CHAPTER 1

INTRODUCTION

1.1 Air pollution

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment, into the atmosphere. An air pollutant is known as a substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made (Air Pollution. 2009).

Atmospheric particles can cause multiple effects on human health and the environment. Particles with the size less than 10 μm (PM_{10}) have long been implicated in causing adverse health effects and increased mortality (Dockery and Pope, 1994) whereas fine ($PM_{2.5}$) and ultrafine particles impose even higher risk (Donaldson *et al*., 1998; Schwartz and Neas, 2000; Ostro *et al*., 2006). Atmospheric particles also interact directly and/or indirectly with the Earth's radiation energy balance and can subsequently affect the global climate (IPCC, 2001; Liu and Daum, 2002). The recently discovered atmospheric/Asian brown cloud, which contains suspended particles as the major component, is believed to cause multiple effects on regional air temperature, precipitation, agriculture, air quality, and health (UNEP and C^4, 2002). Due to their ability to absorb and scatter solar radiation the atmospheric particles, especially fine ones, effectively reduce visibility (Watson, 2002; Kim *et al*., 2001).

There has been a growing concern on monitoring and characterization of size-segregated ambient particulate matter (PM) in the recent years. Efforts and resources are being spent to understand its nature and to develop mechanisms that would help control this harmful pollutant. In many developing countries, however, information on levels of fine particles in the ambient air is still scarce. Until recently, total suspended particulate matter (TSP) was the most monitored and is still a regulated pollutant in most developing countries. However, with the increased awareness of their harmful effects on human health and the environment, there is a tendency toward monitoring fine particles in the ambient air (Oanh *et al*., 2006).

The public concern over air-quality degradation has motivated environmental scientists to conduct in-depth analyses of the fate, behavior, and cycling of atmospheric pollutants over the past decades. In line with such scientific demands, various criteria have been developed and are available to diagnose the degree of air pollution, among which the concentration level of particulate matter (PM) can be considered as one of the most sensitive indicators (Chow, 1995).

The impact of particulate matter (PM) on climate and public health is an environmental key concern. Therefore, an understanding of its source contributions is required in order to establish policies for reducing the emissions. A common technique to apportion the ambient particulate mass is to chemically characterize the aerosol for a set of compounds and to use them as tracers (Caseiro *et al* 2009).

Nowadays some areas of Thailand are also suffering from haze. In Bangkok, Thailand, records show that in the years of 2000, 2001 and 2002, the PM_{10} levels at curbside stations exceeded the 24 h Thai National Ambient Air Quality Standard (120 $\mu g/m^3$) with a frequency of 12.8%, 10.5%, and 3.8%, respectively, while at ambient

sites the corresponding exceedance frequency was 2.1%, 0.3%, and 0.39% (PCD, 2001, 2002, and 2003). Limited published $PM_{2.5}$ data for Bangkok show that 24 h $PM_{2.5}$ in busy parts of the city may be as high as 100 μg/m^3 (Ostro *et al*., 1999). Particulate matter studies in Bangkok Thailand indicated a 1.9% increased risk of dying from cardiovascular disease, and 1.0% risk of all disease for every 10 micrograms per cubic meter of particulate matter. Levels averaged 65 in 1996, 68 in 2002, and 52 in 2004. Decreasing levels may be attributed to conversions of diesel to natural gas combustion as well as improved regulations.

Chiang Mai, A popular tourist destination in North of Thailand is one of the worst affected city. Chiang Mai is one of the fastest growing districts in Thailand. Its environment is unavoidably contaminated because of its economic development, population growth, and urbanization. Besides, the topography of Chiang Mai is surrounding by mountains. So it cause low win speed and be a barrier to spread out pollution from Chiang Mai plain area. Thus, many ambient air pollutant still flow and affect to human health for a long time. It is reported that the cancer incidence rate and mortality have increased in the recent years. This is especially true for Chiang Mai, where the lung cancer incidence rate is much higher than other places in Thailand. In the last decade Chiang Mai face with haze pollution especially in 2007, reported that the level of PM_{10} is highest by 383 μg/m^3 in March 14. Trend of PM_{10} levels in March higher than Thailand PCD standard (24 hours standard, 120 μg/m^3)(Jaikamsueb 2007).

1.2 Airborne particulate matter

Particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to particles and the gas together. Among the most common categorizations imposed on particulates are those with respect to size, referred to as fractions. As particles are often non-spherical (for example, asbestos fibers), there are many definitions of particle size. The most widely used definition is the aerodynamic diameter. A particle with an aerodynamic diameter of 10 micrometers moves in a gas like a sphere of unit density (1 gram per cubic centimeter) with a diameter of 10 micrometers. Range of PM size 0.0002 to 500 micrometers (Total suspended particulate matter: TSP ≤100 μm, PM_{10}: ≤10 μm, $PM_{2.5}$: ≤2.5 μm). These dimensions represent the continuum from a few molecules up to the size where particles can no longer be carried by a gas (US EPA 2007).

Table1.1 Particulate matter size fractions (US EPA 2007).

Fraction	**Size range**
PM_{10} (thoracic fraction)	≤ 10 μm
$PM_{2.5}$ (respirable fraction)	≤ 2.5 μm
PM_1	≤ 1 μm
Ultrafine (UFP or UP)	≤ 0.1 μm
PM_{10}-$PM_{2.5}$ (coarse fraction)	2.5 – 10 μm

1.2.1 Sources

Sources of particulate matter can be man-made or natural. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged over the globe, anthropogenic aerosols those made by human activities, currently account for about 10 percent of the total amount of aerosols in our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer (Manual of Ambient Air Particulate Matter Measurement 2003).

1.2.2 Composition of particulate matter

The composition of aerosol particles depends on their source. Wind-blown mineral dust tends to be made of mineral oxides and other material blown from the Earth's crust, this aerosol is light-absorbing. Sea salt is considered the second-largest contributor in the global aerosol budget, and consists mainly of sodium chloride originated from sea spray. Other constituents of atmospheric sea salt reflect the composition of sea water, and thus include magnesium, sulfate, calcium, potassium, etc. In addition, sea spray aerosols may contain organic compounds which influence their chemistry (IPCC 2001).

Secondary particles derive from the oxidation of primary gases such as sulfur and nitrogen oxides into sulfuric acid (liquid) and nitric acid (gaseous). The precursors for these aerosols such as the gases from which they originate may have an anthropogenic origin (from fossil fuel combustion) and a natural biogenic origin. In

the presence of ammonia, secondary aerosols often take the form of ammonium salts such as ammonium sulfate and ammonium nitrate both can be dry or in aqueous solution. In the absence of ammonia, secondary compounds take an acidic form as sulfuric acid (liquid aerosol droplets) and nitric acid (atmospheric gas). Secondary sulfate and nitrate aerosols are strong light-scatterers. This is mainly because the presence of sulfate and nitrate causes the aerosols to increase to a size that scatters light effectively (Hardin and Kahn 2006).

1.2.3 Health effects

The effects of inhaling particulate matter have been widely studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. The size of the particle is a main determinant of where in the respiratory tract the particle will come to rest when inhaled. Because of the size of the particle, they can penetrate the deepest part of the lungs. Larger particles are generally filtered in the nose and throat and do not cause problems, but particulate matter smaller than about 10 micrometers, referred to as PM_{10}, can settle in the bronchi and lungs and cause health problems. The 10 micrometer size does not represent a strict boundary between respirable and non-respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies. Similarly, particles smaller than 2.5 micrometers, $PM_{2.5}$, tend to penetrate into the gas exchange regions of the lung, and very small particles (< 100 nanometers) may pass through the lungs to affect other organs (Pope *et al.* 2002).

In particular, a study published in the Journal of the American Medical Association indicates that $PM_{2.5}$ leads to high plaque deposits in arteries, causing

vascular inflammation and atherosclerosis, a hardening of the arteries that reduces elasticity which can lead to heart attacks and other cardiovascular problems. Many researchers suggest that even short-term exposure at elevated concentrations could significantly contribute to heart disease. The smallest particles, less than 100 nanometers (0.1 micrometer), may be even more damaging to the cardiovascular system.[8] There is evidence that particles smaller than 100 nanometers can pass through cell membranes and migrate into other organs, including the brain. It has been suggested that particulate matter can cause similar brain damage as that found in Alzheimer patients (Mokdad *et al*. 2004).

1.3 Forest fire

In the last 30 years large parts of Thailand's forests have been cleared for agriculture. Fire played an important role in this since it had been an agricultural tool for many centuries in Southeast Asia, either to clear harvesting debris or to clear new land. At the same time, legally or illegally, large tracts of forest land were logged. Selective felling altered the forest structure letting herbaceous ground vegetation invade the forest ground. Furthermore, the ethnic minorities in the mountains of the North practice slash-and-burn agriculture which is resulting in the spread of large areas of grasslands.

The prolonged and hotter dry seasons and the reduced rainfall are attributed to forest destruction. The drought and heat, combined with the more open forest structure and the availability of readily combustible herbaceous fuels cause a "fire friendly" environment and thus accelerate and close the destructive cycle of forest fires.

Forest fires in Thailand occur annually during the dry season in the deciduous forests of drier environments but now also moist and evergreen forests are affected, and double burning (burning twice per year) on dry sites has become a regular feature.

The amount and distribution of rainfall strongly affect forest fire occurrence. The monsoon rainfalls in Thailand are strongly seasonal, lasting from about May to October. The dry season can last up to 7 months during which day-time temperature extremes can exceed 40°C. On the Malaya Peninsula the climate is moister and less extreme. In Thailand, annual rainfall varies between 700 mm in inland areas and the North-Eastern plateau to about 4000 mm in coastal areas. The distribution of forest types closely follows the rainfall distribution pattern. Natural forest vegetation can be grouped into dry, hill and moist evergreen forests types of the moister areas (totaling about 43%) and mixed and dry dipterocarp forest in drier areas, representing 22% and 31% of the forest respectively. The remaining 4% include primarily mangroves and pine forests (RFD, 1992/2).

In many parts of the United States, particularly in the Pacific Northwest, wood burning is a substantial source of air pollution during Winter. When many sources of air pollution are present, it is often difficult to determine how much comes from wood burning. Tracers of wood smoke are elements, compounds or gases that come from wood burning in characteristic amounts or ratios. Measurement of these tracers in the environment can be used to quantitatively estimate the amount of air pollution from wood burning (Khalil and Rasmussen 2002).

There are quite different types of fire events which are of concern for the aerosol budget. Globally, the emphasis is on wild fires (forest, savanna etc.) and on biomass smoke from primitive use of biofuels (e.g. cooking in Africa and Asia

countryside) (Bond *et al*., 2004). In Europe major biomass burning emissions are regionally from wild fires (in southern Europe) (Pio *et al*., 2008), agricultural fires in eastern Europe (Stohl *et al*., 2007) and wood smoke from fireplaces and stoves in central and northern Europe (Puxbaum *et al*., 2007). In the studies at the American Continent and in Scandinavia the wood smoke from fireplaces and stoves was identified as an important source of wintry fine particle levels, in particular at rural sites (Zheng *et al*., 2002; Khalil and Rasmussen, 2003).

Consistently, wood smoke was an important contributor to PM_{10} during the cold season, the use of wood stoves for auxiliary heating in the transition of warm to cold season. Using the relationships between the different anhydrosugars the combustion of softwood was found to be dominant for the wood smoke occurrence in ambient air at the investigated sites. Potassium, a commonly used tracer for biomass burning, correlated well to levoglucosan, with a mass ratio of around 0.80 in the cold season (Caseiro *et.al.* 2009).

1.4 Water-soluble ions in particulate matter

A quantitative analysis of PM composition generally indicates that a large fraction of PM mass consists of water-soluble ions exist in the form of either cations or anions (Karakas and Tuncel, 1997). Since water-soluble ions are one of the major components of atmospheric aerosols, many studies focus on their size distribution (Wang and Shooter, 2002). Particulate matter and especially fine particles which are enriched with toxicants and able to penetrate deeper in the lungs are among the pollutants highlighted for adverse health effects (Manoli *et al*., 2002; Vassilakos *et al*., 2006). Although campaigns have been carried out in all over the world recording

the particle concentration levels and investigating their composition, there is still uncertainty whether the toxicity of particles is better defined by chemical composition or size (Pateraki *et.al*. 2008).

Water-soluble ions comprise a large part of aerosol particles and play an important role in the atmosphere (Zhuang *et. al*.,2006). In order to achieve the goal of the study, water-soluble major ions, Na^+ , NH_4^+ , K^+ , Mg^{2+}, Ca^{2+}, Cl^-, NO_3^- and SO_4^{2-} were measured. It is stated that the total mass of Na^+, NH_4^+ , K^+ , Mg^{2+}, Ca^{2+}, Cl^-, NO_3^- and SO_4^{2-} typically comprises 60-70% of the total aerosol mass. The chemical composition of soluble substances of the aerosols was determined by different analytical techniques, and the generated data were interpreted through various statistical methods and wind sector analyses (Karakas, 1997).

1.5 Particulate matter monitoring and analytical method

1.5.1 Particulate matter monitoring

The Airmetrics MiniVol™ portable air sampler (Figure 1.1) is a popular choice for use in air quality assessments because it is portable and inexpensive relative to fixed site monitors. The MiniVOL sampler was developed by the Lane Regional Air Pollution Authority and the US Environmental Protection Agency (EPA) to characterize the spatial and temporal distributions of ambient particulate matter (as PM_{10} or $PM_{2.5}$). The sampler's portable design and ease of use have made it a popular choice for air quality assessments. Advantages of the MiniVOL sampler include the flexibility to move or rotate monitoring sites, the ability to increase the number of monitoring sites to improve the spatial distribution of data collected, and the ability to measure contaminant concentrations at almost any location. The

MiniVOL sampler (Airmetrics, Springfield, OR, USA) is a portable PM_{10} or $PM_{2.5}$ monitor capable of sampling at a 5 liters/minute (l/min) rate for up to 24 h on a single battery charge. The units are equipped with timers for unattended start-up and shut down. Impaction inlets are used to selectively sample PM_{10} and $PM_{2.5}$ size ranges (Baldauf *et al.* 2001).

Figure 1.1 The Airmetrics Minivol™ Portable Air sampler.

The MiniVol™ portable air sampler can be configured to collect either $PM_{2.5}$, PM_{10}, or TSP samples, but only one type at a time. The MiniVol's pump draws air at 5 l/min through a particle size separator (impactor) and then through a 47mm filter. The 10 micron or 2.5 micron particle separation is achieved by impaction, or a TSP sample can be collected by removing the impactor(s). Gas samples can be taken simultaneously with particulate matter samples (US EPA 2001).

1.5.2 Particulate matter analytical method

1.5.2.1 Ion chromatography

Ion-exchange processes are based upon exchange equilibria between ions in solution and ions of like sign on the surface of an essentially insoluble, high molecular weight solid. Synthetic ion-exchange resins were first produced in the mid 1930s for water softening, water deionization and solution purification. The most common active sites for cation-exchange resins are the sulfonic acid group-$SO_3^-H^+$, a strong acid and the carboxylic acid group-COO^-H^+, a weak acid. Anionic exchangers contain tertiary amine groups-$N(CH_3)_3^+OH^-$ or primary amine group-$NH_3^-OH^-$, the former is a strong base and the latter a weak one.

The basic components of an ion chromatograph are shown in Figure 1.2. It resembles the setup of conventional HPLC systems.

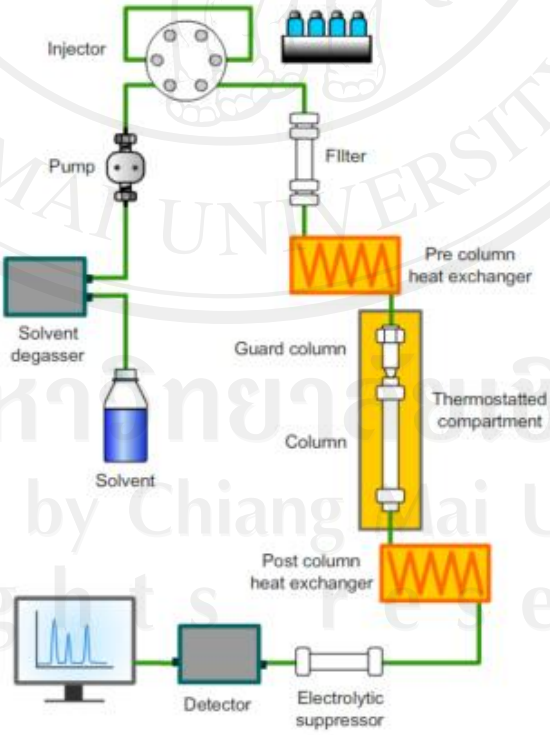

Figure 1.2 Basic components of an ion chromatograph

A pump delivers the mobile phase through the chromatographic system. In general, either single-piston or dual-piston pumps are employed. A pulse-free flow of the eluent is necessary for employing sensitive UV/Vis and amperometric detector. Therefore, pulse dampers are used with single-piston pumps and a sophisticated electronic circuitry with dual-piston pumps. The sample is injected into the system via a loop injector. A three-way valve is required with two ports being connected to the sample loop. The sample loading is carried out at atmospheric pressure. After switching the injection valve, the sample is transported to the separator column by the mobile phase.

1.6 Air quality monitoring station of Pollution Control Department, Thailand

Monitoring is central to implementing an effective air quality management program in any country. Thailand has established an extensive air quality monitoring network with the aim of providing up-to-date information on major atmospheric pollutants. Thailand commenced air quality monitoring in 1983. The monitoring network has progressively evolved and expanded to cover a variety of pollutants. Air pollution monitoring assesses compliance with air quality standards. The majority of sites in all five regions (North, Northeast, East, Central, and South) monitor Particulate matter with diameter < 10 microns (PM_{10}), CO, NO_2, SO_2, and ground-level ozone (O_3) (Thailand Air Quality Monitor, 2002)

1.6.1 Taper Element Oscillating Microbalance (TEOM)

The tapered element oscillating microbalance (TEOM) is used to measure ambient particulate matter concentrations worldwide. TEOM mass detectors or

microbalances utilize an inertial mass weighing principle. Basic physics, through Newton's Second Law, establishes that the quantification of mass determined dynamically through an inertial technique is identical to the same mass determined statically through a gravitational method.

A TEOM detector consists of a substrate (usually a filter cartridge) placed on the end of a hollow tapered tube. The other end of the tube is fixed rigidly to a base. The tube with the filter on the free end is oscillated in a clamped-free mode at its resonant frequency. This frequency depends on the physical characteristics of the tube and the mass on its free end. A particle laden air steam is drawn through the filter where the particles deposit and then through the hollow tube. As particles deposit, the mass of the filter cartridge increases and the frequency of the system decreases. By accurately measuring the frequency change, the accumulated mass is measured. Combining this accumulated mass with the volume of air drawn through the system during the same time period yields the particle mass concentration.

In essence, the system can be considered a simple harmonic oscillator through which the following equation can be derived,

$$\Delta m = K_0 (1/f_f^2 - 1/f_i^2) \quad (1)$$

Where f_i = initial oscillation frequency of the system; f_f = oscillation frequency after the addition of mass; K_0 = calibration (spring) constant of the tapered element, and Δm = mass change from the initial condition.

TEOM technology removes the mass calibration uncertainty that exists with systems that do not measure mass directly. In addition, possible filter handling errors

(at both the sampling site and laboratory) using manual, gravimetric methods are eliminated while having the advantage of providing filter based mass measurements in near real-time. The engineering design of all TEOM-based monitoring instrumentation provides automatic, real-time flow control, sample conditioning and quantification of PM mass (Patashnick *et al*, 2002).

This technique uses a tapered element oscillating microbalance (TEOM) sampler (shown right) fitted with a suitable size-selective inlet to either monitor total suspended particulate (TSP), PM_{10} or $PM_{2.5}$ concentrations. Sample air is drawn into the instrument at 16.7 L/min through an inlet designed to allow particles of the required diameter to pass through. This air stream is split so that 3 L/min of sample is directed to the mass transducer (tapered element) while the remainder is sent to exhaust.

The mass transducer consists of a teflon-coated glass fibre filter cartridge mounted at the tip of a tapered glass tube. This tube, the tapered element (shown right), is fixed at the base, while the tip is free to vibrate at its natural frequency. As particles get trapped and build up on the filter, the additional weight changes the oscillation frequency of the tube. Electronic circuitry senses and maintains the vibration at constant amplitude. Changes in the frequency as the result of the increasing mass of particulate on the filter are converted into a mass rate.

Instrument temperatures and flow rates are strictly maintained and readings are smoothed electronically to reduce noise. This mass rate is divided by the flow rate to give a continuous output of the mass concentration. TEOM samplers operate on a continuous basis and do not need filter changes as frequently as high-volume air samplers.

The advantage of continuous monitoring is that it can provide additional information, such as the time of day that peak concentrations occur. Such information may be used in conjunction with meteorological data to help identify the source of an emission. At some stations, high volume air samplers and TEOM samplers are located together for quality assurance purposes to ensure that data obtained from the two instruments is comparable (Department of Environment and Resource Management The State of Queensland 2011).

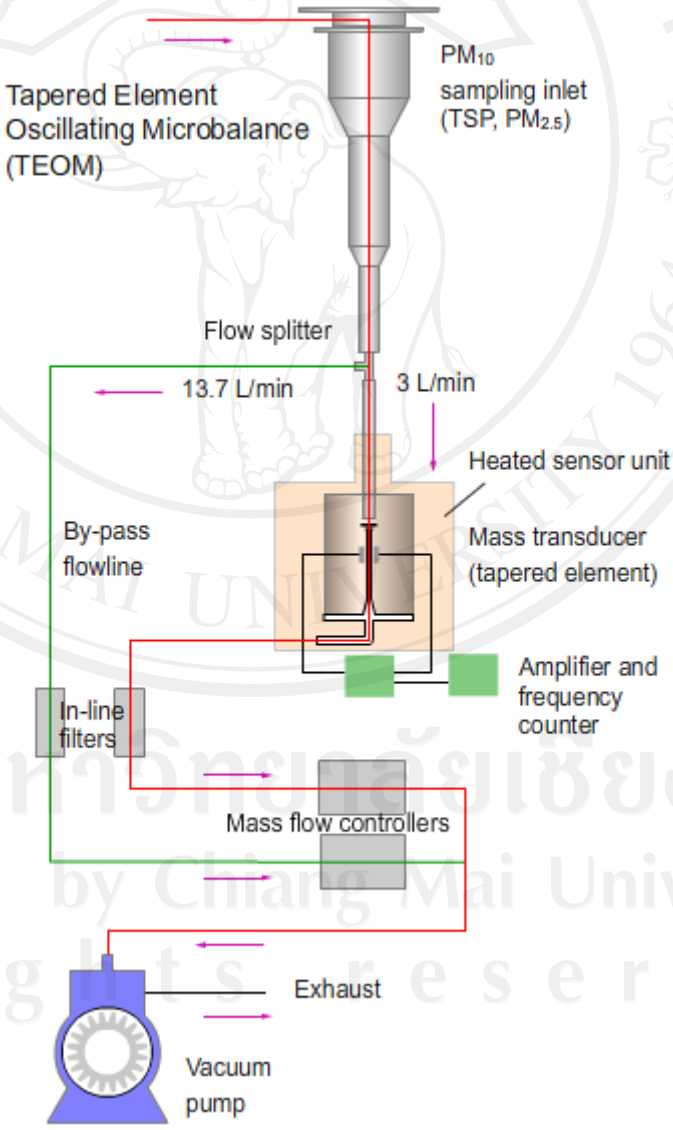

Figure 1.3 Schematic diagram of a tapered element oscillating microbalance (TEOM)

1.7 Study site

1.7.1 Geographical background, population and economic structure of Chiang Mai Province

Chiang Mai is the largest and most significant city in the northern area of Thailand. It is located about 310 meters above sea level and at latitude 17° 15´ to 20° 10´ N and longitude 98° 5´ to 99° 35´ E. Located 700 km^2 from Bangkok, the geography of Chiang Mai is quite noteworthy. The valley of Chiang Mai is located on the coast of the river Ping. Chiang Mai is surrounded in the east by Chiang Rai, Lamphun, and Lampang and Mae Hong Sorn in the west. This is surrounded by monumental walls. This area consists of valleys and hills and forests. The province covers an area of 20,107.057 km^2 (12,566,910 rai), made up of 8,787,656 rai (69.92%) of forest, 1,611,283 rai (12.82%) of agricultural land and 2,167,971 rai (17.25%) of residential and other land (Chiang Mai Information, 2007). Ping River is known to be the support system of Chiang Mai. This is the most important river in this area. It plays a vital role in influencing the geography of Chiang Mai in a positive way. Chiang Mai Province has a total population of 1,670,317 with 819,750 males and 850,567 females. There are approximately 829,400 families and the population density averages 83.24 people per km2 in the province. The Chiang Mai Province consists of 24 districts. Muang district or Chiang Mai City, which is central administrative district of the province, covering an area about 166.47 km^2, has a population of about 240,046 and the population density averages 1,446 people per km^2 (Department of Local Administration, 2008). In relation to the rest of Thailand, Chiang Mai's year round weather is considered to be relatively cool. The annual average temperature is 26.5 ºC. The highest temperature is 40.1 ºC and the lowest is

10.9 ºC. The annual average humidity is 70.2 %. An annual average number of rainy days are around 89.2 mm, while the total rainfall is around 1,070.2 mm (Northern Meteorological Center, 2009).

The Southwest, Northwest and Southeast monsoons are the three main factors influencing season of Chiang Mai to be three seasons as in the following. The rainy season, influenced by the southwest monsoon, begins in mid-May and continues until October. The cold season begins in November and continues until March and is influenced by the Northwest monsoon, which brings cold air from Siberia, through China and down into Northern Thailand. The summer season begins in March to mid-May and is influenced by the Southeast monsoon. The most important occupations are cultivation of rice, peanuts, soy beans, longan, lychee, strawberries and tobacco, weaving, wood products and handicrafts. Other local activities include the tobacco leaf drying industry, rice milling, foods and beverage industries.

1.8 Literature Review on Atmospheric PM_{10} and PM_{10} Binding Cations

Chantara *et. al.* (2009) studied the concentrations of airborne PM_{10} and PM_{10} bound ions in Chiang Mai and Lamphun during June 2006 to June 2007 and found that PM_{10} concentration increased at the beginning of dry season (December) and reached its peak in March before decreasing by the end of April. The mean PM_{10} concentrations were in the range from 33.17 ± 21.39 µg/m^3 in rainy season to 73.64 ± 25.34 µg/m^3 in dry season. Water-soluble ions bound with PM_{10} both anions (Cl^-, NO_3^- and SO_4^{2-}) and cations (Na^+ , NH_4^+ , K^+ , Mg^{2+} and Ca^{2+}) were significantly higher in dry period (Dec-Mar) and (Oct-Nov) than those in other seasons. The dominant anion and cation were SO_4^{2-} and NH_4^+ respectively. Noticeably, K^+ as a

tracer of biomass burning was significantly higher in dry season and correlate to high frequency or large area of open burning.

Vinitketkumnuen *et. al. (*2002) indicated that daily levels of particulate matter (PM) in the ambient air ($PM_{2.5}$ and PM_{10}) were measured in a northern city of Thailand (Chiang Mai) from March 1998 to October 1999. Twenty-four-hour air particulate matter samples were collected each day with Airmetric Minivol portable air samplers. Monthly averages of $PM_{2.5}$ from four stations in Chiang Mai varied from 15.39 to 138.31 μg/m^3 and 27.29 to 173.40 μg/m^3 for PM_{10}. The $PM_{2.5}$ annual average was 58.48 μg/m^3 and PM_{10}, 86.38 μg/m^3. during the winter season (December to March), levels of $PM_{2.5}$ and PM_{10} in the Chiang Mai atmosphere are very high, and there may be significant health implications associated with these high concentrations.

Pio *et. al.* (2008) conducted study in Portugal. During summer 2003, unusually large forested areas (>300,000ha) were destroyed by fire, emitting pollutants to the atmosphere. Mass of fine (PM_{10}) and coarse ($PM_{2.5}$) particles and chemical aerosol composition between heavily smoke-impacted periods and the rest of the summer permit to evaluate the contribution of forest fires to the regional aerosol load. Eight major water-soluble inorganic species (Cl^-, NO_3^-, SO_4^{2-} , Na^+, NH_4^+, K^+, Ca^{2+} and Mg^{2+}) were quantified which SO_4^{2-} was the most abundant ion, followed by NH_4^+ and NO_3^-. Potassium is an important species emitted by biomass burning, since the combustion of plant matter, which contains K^+ as a major electrolyte within the cytoplasm, releases great quantities of K-rich particles. Biomass burning aerosols can be identified by the ratio of fine to coarse mode K^+. The

enrichment of K^+ in the fine mode was obvious during the intense forest fire periods (fine/coarse ratio of 14, instead of 4 for base line periods).

Shen *et al*. (2009) studied on TSP and $PM_{2.5}$ samples were collected at Xi'an, China during dust storms (DSs) and several types of pollution events, including haze, biomass burning, and fireworks displays. Aerosol mass concentrations were up to 2 times higher during the particulate matter (PM) events than on normal days (NDs), and all types of PM led to decreased visibility. Water-soluble ions (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, NO^{3-}, and SO_4^{2-}) were major aerosol components during the pollution episodes, but their concentrations were lower during DSs. NH_4^+, K^+, F^-, Cl^-, NO^{3-}, and SO_4^{2-} were more abundant in $PM_{2.5}$ than TSP but the opposite was true for Mg^{2+} and Ca^{2+}. PM collected on hazy days was enriched with secondary species (NH_4^+, NO^{3-}, and SO_4^{2-}) while PM from straw combustion showed high K^+ and Cl^-. Fireworks display caused increases in K^+ and also enrichments of NO^{3-} relative to SO_4^{2-}. During DSs, the concentrations of secondary aerosol components were low, but Ca^{2+} was abundant. Ion balance calculations indicate that PM from haze and straw combustion was acidic while the DSs samples were alkaline and the fireworks' PM was close to neutral. Ion ratios (SO_4^{2-}/K^+, NO^{3-}/SO_4^{2-}, and Cl^-/K^+) proved effective as indicators for different pollution episodes.

Caseiro *et.al. (*2009) studied wood burning impact on PM_{10} in three Austrian regions. They suggested that anhydrosugar (levoglucosan) and potassium compounds can be used as the wood burning tracer. Average potassium concentrations ranged from 0.2 to 0.57 $\mu g/m^3$ and were clearly higher in Graz than in Salzburg or Vienna, as for levoglucosan and other anhydrosugar.

Oanh *et.al.* (2006) designed and implemented a monitoring program for particulate matter pollution in six Asian cities/metropolitan regions including Bandung, Bangkok, Beijing, Chennai, Manila and Hanoi. In all six cities, the levels of PM_{10} and $PM_{2.5}$ were high, especially during the dry season. The average concentrations of $PM_{2.5}$ and PM_{10} in the cities ranged, 44-168 and 54-262 $\mu g/m^3$ in the dry season, and 18-104 and 33-180 $\mu g/m^3$ in the wet season respectively.

Baldauf *et al*. (2001) studied that the MiniVOL sampler is a popular choice for use in air quality assessments because it is portable and inexpensive relative to fixed site monitors. However, little data exist on the performance characteristics of the sampler. The reliability, precision, and comparability of the portable MiniVOL PM_{10} and $PM_{2.5}$ sampler under typical ambient conditions are described in this paper. Results indicate that the MiniVOL (a) operated reliably and (b) yielded statistically similar concentration measurements when co-located with another MiniVOL (r^2 = 0.96 for PM_{10} measurements and r^2 = 0.95 for $PM_{2.5}$ measurements). Thus, the characterization of spatial distributions of PM_{10} and $PM_{2.5}$ mass concentrations with the MiniVOL can be accomplished with a high level of confidence. The MiniVOL also produced statistically comparable results when co-located with a Dichotomous Sampler (r^2 = 0.83 for PM_{10} measurements and r^2 = 0.85 for $PM_{2.5}$ measurements) and a continuous mass sampling system (r^2 = 0.90 for PM_{10} measurements). Environmental factors such as ambient concentration, wind speed, temperature, and humidity may influence the relative measurement comparability between these sampling systems.

Saitoh *et al*. (2001) investigated the chemical characterization of particles in winter-night smog within a large area of the Japan Kanto Plain including the Tokyo

Metropolitan area. Ionic species (anion: F^-, Cl^-, NO^{3-}, SO_4^{2-} and $C_2O_4^{2-}$; cation: Na^+, NH_4^+, K^+, Ca^{2+} and Mg^{2+}) in the filter samples were analyzed by ion chromatography. The temporal variation patterns of $PM_{2.5}$ were similar to those of PM_{10} and carbon. $PM_{2.5}$ made up 90% of the PM_{10} at a high concentration, and 70% at a low concentration.

1.9 Research Objectives

1.9.1 To determine PM_{10} and PM_{10} bound cation concentrations in ambient air of Chiang Mai.

1.9.2 To find out correlation of PM_{10}, its cations content and tracer of biomass burning in different seasons.