# CHAPTER 1

# INTRODUCTION

## 1.1 Statement and significance of the problem

### 1.1.1 Air pollution

Air pollution is a complex mixture of thousands of pollutants in the air. This mixture may consists of both solid and liquid particles suspended in air, and different type of gases such as ozone ($O_3$), nitrogen oxides ($NO_x$), volatile organic carbons (VOCs), and carbon monoxide (CO). While particles vary in number, size, shape, surface area and chemical composition, both particles and gases may vary in solubility and toxicity. Of all these pollutants, particulate matter (PM) is frequently monitored in most urban settings as $PM_{10}$ (particles with mean aerodynamic diameter less than 10 micrometer) and/or $PM_{2.5}$ (particles with mean aerodynamic diameter less than 2.5 micrometer). Size of particles links to their potential for deposition and clearance in the respiratory tract, which is highly relevant for triggering deleterious health effects (Pope and Dockery, 2006; Sava and Carlsten, 2012).

### 1.1.2 Air pollution in Chiang Mai

Chiang Mai is the second largest city of Thailand and situated down near Ping river and the foothill of Suthep Mountains. It is situated approximately 700 km from Bangkok in the upper north region of the country. The Pollution Control Department (PCD), Ministry of Natural Resources and Environment provides the information on air quality parameters include $PM_{10}$, $NO_x$, $O_3$, $SO_2$, CO from two air quality

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monitoring stations in Chiang Mai city. The first station is located at the Yupparaj Wittayalai school (YP) in central Chiang Mai city and the second one is located at Chiang Mai city hall (CM) that is in suburban area in the north of Chiang Mai city. Airborne $PM_{10}$ had become a serious air pollutant problem in Chiang Mai city and its rural areas (Prapamontol *et al.*, 2010 and 2012). Trend of $PM_{10}$ levels in Chiang Mai city is likely to increase in dry season, especially in February and March of every year and exceeds the standard limit as shown in Figure.1.1. From a previous air pollution report from Chiang Mai city, the major sources that contributed to elevated $PM_{10}$ levels were agricultural burning settings and forest fires (Pengchai *et al.*, 2009, Wiwatanadate and Liwsrisakun, 2011)

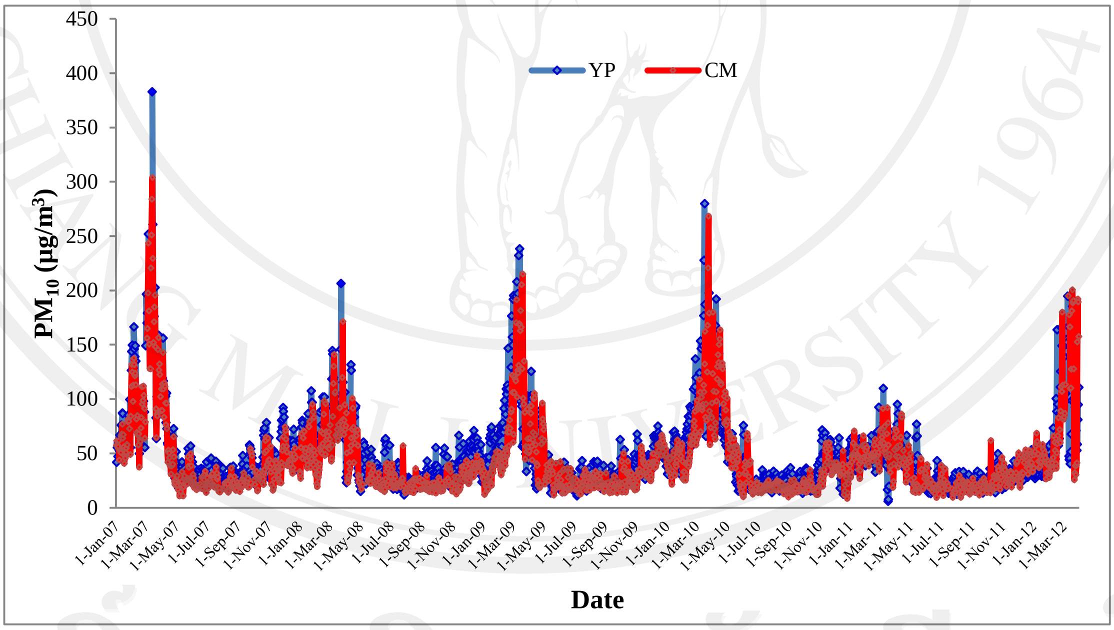

**Figure.1.1** Daily $PM_{10}$ concentrations ($\mu g/m^3$) from January 2007-March 2012 by air quality monitoring stations at Yupparaj Wittayalai school (YP) and Chiang Mai city hall (CM) Chiang Mai. (Source: The Pollution Control Department, Ministry of Natural Resources And Environment, Thailand).

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### 1.1.3 Indoor air pollution

Indoor air pollution is recognized as a significant source of potential health risk to exposed populations throughout the world. The major sources of indoor air pollution worldwide include combustion of fuels, tobacco and coal; ventilation systems; furnishings; and construction materials. These sources vary considerably between developing and developed nations. The most significant issue that concerns indoor air quality in household environments of developing countries is that of exposure to pollutants released during combustion of solid fuels including biomass (wood, dung, and crop residues) or coal used for cooking and heating. A majority of rural households burns these simple solid fuels in inefficient earthen or metal stoves, or use open pits in poorly ventilated kitchens, resulting in very high concentrations of indoor air pollutants (Balakrishnan *et al.*, 2002). It is estimated that use of open fires with these fuels exposes nearly 2 billion people in the world to enhance concentrations of particulate matter and gases, up to 10-20 times higher than health-based guideline values available for typical urban outdoor concentrations (Behera and Balamugesh, 2005). Although biomass makes up only 10-15 percent of total human fuel use, since nearly half the world's population cooks and heats in their homes with biomass fuels on a daily basis, indoor exposures likely exceed outdoor exposures to some major pollutants on a global scale (Smith, 1988).

In upper northern Thailand, there have been inhabited by various groups of ethnic hill tribes such as Hmong, Karen and Lisu. Khun Chang Kian (KCK) village is one of Hmong villages in Chiang Mai province. The house characteristic in KCK is one multi-purpose room with poor ventilation. Biomass burning for cooking and

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residential heating in this room is common activity which always happen throughout the year. The common biomass fuel includes wood, dry leaves, and plant twigs.

### 1.1.4 Wood smoke

Wood smoke consists of a mixture of particulate matter, sulfur and nitrogen oxides, volatile organic compounds, free radicals, chlorinated dioxins, and many other compounds (Naeher *et al.*, 2006). Many of these compounds are known carcinogens and can lead to a multitude of adverse effects (Simpson and Naeher, 2010). Epidemiologic studies have shown an association between wood smoke exposure and increased mortality, hospitalization, and variability in heart rate (Hinwood *et al.*, 2008).

Residential wood combustion refers to the burning of wood in fireplaces, woodstoves and other devices used to heat the home. These devices produce smoke when wood does not burn completely. If operated incorrectly, even the most modern wood-burning devices can produce smoke. Smoke from wood-burning stoves and fireplaces contains a complex mixture of gases and particles. The size of particles is directly linked to their potential for causing health problems. Small particles i.e. $PM_{10}$ or smaller pose the greatest problems, because they can get deep into the lungs, and some may even get into the bloodstream.

## 1.2 Particulate matter (PM)

Particulate Matter (PM) is one of the six criteria air pollutants, and the most important in terms of adverse effects on human health, especially very small particles are likely to cause adverse health effects including increasing morbidity and mortality in susceptible individuals. These results influenced organization and governments to establish strategies to control air pollution. Air quality guidelines and standards were

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developed in an attempt to reduce adverse impacts on human health and the environment. Ambient air quality standards for PM from Environmental Protection Agency USA (EPA, USA); California, USA; European Union (EU); World Health Organization (WHO); and Thailand were shown in Table 1.1**.**

**Table 1.1** Ambient air quality standards for PM from EPA, USA; California, USA; EU; WHO; and Thailand

| **Source** | **Particulate matter** | **Particulate matter concentration (μg/m$^3$)** | |
|---|---|---|---|
| | | **Annual average** | **24-hour average** |
| EPA, USA | $PM_{10}$ | 50 | 150 |
| | $PM_{2.5}$ | 15 | 35 |
| California, USA | $PM_{10}$ | 20 | 50 |
| | $PM_{2.5}$ | 12 | – |
| EU | $PM_{10}$ | 40 | 50 |
| | $PM_{2.5}$ | 35 | – |
| California, USA | $PM_{10}$ | 20 | 50 |
| | $PM_{2.5}$ | 12 | – |
| WHO | $PM_{10}$ | 20 | 50 |
| | $PM_{2.5}$ | 10 | 25 |
| Thailand | $PM_{10}$ | 50 | 120 |
| | $PM_{2.5}$ | – | – |

PM is the term used for a mixture of solid particles and liquid droplets suspended in the air. The originate of PM from a variety of sources such as power plants, industrial processes, diesel trucks, and they are formed in the atmosphere by transformation of gaseous emissions. Their chemical and physical compositions depending on location, time of year and weather. The particles ranges from molecular structure in the range of few nanometers to coarse, multi

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component particles in the range of about 100 µm. PM may be characterized in terms of mass, size, numbers, surface area, chemical position or optical properties. Primary PM exists in the same chemical form it was generated, while secondary PM is formed through an atmospheric reaction of precursor gases (Samet *et al.*, 2000). The larger particles of up to 100 µm in diameter are comparable to the thickness of a human hair (Figure.1.2).

The primary source of PM from natural and combustion natural aerosolization of crustal matter are windblown dust storm, during agricultural practices, and during excavations for construction which all result in relatively larger size particles closer to 10 µm in diameter. This category also includes re-suspended dust from roadways, coal and oil fly ash, sea salt, and biological material such as pollen, mould and fungi (Air pollution and health, 1998). The combustion are gasoline and diesel fuel vehicle combustion, industry combustion, coal combustion in the process of electricity generation, and burning of vegetative material such as wood burning for residential heating and grass burning for clearing agricultural land (Andreau *et al.*, 2012).

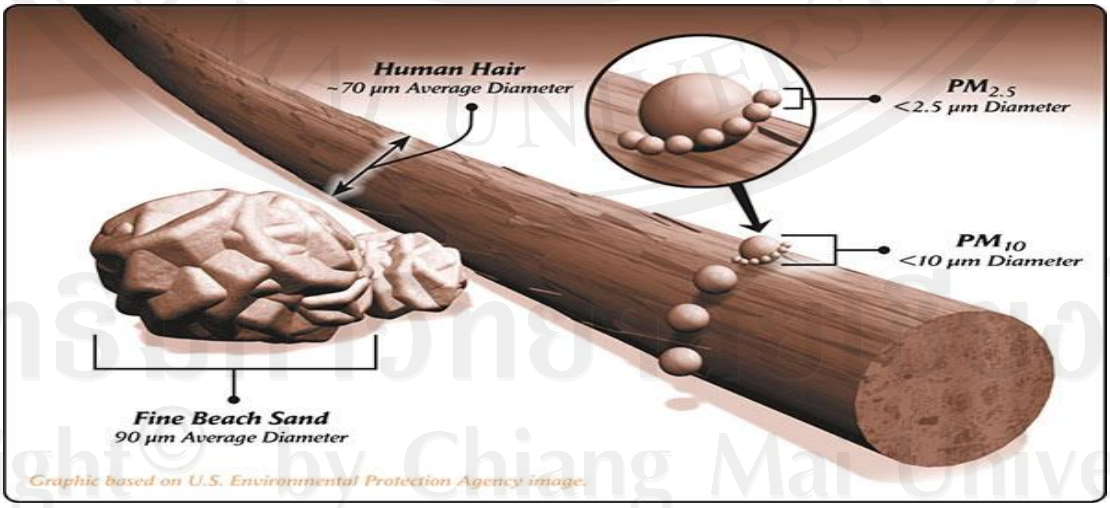

**Figure.1.2** Comparison of particle size to a strand of hair and beach sand

(Source: http://www.iaquk.org.uk/ResourcesParticulate.html)

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PM is composed of both coarse and fine particles. Coarse particles ($PM_{10}$) have an aerodynamic diameter between 2.5µm and 10 µm. They are formed by mechanical disruption (e.g.crushing, grinding, abrasion of surfaces); evaporation of sprays, and suspension of dust. $PM_{10}$ is composed of aluminosilicate and other oxides of crustal elements, and major sources including fugitive dust from roads, industry, agriculture, construction and demolition, and fly ash from fossil fuel combustion. The lifetime of $PM_{10}$ is from minutes to hours, and its travel distance varies from less than 1km to 10 km. Fine particles have an aerodynamic diameter less than 2.5µm ($PM_{2.5}$). They differ from $PM_{10}$ in origin and chemistry. These particles are formed from gas and condensation of high-temperature vapors during combustion, and they are composed of various combinations of sulfate compounds, nitrate compounds, carbon compounds, ammonium, hydrogen ion, organic compounds, metals (Pb, Cd, V, Ni, Cu, Zn, Mn, and Fe), and particle bound water. The major sources of $PM_{2.5}$ are fossil fuel combustion, vegetation burning, and the smelting and processing of metals. Their lifetime is from days to weeks and travel distance ranges from 100 km to greater than 1000 km. In addition, fine particles are associated with decreased visibility (haze) impairment in many cities of the USA.

### 1.3 $PM_{10}$ Monitoring equipment

Personal air sampler (SKC, USA) was used to collect $PM_{10}$ samples (Figure.1.3). This equipment can be operated by using pump to draw air at flow rate about 2 L/min through a particle size separator (cyclone), and then through a 37 mm. of quartz filter which is inserted into a filter holder inside a size separator column. The 10 µm or 2.5 µm particle separation is achieved by the Height Density (HD) cyclone. The samples is also equipped with rot meter (flow rate controller), an on/off digital control timer

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and a battery, which continuous powered a 12 hr sampling. The $PM_{10}$ samples are caught on the filter, which are weighed before and after sampling, with a microbalance accurate to one microgram. The unit of $PM_{10}$ samples reported in µg/m$^3$. Before a monitoring program is conducted, the sampler must be properly calibrated in order to ensure that its flow rate is about 2 L/min. Finally, it will be transferred to air volume in 12 hr in the present study.

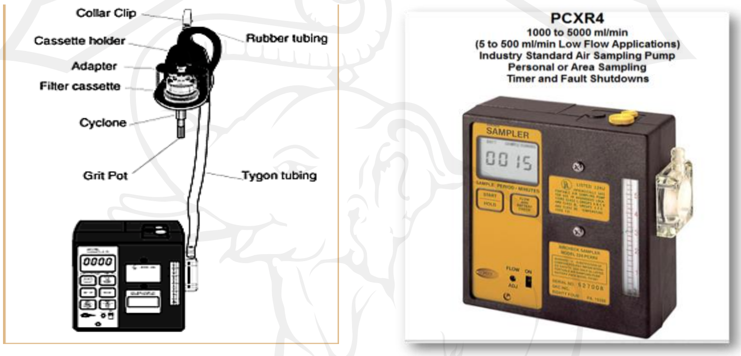

**Figure.1.3** Personal Air Sampler (SKC, USA.)

## 1.4 Biomarker of Air pollution from biomass burning

### 1.4.1 Levoglucosan

Levoglucosan (1,6-anhydro-b-D-glucopyranose, LG) and its isomers (mannosan and galactosan) are dehydro-monosaccharide derivatives formed exclusively from the thermal breakdown of cellulose and hemicellulose, respectively, during combustion. Such as, they are source specific and should hypothetically be found in residues of incomplete combustion of fuels containing cellulose/hemicellulose (Simoneit *et al.*, 1999; Frase and Lakshmanan, 2000; Simoneit, 2002) were among the first to show that levoglucosan and related degradation products from cellulose could be utilized as specific indicators for the presence of emissions from biomass burning in samples of atmospheric fine PM. Detailed characterization of the proportional yield of levoglucosan to its isomers and particularly to mannosan in fuel source emissions has

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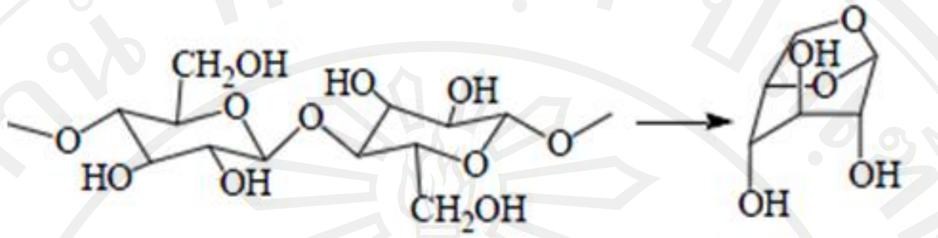
further permitted discrimination between specific inputs of combustion (i.e. softwood vs. hardwood, brown coal vs. recent biomass) in atmospheric PM (Ward *et al.*, 2006).



Section of cellulose Levoglucosan

**Figure.1.4** Levoglucosan was formed in high yields (up to 60 %) by the pyrolytic unzipping of cellulose (Shafizadeh, 1984)

**Table 1.2** Physical-chemical properties of levoglucosan

| **Properties** | **Value** |
|---|---|
| Chemical Abstract Service registry number (CAS#) | 498-07-07 |
| Molecular weight (g/mol) | 162.14 |
| Physical State: | powder |
| Color | light beige |
| Odor | none reported |
| pH | not available. |
| Water solubility (g/L) | 1600 |
| Melting point (ºC) | 183 |
| Boiling point (ºC) | 384 |
| Polarizability | 14.13 |

(source:

http://www.sigmaaldrich.com/catalog/product/aldrich/316555?lang=en&region=TH**)**

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### 1.4.2 2-Methoxyphenol

2-Methoxyphenol is resulted from pyrolysis of lignin, which is commonly found in cell walls of plants and is a waste product of the paper industry (Simoneit *et al.*, 1993). Some previous studies have suggested that various methoxyphenols in particulate matter can be used as tracers of wood smoke (Simpson *et al.*, 2005). The type of wood burned (in particular, hardwood versus softwood) affects the ratio of guaiacols to syringols and other classes of methoxyphenols. Unlike the other chosen compounds, the 2-methoxyphenol is semi-volatile, so its presence will not be limited to the particulate phase (Dills *et al.*, 2006). The one methoxyphenols that were monitored in this study was 2-methoxyphenol which the most abundant methoxyphenols measured (Ward *et al.*, 2006).

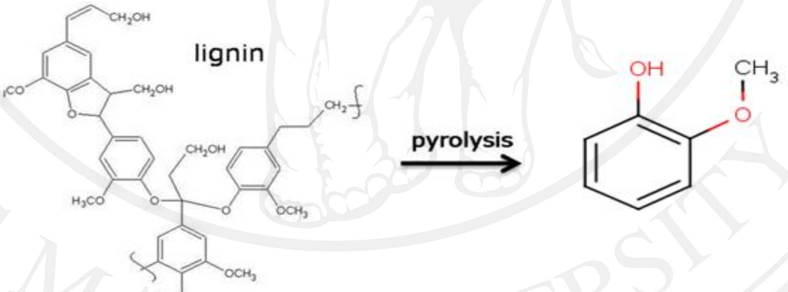

**Figure.1.5** Pyrolysis of lignin to 2-methoxyphenol.

(source: http://www.zimmermann.chemie.uni-rostock.de/en/agz-forschung/agz-feld2/holz/)

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**Table 1.2** Physical-chemical properties of 2-methoxyphenol

| **Properties** | **Value** |
|---|---|
| Chemical Abstract Service registry number (CAS#) | 90-05-1 |
| Molecular weight (g/mol) | 124.14 |
| Physical State | powder |
| Colors | light beige |
| Odor | aromatic odor |
| pH | not available |
| Water solubility (g/L) | 17 |
| Melting point (ºC) | 28 |
| Boiling point (ºC) | 205 |
| Vapor density | 4.27 |
| Vapor pressure (mmHg) | 0.11 |

(source:
http://www.sigmaaldrich.com/catalog/product/sigma/g5502lang=en&region=TH)

## 1.5 GC Derivatization

### 1.5.1 Introduction

Derivatization reactions are meant to transform an analyte for detectability in gas chromatography (GC) or other instrumental analytical methods. Derivatization in GC analysis can be defined as a procedural technique that primarily modifies an analyte's functionality in order to enable chromatographic separations. A modified analyte in this case will be the product, which is known as the derivative. The derivative may have similar or closely related structure, but not the same as the original non-modified

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chemical compound. Volatility of sample is a requirement for GC analysis. Derivatization will render highly polar materials to be sufficiently volatile so that they can be eluted at reasonable temperatures without thermal decomposition (Knapp, 1979) or molecular re-arrangement (Blau and King 1979; Kuhnel *et al*., 2007). Understanding the chemistry of the analytes, derivatizing reagents used in sample preparation, and the detailed functionality of gas chromatography are important to get reliable results. For GC analysis, compounds containing functional groups with active hydrogens such as -SH, -OH, -NH and -COOH are of primary concern because of the tendency of these functional groups to form intermolecular hydrogen bonds (Zaikin and Halket, 2003). These intermolecular hydrogen bonds affect the inherent volatility of compounds containing them, their tendency to interact with column packing materials and their thermal stability (Sobolevsky *et al.*, 2003). Since GC is used to separate volatile organic compounds, modification of the functional group of a molecule by derivatization enables the analysis of compounds that otherwise can not be readily monitored by GC. Derivatization process either increases or decreases the volatility of the compound of interest. It also reduces analyte adsorption in the GC system and improves detector response, peak separations and peak symmetry. In addition to particular analytes such as pharmaceuticals, biomolecules such us organic acids, amides, poly-hydroxy compounds, amino acids, pesticides and other persistent organic compounds, new classes of compounds of interest for example fluorinated alkylated substances and polycyclic aromatic hydrocarbons continue to emerge. It is necessary to develop and/or improve on chemical analytical methods and hence the need to familiarize with derivatization methods that are applicable to GC analysis.

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Generally derivatization is aimed at improving on the following aspects in Gas Chromatography**.**

### 1.5.2 Derivatization reagent

Derivatization reagent is the substance that is used to chemically modify a compound to produce a new compound which has properties that are suitable for analysis in GC or LC. The following criteria must be used as guidelines in choosing a suitable derivatization reagent for GC analysis. The reagent should produce more than 95% complete derivatives. It should not cause any rearrangements or structural alterations of compounds during formation of the derivative and should not to loss of the sample during the reaction. The produced derivative that also will not interact with the GC column.

### 1.5.3 Objectives for derivatization

The following outlined objectives among others can be achieved by application of proper derivatization procedures;

1.) Improvement of resolution and reduce tailing of polar compounds which may contain –OH, –COOH, =NH, $-NH_2$, –SH, and other functional groups.
2.) Reduction of volatility of compounds prior to GC analysis.
3.) Improvement of analytical efficiency and hence increase detectability.
4.) Stabilization of compounds for GC analysis.

### 1.5.4 Derivatization reactions for levoglucosan and 2-methoxyphenol

Silylation is the most prevalent derivatization method as it readily volatizes the sample and therefore very suitable for non-volatile samples for GC analysis. Silylation is the introduction of a silyl group into a molecule, usually in substitution for active hydrogen such as dimethylsilyl [$SiH(CH_3)_2$], t-butyldimethylsilyl [Si

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$(CH_3)_2C(CH_3)_3$] and chloromethyldimethylsilyl [$SiCH_2Cl(CH_3)_2$]. Replacement of active hydrogen by a silyl group reduces the polarity of the compound and reduces hydrogen bonding (Pierce, 1968). Many hydroxyl and amino compounds regarded as nonvolatile or unstable at 200-300 ºC have been successfully analyzed in GC after silylation (Lin *et al.*, 2008 & Chen *et al.*, 2007). The silylated derivatives are more volatile and more stable and thus yielding narrow and symmetrical peaks (Kataoka, 2005).

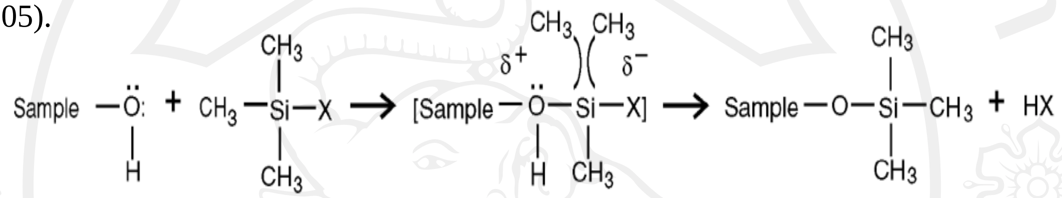

**Figure.1.6** General reaction mechanism for the formation of trialkylsilyl derivatives for trimethylchlorosilane, X = Cl.

The silylation reaction is driven by a good leaving group, which means a leaving group with a low basicity, ability to stabilize a negative charge in the transitional state, and little or no back bonding between the leaving group and silicon atom (Knapp, 1979). The mechanism involves the replacement of the active hydrogens (in -OH, -COOH, -NH, -$NH_2$, and –SH groups) with a trimethylsilyl group. Silylation then occurs through nucleophilic attack ($SN_2$), where the better the leaving group, the better the siliylation. This results to the production of a bimolecular transition state (Kuhnel *et al.*, 2007) in the intermediate step of reaction mechanism. The general reaction for the formation of trialkylsilyl derivatives is shown by Figure.1.6. The leaving group in the case of trimethylchlorosilane (TMCS) is the Cl atom.

In silylation derivatisation, care must be taken to ensure that both sample and solvents are dry. Silyl reagents generally are moisture sensitive, and should be stored in tightly sealed containers (Sobolevsky *et al.*, 2003) and therefore the solvents used

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should be as pure and as little as possible. This will eliminate excessive peaks and prevent a large solvent peak. In silylation, pyridine is the most commonly used solvent. Although pyridine may produce peak tailing, it is an acid scavenger and will drive the reaction forward. In many cases, the need for a solvent is eliminated with silylating reagents. The completion of the derivatization process in silylation is usually observed when a sample readily dissolves in the reagent. According to Regis the ease of reactivity of the functional group toward silylation follows the order: Alcohol > Phenol > Carboxyl > Amine > Amide /hydroxyl For alcohols, the order will be as follows: Primary > Secondary > Tertiary. Many reagents will require heating that is not in excess of 60 ºC for about 10-15 minutes, to prevent breakdown of the derivative. Although hindered products may require long term heating.

## 1.6 Gas chromatography for levoglucosan and 2-methoxyphenol analysis

The most popular analysis method for levoglucosan and 2-methoxyphenol is chromatographic method. GC is most commonly used for levoglucosan and 2-methoxyphenol detection. GC has been one of the most versatile and widely applicable techniques leading the field of analytical chemistry over the last forty year. The popularity of GC stems from its fast, simple, relatively inexpensive, and reproducible nature. As a method used to separate volatile and semi-volatile organic compounds, GC can be utilized in numerous analytes including petrochemical, environmental, pharmaceutical, and food science. Separation in GC based on the vapor pressure of pressure of the volatilized compounds and their affinity for the liquid stationary phase, which coats a solid support, as they pass through the column with carrier gas. Capillary column is most popular for GC device (Bower, 2000). The

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basic components of an instrument for gas chromatography are illustrated in Figure 1.6

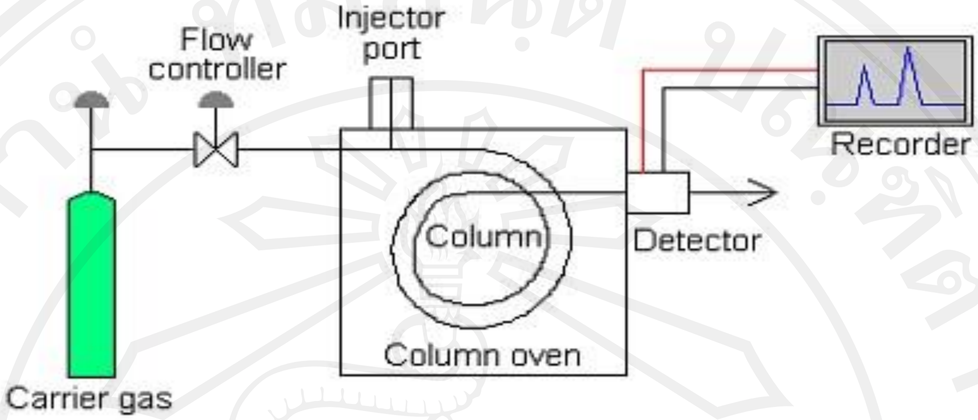

**Figure.1.7** Block diagram of gas chromatograph

(Source: http://teaching.shu.ac.uk/hwb/chemistry/tutorials/chrom/gaschrm.htm)

Flame ionization detectors (FID) are the most generally applicable and most widely used detectors. In a FID, the sample is directed at an air-hydrogen flame after exiting the column. At the high temperature of the air-hydrogen flame, the sample undergoes pyrolysis, or chemical decomposition through intense heating. Pyrolized hydrocarbons release ions and electrons that carry current. A high-impedance Pico ammeter measures this current to monitor the sample's elution. It is advantageous to used FID because the detector is unaffected by flow rate, noncombustible gases and water. These properties allow FID high sensitivity and low noise. The unit is both reliable and relatively easy to use. However, this technique does require flammable gas and also destroys the sample (Bower, 2000).

High-resolution mass spectrometry is a powerful and well- established technique in analytical chemistry, which has been used for over four decades. For organic analyses the equipment is often connected to a gas chromatograph or to thermal probe

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sources. it is only through the development of bench-top instruments based on the ion trap and quadrupole designs that these new small low resolution mass spectrometers have become to be considered as simply a detector for the gas chromatograph. Single ion monitoring (SIM) instead of scanning the whole molecular mass range, normally ~40 to 650 a.m.u. (atomic mass units), the instrument is programmed to detect a single ion mass or very narrow range of ion masses, it is usual to select the most abundant or most characteristic ion mass for the analyte of interest. This can lead to a chromatogram containing only one compound peak. The signal to noise ratio of the compound peak is strongly enhanced by using SIM, leading to a much lower limit of detection for that compound.

The mass spectrum (ion fragmentation spectrum) for each chromatographic peak can be compared against reference spectra in order to identify a compound. Even the simpler bench top mass spectrometers are supplied with reference libraries, commonly containing the reference spectra of over 40,000 compounds. Libraries can be searched and the best matches to the unknown can be found. A scoring system is used to indicate the closeness of each match with the unknown. Experienced analysts can also interpret the fragmentation patterns to identify the structural units and functional groups present. Combination of mass spectrum data and other spectroscopic techniques, it is possible for the analyst to build a complete molecular structure and to identify the compound (Bower, 2000).

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## 1.7 Literature review of levoglucosan (LG) and d 2-methoxyphenol (MP)

Bari *et al.*, 2010 collected particle-phase $PM_{10}$ samples at a residential site Dettenhausen near Stuttgart. PAHs and other wood smoke tracer compounds (e.g.levoglucosan, methoxyphenols) bounded in $PM_{10}$ were analyzed by GC-MS. High concentrations of $PM_{10}$, hardwood markers and total PAHs were observed in winter season. Based on the emission ratio of hardwood markers and $PM_{10}$, it can be shown that 57% of ambient $PM_{10}$ pollution in Dettenhausen was attributed from hardwood combustion for winter. An improved analytical method was developed for determination of the monosaccharide anhydrides (MAs), including levoglucosan, mannosan, and galactosan in atmospheric aerosol samples. These chemicals were extracted from PM using dichloromethane and analyzed by GC-FID and GC-MS. The method was applied to aerosol samples from urban and tropical locations. The atmospheric mean concentration of the MAs in $PM_{2.5}$, which collected from forest site of Brazil, was 2.15 $ug/m^3$ in the dry season (intensive biomass burning). It was 400 times higher than the wet season (no burning). For urban site of Belgium, the concentration of MAs was 0.56 $ug/m^3$ in winter season, which was a factor of 20 higher than summer season. The major MA was levoglucosan, with a relative abundance in the range of 76-93%.

Bergauff *et al.*, 2010 developed an analytical method by using solvent extraction and GC-MS analysis for organic compound in $PM_{2.5}$, including levoglucosan, dehydroabietic acid, abietic acid, vanillin, acetovanillone, guaiacol, and 4-ethylguaiacol, as tracers for wood smoke. The developed analytical method was applied to ambient particulate matter samples collected in Libby, MT. Levoglucosan, dehydroabietic acid, and abietic acid expressed the suitable tracers for wood smoke in

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$PM_{2.5}$ and those organic compounds indicated that 82% of the $PM_{2.5}$ in Libby resulted from residential wood smoke.

Dhammapala *et al.,* 2007 evaluated the emission factors (EFs) of pollutants from wheat and Kentucky bluegrass (KBG) stubble burning in a US EPA test burn facility. The EFs of PAHs, MPs for combined solid and gas phases are 17±8.2 mg/kg and 79±3.6 mg/kg, respectively, for wheat and 21±15 mg/kg and 35±24 mg/kg, respectively, for KBG. EFs of LG , particulate elemental carbon (EC) and artifact-corrected organic carbon (OC) are 150±130 mg/kg, 0.35±0.16 g/kg and 1.9±1.1 g/kg, respectively, for wheat and 350±510 g/kg, 0.63±0.056 g/kg, and 6.9±0.85 g/kg, respectively, for KBG. The EFs of these pollutants were generally depended on combustion efficiency (CE) and lignin content in plant.

Fu *et al.,* 2007 collected total suspended particles (TSP) at Alert in the Canadian high Arctic. More than 100 organic species were observed from analysis of extracted TSP by GC-MS. The concentrations of total quantified organics were in the ranges of 6.7-17.7 ng/m$^3$ and it was slightly higher in dark winter aerosols than those after polar sunrise. The chemical composition of organic aerosols in the Arctic region was influenced from long-range transport, solar irradiance, and temperature of ambient.

Jimenez *et al.,* 2007 evaluated LG and MPs as potential tracers for apportioning field burning smoke. The sample from wheat and KBG stubble smoke were collected from chamber and field burns. The samples were analyzed for inorganic and organic tracers, including LG and 19 MPs. For the chamber experiments, the amount of LG, ~23 µg/mg $PM_{2.5}$, found in wheat and KBG stubble smoke was similar, while the total MPs was higher in wheat. Syringaldehyde, acetosyringone, and coniferylaldehyde were found to be the most prominent particle-phase MPs in wheat smoke, and these

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compounds were not always present in detectable amounts in KBG smoke. The ratio of LG/syringaldehyde found in wheat (78±27) was higher than the same ratio reported for softwoods (22±3) and hardwoods (~5). Similarly, the ratio of LG/coniferylaldehyde was higher in wheat stubble smoke (180±39) compared to that in softwoods (~7) and hardwoods (~8).

Jordan *et al.*, 2007 collected ambient air samples in Launceston, Australia. $PM_{10}$ was analyzed for LG in the contribution of wood burning assessing. Wood smoke was estimated to comprise about 95% of winter time air pollution in Launceston, and the resulting average LG wood burning emission factor of around 140 mg/g particulate matter was found to be consistent with determined wood heater emissions.

Simoneit *et al.*, 1999 suggested that LG and the related degradation products from cellulose can be utilized as specific and indicator compounds for the presence of emissions from biomass burning in samples of atmospheric particulate matter. Especially for LG, it was emitted in high concentration from biomass burning. Moreover, the other organic compounds also used to additional specify type of biomass.

Simpson and Naeher, 2010 determined the contribution of wood smoke to ambient atmospheric fine PM between 1999 and 2000 in Seattle, Washington. Particle-bound MP concentrations in the range <0.1 to 22 $ng/m^3$ were observed and the MPs were present almost exclusively in the fine ($PM_{2.5}$) size fraction. Moreover, there was found XRF analysis of samples of atmospheric PM collected on Teflon filters significantly reduced the levels of MPs measured in the PM samples in subsequent assay of the same filters. Therefore, XRF analysis of filters, commonly undertaken to obtain trace element concentrations for use in source apportionment

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analyses, would preclude the subsequent analysis of those filters for MPs and other similarly semivolatile or reactive organic chemicals.

### 1.8 Hypotheses of the present study

The concentrations of $PM_{10}$, LG and MP in the air from the house using wood for cooking in dry season are higher than wet season**.**

### 1.9 Purpose of the study

The main objective of the present study was to determine LG and MP in the houses which used wood for cooking in KCK village.

The aims of this research work can be summarization as follows:

1) To determine $PM_{10}$ in the houses that use wood for cooking**.**

2) To determine LG and MP on $PM_{10}$**.**

3) To study the correlations among $PM_{10}$, LG and MP**.**

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