corresponded hygroscopicity parameter (k) ranges from 0.2 to 0.35. Size and fuel type-dependence of density and k are obvious. The integrated effective densities (ρ) and (k) both scale with alkali species, which could be parameterized as a function of organic and inorganic mass fraction (forg & finorg) in smoke. The results shows that ρ_{inorg} and k_{inorg} are 2.13 g cm^{-3} and 0.734 g cm^{-3} while are ρ_{org} and k_{org} 1.14 g cm^{-3} and 0.087 g cm^{-3}, respectively. And a quick overview of closed and open system combustion chambers presented in Table 1.1.

Ultimately, Analysis of particulate emission from tropical biomass burning using a global aerosol model and long-term surface observations, shows that both amount of $PM_{2.5}$ and Aerosols Optical depth in tropical regions strongly impacted by biomass burning, and the study suggests further analysis of particulate matter emission from tropical biomass burning, (Reddington et al., 2016). Shon (2015) studied a long-term variation in $PM_{2.5}$ emission from open biomass burning in Northeast Asia derived from satellite-derived data for 2000–2013, where it was found that biomass open burning plays a significant role in $PM_{2.5}$ emissions.

Table 1.1 Overview of closed and open system combustion chambers

Combustion Chamber name	Biomass Types	Measurement Parameters	Pollutant		Reference
			PM	Gas/ion	
<u>Closed system</u>					
Self-designed combustion stove	Rice, wheat and corn straws	EFs Size	PM_1 $PM_{2.5}$	PAH	Zhang, et al., 2011
Combustion chamber	Forest biomass (hardwood and softwood)	Size EFs	PM_{1-10}	CO_2, CO NO_x	Amaral, et al., 2014
Dark aerosol chamber system	Wheat, corn, rice, soybean and cotton	Particle size	$PM_{2.5}$ PM_{10}	*OC, EC*	Li, et all., 2016
Stainless-steel combustion chamber	Rice straw, maize residue and leaf litter	EFs	PM_{10}	Ions	Sillapapiromsuk, et al., 2012, Wiriya, et al., 2016
<u>Open system</u>					
Nine Hoods	Rice straw	EFs ppm	$PM_{2.5}$ PM_{10}	CO_2, CO, EC, OC, PAH, Ions, metals	Oanh, et al., 2011

Consequently, the hypothesis is, that biomass open burning is an important sources of trace gases and PM, and PM from biomass burning can substantially degrade global and regional air quality, leading to adverse effect on human health (Tippayawong & Lee, 2006), which exposure to PM especially $PM_{2.5}$, is associated with a wide range of diseases, including respiratory infection, lung cancer and bronchus (Shen et al., 2010). As air quality has become a major concern and has been steadily deteriorating over the past ten years in Chiang Mai (Chantara et al.,2012), as well as in other provinces located at the Upper Northern Thailand, and emission from open burnings and forest fires have been recognized as the major emission sources of severe air pollution in the Upper Northern Thailand, (Wiwatanadate & Liwsrisakun, 2011). A better understanding of $PM_{2.5}$ emission factor of commonly produced agricultural residues is needed to improve prediction of the impacts of biomass open burning on the air quality (Reddington et al., 2016; W. Wang et al., 2014). Eventually, there is a shortage of clear information on the composition of $PM_{2.5}$ emitted from bimass open burning so far, which is essential to assess the effects of $PM_{2.5}$ on air quality (Rastogi *et al.*, 2014) and human health. Thus, in this research, a new construscted open-system combustion chamber is used to simulate open burning to acquire multi-pollutant emission factors and source profiles of crop residues such as rice straw, maize residues and two types of forest leaf litters (dry dipterocarps and mixed deciduous forests) in order to determine emission factor of $PM_{2.5}$, and $PM_{2.5}$ and ash elemental compositions and concentration produced by biomass open burning with the intention of predicting the contribution of biomass open burning on air pollution in Northern Thailand and to create oportunity for further study of health impact caused by biomass open burning.

1.5 Research Objectives

Considering the air pollution challenge and identified source in Northern Thailand, objectives of this research are set as bellow.

1) To collect and analyze elemental composition of $PM_{2.5}$ and ash samples obtained from biomass burning in the open system combustion chamber.

2) To estimate the pollutant emission (EF) from biomass burning.