โครงการ

การเรียนการสอนเพื่อเสริมประสบการณ์

ชื่อโครงการ Altitude distribution of fine particulate matters PM_1 $PM_{2.5}$ and PM_{10} in Bangkok

ชื่อนิสิต Hathairat Kittipalarak ID 5933349823

ภาควิชา Environmental Science

ปีการศึกษา 2019

คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

Altitude distribution of fine particulate matters PM_1 $PM_{2.5}$ and PM_{10} in Bangkok

Miss Hathairat Kittipalarak

A Senior Project Submitted in Partial Fulfillment of the Requirements
for the Degree of Bachelor of Science
Department of Environmental Science, Faculty of Science,
Chulalongkorn University
Academic Year 2019

Title	Altitude distribution of fine particulate matters PM_1 $PM_{2.5}$ and PM_{10} in Bangkok
By	Miss Hathairat Kittipalarak **ID** : 5933349823
Department	Environmental of Science
Academic year	2019
Project advisor	Professor Dr.Wanida Jinsart

Accepted by Department of Environmental Science, Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Bachelor's degree

.... Head of Department of Environmental Science

(Professor Dr.Wanida Jinsart)

PROJECT COMMITTEE

.... Chairman

(Associate Professor Naiyanan Ariyakanon, Ph.D.)

.... Committee

(Dr. Sumeth Wongkiew)

.... Project Advisor

(Professor Dr.Wanida Jinsart)

Title Altitude distribution of fine particulate matters PM_1 $PM_{2.5}$ and PM_{10} in Bangkok

By Miss Hathairat Kittipalarak ID : 5933349823

Department Environmental of Science

Academic year 2019

Project advisor Professor Dr.Wanida Jinsart

ABSTRACT

Fine particulate matter particles with a diameter less than 1 micron (PM_1), less than 2.5 micron ($PM_{2.5}$) and less than 10 micron ($PM_{2.5}$) have been measured in different height 1.5 m, 25 m and 75 m respectively. The sampling sites were located at Mahamakhut Sci0025 Building Faculty of Science Chulalongkorn University. The particulate matters were sampling from January to March 2020. $PM_{10-2.5}$ and $PM_{2.5}$ were collected using personal modular impactor with filters pack attached and air pump sampler flowrate 3 L/min for 8 hours on both weekend and weekdays. PM_1concentrations were determined by Dust Track with self reading sensor. The highest concentration of $PM_{2.5}$ and $PM_{10-2.5}$ were found at the fifth floor 25 m height with average concentration 62.33 ± 3.04 and 64.42 ± 5.16 μg/m^3 respectively. The highest concentration of PM_1 was found at the fifthteen floor 75 m height with average concentration 66.33 ± 31.72 μg/m^3. This 5th floor has many teaching activities. There are many students using this area. The results show that the PM levels in the ground area, 1.5 m is much lower than in the aerosol suspended in the high altitude. The SCI 025 building is far from the main road about 300 m. So the traffic emission should have some impact on the ambient PM concentration. This study illustrated the variability of PM distribution with altitude and high-risk locations. These results could be used for the decision of living in high altitude in urban area.

Keywords: Particulate Matter, altitude, Bangkok

หัวเรื่อง การกระจายตัวตามความสูงของฝุ่นขนาดเล็ก PM_1 $PM_{2.5}$ และ PM_{10} ในกรุงเทพมหานคร

โดย นางสาวหทัยรัตน์ กิตติพลารักษ์ รหัสประจำตัวนิสิต 5933349823

คณะวิทยาศาสตร์ ภาควิชาวิทยาศาสตร์สิ่งแวดล้อม

ปีการศึกษา 2562

อาจารย์ที่ปรึกษา ศาสตราจารย์ ดร. วนิดา จีนศาสตร์

บทคัดย่อ

อนุภาคของฝุ่นละเอียดที่มีเส้นผ่านศูนย์กลางน้อยกว่า 1 ไมครอน (PM1), น้อยกว่า 2.5 ไมครอน (PM2.5) และน้อยกว่า 10 ไมครอน ($PM_{2.5}$) ได้รับการตรวจวัดที่ความสูงที่แตกต่างกันคือ 1.5 เมตร, 25 เมตรและ 75 เมตรตามลำดับ โดยสถานที่เก็บตัวอย่างในการศึกษาครั้งนี้ตั้งอยู่ที่อาคารมหามกุฏ SCI 025 คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย โดยระยะเวลาการเก็บตัวอย่างฝุ่นละอองเริ่มตั้งแต่เดือนมกราคมถึงมีนาคม 2563 และในการเก็บข้อมูล $PM_{10-2.5}$ และ $PM_{2.5}$ ใช้เครื่องมือหัวคัดแยกฝุ่นขนาดเล็กและเก็บตัวอย่างอากาศด้วยอัตราการไหล 3 ลิตรต่อนาทีเป็นระยะเวลา 8 ชั่วโมงทั้งวันหยุดสุดสัปดาห์และวันธรรมดา โดยระดับความเข้มข้น PM_1 ถูกตรวจวัดโดย Dust Track พร้อมเซ็นเซอร์อัตโนมัติ ในส่วนความเข้มข้นสูงสุดของ $PM_{2.5}$ และ $PM_{10-2.5}$ พบที่ชั้น 5 ที่ความสูง 25 เมตรโดยมีความเข้มข้นเฉลี่ย 62.33 ± 3.04 และ 64.42 ± 5.16 ไมโครกรัมต่อลูกบาศก์เมตรตามลำดับ ความเข้มข้นสูงสุดของ PM_1 ถูกพบที่ชั้น 15 ที่ความสูง 75 เมตร โดยมีความเข้มข้นเฉลี่ย $66.33 \pm 31.72\ \mu g / m^3$ ชั้น 5 นี้มีกิจกรรมการสอนมากมาย มีนักเรียนจำนวนมากใช้พื้นที่นี้ ผลการวิจัยพบว่าระดับ PM ในพื้นที่พื้นดิน 1.5 เมตรนั้นต่ำกว่าฝุ่นละอองที่ลอยอยู่ในระดับสูง อาคาร SCI 025 อยู่ไกลจากถนนใหญ่ประมาณ 300 ม. ดังนั้นการปล่อยสัญญาณไฟจราจรควรมีผลกระทบต่อความเข้มข้นฝุ่นละอองขนาดเล็กรอบข้าง การศึกษาครั้งนี้แสดงให้เห็นถึงความแปรปรวนของการกระจายตัวของฝุ่นละอองขนาดเล็กด้วยความสูงและที่ตั้งที่มีความเสี่ยงสูง ผลลัพธ์เหล่านี้สามารถนำไปใช้ในการตัดสินใจประกอบการเลือกใช้ชีวิตในบริเวณพื้นที่สูงในเขตเมือง

คำสำคัญ: ฝุ่นละอองขนาดเล็ก, ความสูง, กรุงเทพมหานคร

ACKNOWLEDGEMENTS

This senior project becomes successfully because of many kinds and supports. I would like to express my sincere thankful to all my supporter.

Foremost, I am very appreciated for my senior project advisor Professor Dr.Wanida Jinsart for supporting my senior project to successfully deliver this project. She kindly gave the assistance in every steps of this project. The supports and guidance from her could break through the problems and encourage me.

I am thankful to my senior project Chairman, Associate Professor Naiyanan Ariyakanon, Ph.D. and the committee Dr. Sumeth Wongkiew for the kindness and knowledge, which support towards the successful of my study.

I would like to thank to Center for Safety, Health and Environment of Chulalongkorn University for the support that lends DustTrak™ II Aerosol Monitor for use in PM_1 concentration measurements.

This project could not complete without laboratory staffs, Mrs. Ketsara Kaenkaew and Ms. Pansuree Jariyawichit. They brought me tender encouragement.

Finally, I would like to thankful my family and Department of Environmental Science for supporting. They have contributed my senior project. I am very appreciated of helpful contribution.

CONTENTS

Page

CONTENTS (CONT.)

Page

LIST OF FIGURES

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION

1.1 Introduction

Outdoor air pollution is a major environmental health problem affecting everyone in low-, middle-, and high-income countries (WHO, 2018). In 2016, the World Health Organization (WHO) air quality model confirmed that 91% of the world's population are living in areas with air quality levels that exceed the WHO standards and about 4.2 millions people worldwide death prematurely due to outdoor air pollution which causes heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections in children.

The rapid economic growth has created high levels of air pollution in Thailand, where Particulate Matter (PM) originates into two types, which are occurs naturally, such as forest fires, soil, rocks, and sand and caused by human activities such as transportation, burning in open space, industrial, and the construction, all of which contribute to air pollution especially in Bangkok. Due to there are approximately 6 million people living, which does not include the hidden population when comparing the population of Bangkok with the total population in Thailand, it can be seen that Bangkok has a higher population density than other provinces. Therefore, when faced with the problem of air pollution that exceeds the standard value, causing affecting many people.

Particulate Matter (PM) is a mixture of solids and liquid droplets floating in the air, when divided by size, it can be divided into three main groups: coarse particles, fine particles and inhalable particles. Coarse particles (PM_{10}) have an aerodynamic diameter of 2.5 to 10 micrometers, in which originate from the crushing or grinding process and dust generated by road vehicles (Zhang et al., 2018). Fine particles ($PM_{2.5}$) have an aerodynamic diameter of 2.5 micrometers or smaller and can only be seen with an electron microscope. $PM_{2.5}$ can occur from all types of combustion, including automobiles, power plants, residential fires, forest fires, agricultural combustion and certain industrial processes. Inhalable particles (PM_1) have an aerodynamic diameter of less than 1 micrometers. PM_1 can be formed from secondary aerosols and coal combustion, vehicle, industry, biomass burning and dust (Yanyun et al., 2018).

The concentration of air pollution measured can vary depending on many factors, for example location of measurement, measurement time, period, meteorological factors and altitude. In Bangkok, there are a few studies on the air pollution at different altitudes and periods. Therefore, in this study, it is interesting to study the relationship between concentrations of PM_1, $PM_{2.5}$, and PM_{10} in the outdoor area on the fifth floor and fifteenth floor at mahamakut building, which these buildings are located at, chulalongkorn university, Bangkok, Thailand.

1.2 Objective

1.2.1 To investigate the concentration of PM_1, $PM_{2.5}$, and PM_{10} in each sampling points which have different altitudes.

1.2.2 To find the relationship between PM_1, $PM_{2.5}$, and PM_{10} concentration and altitude.

1.3 Scope of the study

1.3.1 Period of study during January, 2020 – May, 2020

1.3.2 Sampling points will be collected on the fifth and fifteenth floor located at mahamakut building, Chulalongkorn University, Bangkok, Thailand.

1.3.3 Samples of $PM_{2.5}$ are collected on PTFE filter and PM_{10} samples are collected on PVC filter, both of which are filtered in the Personal Modular Impactor® (PMI) connected to the Personal air pump (SKC, Gillian GilAir5) for 8 hours per day. Samples of PM_1 will be measured by Dusttrak™ II Aerosol Monitor. Samples of deposit dust are collected on PTFE filter, PVC filter and Glass fiber filter paper, which will be placed in the same area as the sampling point.

1.4 Expected Outcomes

1.4.1 To know the difference in the concentration of pollutants in the air at different altitudes and periods.

1.4.2 To identify the relationship of the concentration of each pollutant in the air at various altitudes.

CHAPTER II

THEORIES AND LITERATURES REVIEWS

2.1 Description of study area

2.1.1 Geography

Bangkok is the capital city of Thailand, located in the lower central region of Thailand at the latitude of 13.45 degrees north, 100.28 degrees east longitude, with a total area of approximately 1,568.7 square kilometers, with a population of more than 5 million people, an area of approximately half that is approximately 700 square kilometers of urban area. Bangkok has three types of land use, which are land use for housing, land use for agriculture and vacant land. Other than that, it is the use of various types of land, such as for commerce, industry, government offices (BMA data center, 2020).

Mahamakut Building is the tallest building in Chulalongkorn University, which is located at the Faculty of Science, with a total of 19 floors, representing 49,653.64 square meters. This building is located nearby to many places such as Chamchuri Square, Sam Yan Mitr Town and adjacent to Phaya Thai Road, which is considered an important area of Bangkok.

Chulalongkorn Centennial Park (CCP) was built to celebrate the 100 th anniversary of Chulalongkorn University and to increase green space for urban communities. The garden is located in the center of the commercial area and has been designed to be modern and versatile, which serves as an oasis for Bangkok residents and visitors.

The main entrance of Chulalongkorn University is located next to Phaya Thai Road, which is located in the center of Bangkok and is a road with heavy traffic, especially during rush hours.

Figure 2.1 Mahamakut Building

2.2 Particulate Matter

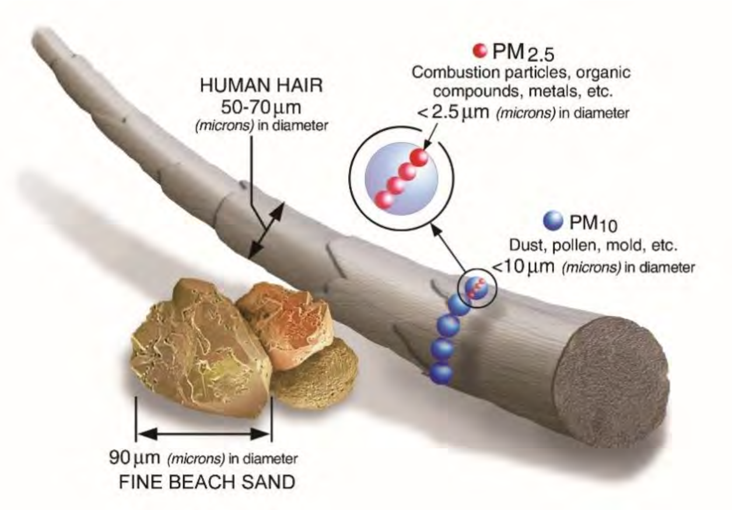

Figure 2.2 Characteristics of $PM_{2.5}$ and PM_{10} (USEPA, 2016)

Particulate Matter (also called particle pollution, PM) 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 (USEPA, 2018).

These particles can vary in size, shape and composition. EPA is especially concerned about particles that are 10 micrometers in diameter or smaller because these particles are inhalable (USEPA, 2019). PM can be divided by size into three types consisting of PM_1, $PM_{2.5}$, PM_{10}. PM_1 is a particle with an aerodynamic diameter less than 1 micrometers, also known as inhalable particles. $PM_{2.5}$ is a particle with an aerodynamic diameter less than 2.5 micrometers, also known as fine particles. PM_{10} is a particle with an aerodynamic diameter less than 10 micrometers, also known as coarse particles. The particles come from a variety of sources, both stable and mobile, and may be released directly. (Primary emissions) or occurs in the atmosphere (Second emissions) by deformation of gas release. The primary source of PM originates from both human activities and nature. The main source of PM originates from a variety of human activities, for example agricultural work, industrial processes, combustion of wood and fossil fuels, construction and demolition activities, and road dust. Natural (Nonanthropogenic or biogenic) sources of PM can also cause overall PM problems, including windblown dust and forest fires. Secondary PM sources can be caused by contaminants in the air, released directly into the atmosphere or may help in PM formation. These secondary pollutants include SOx, NOx, VOCs and ammonia, which can be the precursors to create PM.

There are scientific studies linked to PM exposure to various health effects such as eye, nose and throat irritation, exacerbating vascular and respiratory diseases, and premature death in people with heart or lung disease. When exposed to inhalable particles it may affect both the lungs and the heart. Many studies have shown that particle sizes have a direct impact on health problems. Small particles with a diameter of less than 2.5 micrometers can able to penetrate the human respiratory system through the alveoli then will accumulate in the lung tissue and entering into the bloodstream causing cardiovascular, lung function to deteriorate, bronchitis and asthma. For people with heart or lung disease such as coronary artery disease, congestive heart failure, and asthma or COPD, people who may be at high risk of exposure to PM are children and the elderly with both short-term and long-term effects of air pollution causing various body disorders, such as reduced lung function, respiratory infections, and aggravated asthma. When the pregnant person is exposed to the ambient air pollution, it is found to be related to the effects such as low birth weight, premature birth and small gestational age during pregnancy. In addition, new evidence emerges which can indicate that the ambient air pollution may affect diabetes and neurological development in children. In 2013, WHO's International Agency for Research on Cancer (IARC) has classified PM as a cause of lung cancer (WHO).

2.3 Literature review

T.N. Quang et al. (2012) performed this study to assess the variations in particle number size distribution (PNSD), particle number (PN) and $PM_{2.5}$ concentrations by measuring simultaneously at the rooftop and street level of three urban office buildings. Study the concentration of PNSD and $PM_{2.5}$ vertically and analyze the influence of vehicle emissions and nucleation events on vertical distribution. In addition, quantify and find the difference between PNSD and $PM_{2.5}$ concentrations are measured at different levels. Two sets of instruments are used to measure PNSD, PN and $PM_{2.5}$ concentrations. The first set is continuously measured at the highest level (usually on the rooftop), which is designated as a reference area for each building. The second set of measurements simultaneously at one lower level. The results showed that The concentration of $PM_{2.5}$ around the building is constantly decreasing while increasing the distance of the nearby roads, so it can indicate that the PNSD and $PM_{2.5}$ concentrations around the building was influenced by vehicles emission and new particle formation. The simultaneous measurement indicates that it does not just vehicle emissions but the formation of new particles, it has a high influence on the vertical distribution of particle concentration. During the formation of the new particle, PN concentrations are in size range in less than 30 nm and the concentration of PN increased while the concentration of $PM_{2.5}$ decreased with height.

Xuejiao et al. (2015) performed a study by measuring the concentrations of PM_1, $PM_{2.5}$ and PM_{10} at Canton Tower in Guangzhou, China which were measured at the height of 121 and 454 meters from November 2010 to May 2013. The results show that the annual average of the concentrations of PM_1, $PM_{2.5}$ and PM_{10} at 121 meters is higher than at 454 meters. Air pollution is a problem in winter and daily change in PM at two heights is different, which may be the result of the structure and usage of the building. In addition, the vertical distribution of PM_1, $PM_{2.5}$ and PM_{10} concentrations decreased with height.

Hong et al. (2015) studied the concentrations of $PM_{2.5}$ at the four heights, consisting of 10m, 40m, 120m, and 220m, which were performed during the daytime and nighttime of the summer at the meteorological tower in Tianjin, China. Overall, the concentration of $PM_{2.5}$ and the main chemical components decreased while the height increased. On the other hand, the percentage of SO_4^{2-}, NO_3^- and OC tends to increase as the height increases. In addition, it was found that the concentration of ion species and carbon compounds in the $PM_{2.5}$ samples measured during the daytime are higher than the nighttime, which may be the result of daytime have more human activities and different meteorological conditions.

Lei Li et al. (2020) studied presents three important air pollution observation data, including $PM_{2.5}$, O_3 and NO_x, along with meteorological parameters, including temperature, relative humidity, wind speed / direction, and visibility at different altitudes. In addition, it also studies different vertical distribution patterns to provide complete information about the source of each type of air pollution at various heights. Which measure $PM_{2.5}$ and NO_x at four different heights, including 70, 120, 220 and 335 meters. While measuring O_3 at four different heights, consisting of 60, 110, 210 and 325 meters. From the study, it was found that the mechanism of $PM_{2.5}$ formation at higher altitudes may differ from those at low altitudes. Chemical reactions are the main reason that controls the variation of $PM_{2.5}$ at higher altitudes, while night chemistry and low mix height may be the main reason for controlling $PM_{2.5}$ at low altitudes. The concentration of O_3 has a time interval which has the highest value at all levels. The daily NO_x concentration change will be twice as high during peak hour traffic during the day. PM2.5 and NO_x concentrations generally decrease with height, while O_3 concentrations increase with height.

Kun Zhang et al. (2020) studied the vertical distribution of $PM_{2.5}$, NO, NO_2, SO_2 and O_3 at an altitude of 1,000 meters, which studies the source of air pollution and compares the characteristics of the vertical distribution of air distribution on clean days and haze days. Tethered balloon surveys were conducted from November 26 to December 26, 2017 at the Science and Technology Campus of East China University, Shanghai. The environment is mostly occupied by many universities. This study uses a balloon capable of 170 kilograms and a maximum height of 1300 meters with a custom designed platform. From the results of the study, it was found that when the altitude increased, the pattern of $PM_{2.5}$, NO, and NO_2 decreased significantly and NO_2 could be the most important factor influencing the vertical distribution of $PM_{2.5}$ in both clean and haze days. SOA and heat emissions are the main source of $PM_{2.5}$ on clean days. Air pollution on haze days may come from similar sources. It is also found that the main sources of NO are vehicles and industrial emissions, where the height increases will cause most of the NO concentrations to decrease rapidly in both on haze and clean days. On the other hand, O_3 shows an increased pattern when the altitude increases in both clean and haze days.

Parkpoom Choomanee et al. (2020) studied focuses on determining the vertical distribution of $PM_{2.5}$ concentrations and the carbonaceous aerosol content of $PM_{2.5}$ at various mixing heights related to meteorological parameters and use the backward trajectory analysis to evaluate a possible contribution of remote sources. $PM_{2.5}$ particles are monitored continuously and simultaneously by collecting samples at three heights, consisting of 30 m, 75 m and 110 m from the ground. The time required for measurement is divided into two stages : day time (08:00–19:00 local time) and night time (20:00–07:00) using the dust detector in the area. Sampling site was the Microclimate and Air Pollutants Monitoring Tower at Kasetsart University (KU). The observed $PM_{2.5}$ concentration tends to increase with altitude, which is generally higher during the daytime than at night. The areas in the urban that are closest to Bangkok are most influenced by traffic pollution, which is considered a major source of $PM_{2.5}$. It may also be related to the formation of photochemistry during the day of NO_3^-, which helps the oxidation reaction of VOCs in the form of secondary organic aerosols (SOAs) which increase the hygroscopicity of aerosols. It is found that carbonaceous aerosols consist of 20–50% of the mass of $PM_{2.5}$ in most urban areas, which are influenced by seasonal variations in emissions intensity and meteorological factors.

CHAPTER III

METHODOLOGY

3.1 Site description

3.1.1 Study area and sampling sites.

Chulalongkorn University located in the central of Bangkok with high density of population and high polluted areas including high traffic density. There are many sources of fine particulate matters which created the atmospheric aerosol around. In this study, the distribution of the ultrafine and fine PMs has been investigated. The studied sites were Mahamakut building, main entrance of Chulalongkorn university and Chulalongkorn university Centenary park (CCP). Mahamakut building was chosen as a sampling point because it is the tallest building in Chulalongkorn University and the surrounding area has many buildings. Installation of equipment on the 5th and 15th floors at the altitude of 25 and 75 meter respectively. The 5th floor is a floor that still has a lot of buildings around, causing the air to circulate poorly, while the 15th floor is a floor that has very few buildings around, resulting in good air circulation. The CCP and the main entrance of Chulalongkorn University have used the results from the PMs Lab experiment for reference.

Data were collected at Mahamakut building (13º44'10.6"N 100º31'50.3"E), which is located at Chulalongkorn University, Bangkok, Thailand. The equipment will be installed in the outdoor areas on the terrace at the fifth and fifteenth floors. The three selected sampling points represent different altitude. In addition, measurements will be made in two periods, so studies were performed to quantify PM_1, $PM_{2.5}$ and PM_{10}. Each sampling point will have two samples collected and measured for 8 hours a day.

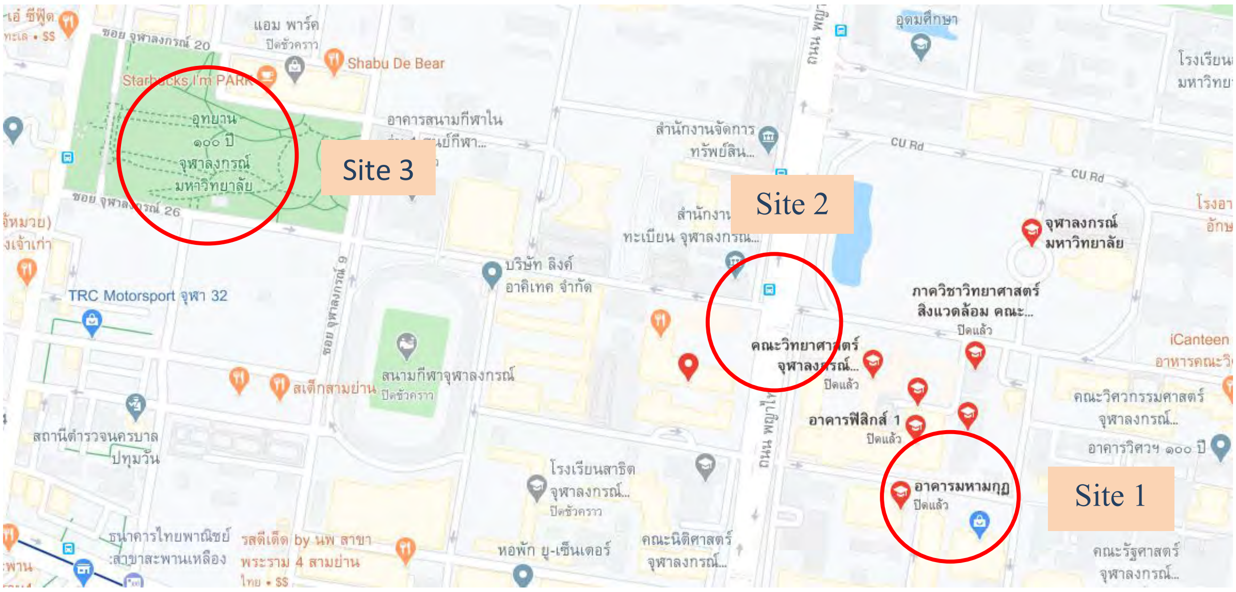

Figure 3.1 Sampling location

Site 1 Mahamakut building (SCI 025)

Site 2 Main entrance of Chulalongkorn university

Site 3 Chulalongkorn university Centenary park (CCP)

3.2 Measurement data

3.2.1 Equipment

- Personal air pump (SKC, Gillian GilAir5)
- Personal Modular Impactor® (PMI) (SKC: Eighty Four, PA, USA)
- PTFE filter Ø 37 mm, 1.0 µm for $PM_{2.5}$ (R2PJ037, PALL, Pall Corporation Filtration & Separations (Thailand) Ltd)
- PVC filter Ø 25 mm, 5.0 µm for PM_{10} (MCE4537100, Sterlitech, Sterlitech Corporation, USA for particulate matter with diameter less than 10 µm)
- Glass Fiber filter paper
- Microbalance with 7 decimals (UMX2, Mettler-Toledo, Mettler- Toledo International Inc, USA)
- Microbalance with 5 decimals (Denver Instrument Company)
- Defender volumetric flow rate calibrator (D-150-L, Casella, JJS Technical Services, USA)
- Desiccator
- DustTrak™ II Aerosol Monitor

3.2.2 $PM_{2.5}$ and PM_{10} measurement

Samples of $PM_{2.5}$ are collected on PTFE filter Ø 37 mm, 1.0 µm for $PM_{2.5}$ and PM_{10} samples are collected on PVC filter Ø 25 mm, 5.0 µm for PM_{10}, both of which are filtered in the Personal Modular Impactor® (PMI) connected to the Personal air pump (SKC, Gillian GilAir5).

The personal air sampler consists of personal pump and PMI Cascade. The sampling pump uses an active sampler, which uses force in sucking air to trap dust with filters through the air inlet at constant flow rate. PMI Cascade is a filter used to collect particles of dust based on the principle of collisions with suspended air particles also known as impaction. The flow of air at high speed when the air collide an obstacle, it will cause the air to divert the direction of movement, but the inertial particles still collide with the obstruction, causing it to accumulate on the surface of the solid.

The sample collection using gravimetric method. The first step is to put the filter into the cassette and put into the desiccator for 24 hours. After that, weighted the filter and record the weight. To collect the sample, put the filter in the dust separator head (Personal Modular Impactor) and connect to the personal air pump. After that, calibrate the air flow rate of the personal air pump to have an air flow rate of 3 liters per minute and record the measured air flow rate before sampling. After the measurement is complete for 8 hours, bring the personal air pump to measure the air flow rate after the sample is collected and put the filter paper in the cassette and put it in the desiccator for 24 hours, then weight the filter. The concentration of $PM_{2.5}$ and PM_{10} is calculated using equations 1 and 2:
Air volume (V) are calculated using;

$$V = Q \times T \times 10^{-3} \qquad (1)$$

For; V = air volume (m^3)
Q = air flow rate (L/min)
T = sampling time (min)

$$C = \frac{W_f - W_i}{V} \times 10^3 \qquad (2)$$

For; C = concentration of paticulate matter (µg/m^3)
W_f = filter weight after sampling (mg)

W_i = filter weight before sampling (mg)

V = air volume (m^3)

3.2.3 PM_1 measurement

DustTrak is a measuring device that uses light scattering principles which allows to instantly read the mass of suspended particles in the air. Is a very common principle in automatic dust collectors, this method does not require filter. This device will operate by sucking the air with the suction pump inside the device. The dusty air moves through the laser beam, when the light hits the dust particles, it will scatter the light into a small angle. The light scattering from the dust of different sizes will have different angles and have the inspection equipment. Light Detector, which measures light and sends scattered light intensity information from particles into the device's processor. When the processor processes the light angle data, the measurement results are shown in concentration. Also, in the case of highly concentrated samples. Light has a chance to scatter with other particles before the light measuring device can detect. This results in the error of particle size separation. This technique can analyze the smallest particles up to 1 nanometer. The dust concentration range that can be measured is between 0.001 to 400 mg/m^3.

3.2.4 Deposit Particulate Matter measurement

Samples of Deposit Particulate Matter are collected on PTFE filter Ø 37 mm, PVC filter Ø 25 mm and Glass Fiber filter, where the filter is placed in the same area as the sampling point. The first step is to put the filter into the cassette and put into the desiccator for 24 hours. After that, weighted the filter and record the weight. To collect the sample, put the filter in the cassette and then place it at the sampling point. After the measurement is complete, put the filter paper in the cassette and put it in the desiccator for 24 hours, then weight the filter.

3.2.5 Data collection

3.2.4.1 $PM_{2.5}$ and PM_{10} samples

Sampling of $PM_{2.5}$ and PM_{10} were collected for 8 hours per day. At mahamakut building, the sample were collected from January 29-31, 2020 and March 1-5, 2020. For the equipment to be installed, it consists of a personal air pump at a calibration of 3 liters per minute of air flow rate and the PMI by installing the personal air pump connected to the PMI and placing it on a tripod at the terrace area, which is approximately 1.5 meters above the ground and about 1 meter away from the nearby pillar.

Figure 3.2 Installation of Personal Air Sampler

3.2.4.2 PM_1 samples

Samples of PM_1 are collected by DustTrak™ II Aerosol Monitor for 8 hours per day for 6 days, from February 24-29, 2020. For installation, the device is placed on a tripod at the terrace area, approximately 1.5 meters above the ground and about 1 meter away from the nearby pillar.

Figure 3.3 Installation of DustTrak

3.2.4.3 Deposit Particulate Matter samples

At Mahamakut building, sampling of deposit particulate matter were collected for 8 hours per day from January 29-31, 2020 and March 1-5, 2020 and collected for 8 hours per day on May 18, 2020. For installation, the filter is placed on a tripod at the terrace area, approximately 1.5 meters above the ground and about 1 meter away from the nearby pillar.

3.2.4.4 Meteorological data

Meteorological data will be measured at the sampling point. The measured data consists of weather conditions such as temperature, humidity and pressure, which are measured at the start of the sample collection and after sampling, then taken to average.

3.3 Data analysis

Data analysis was performed using SPSS (IBM, Inc., New York, USA).

T-test analysis used to test the hypothesis to find the difference in the mean of one sample group that is different from the other or not, in this to find the difference between the concentration of PM_1, $PM_{2.5}$, $PM_{10-2.5}$ and PM_{10} and altitude.

3.4 Study frame work

Data collecting

- Measurement PM_{10} $PM_{2.5}$ and PM_1
- Meteorological data

Sample analysis

Identify PM_{10} $PM_{2.5}$ and PM_1 at different altitudes.

Data analysis

Using T-test analysis in SPSS to find the difference between the concentration of PM_1, $PM_{2.5}$, $PM_{10-2.5}$ and PM_{10} and altitude.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Deposit Particulate Matter

For field survey of the deposit particulate matter in the air environment. PTFE filter, PVC filter and Glass Fiber filter were placed in the same area as the sampling point in order to check the deposit particulate matter, which have found the average very low weight of the deposit particulate matter as shown in Table 4.1. At the sampling site SCI 025, the average weight for PTFE filter at the altitude of 25 and 75 meters is 5.0 ± 2.50 and 5.0 ± 3.41 micrograms per square centimeter, respectively, while the average PVC filter at altitude of 25 and 75 meters is 6.1 ± 2.04 and 5.8 ± 2.26 micrograms per square centimeter respectively and for glass fiber filter, placed 8 hours at the altitude of 25 and 75 meters, with an average weight of 1.2 ± 0.08 and 1.3 ± 1.00 micrograms per square centimeter respectively.

Table 4.1 Collecting deposit particulate matter

Date	Site	Altitude (m)	Paper Sample	Weight (µg) (post-pre)	Deposited particulate matter ($\mu g/cm^2$)	Note
Wed 29 Jan 2020	SCI 025	25	PTFE	13.0	2.4	PVC (area 4.91 cm^2) PTFE (area 5.38 cm^2) Glass Fiber filter (area 128.91 cm^2)
		75		1.4	0.2	
		25	PVC	12.7	2.6	
		75		15.8	3.2	
Thu 30 Jan 2020		25	PTFE	28.9	5.4	
		75		22.4	4.2	
		25	PVC	32.3	6.6	
		75		10.0	2.0	
Fri 31 Jan 2020		25	PTFE	35.7	6.6	
		75		33.4	6.2	
		25	PVC	18.3	3.7	
		75		24.8	5.1	

Date	Site	Altitude (m)	Paper Sample	Weight (µg) (post-pre)	Deposited particulate matter (µg/cm^2)	Note
Sat 29 Feb 2020		25	PTFE	27.4	5.0	PVC (area 4.91 cm^2) PTFE (area 5.38 cm^2) Glass Fiber filter (area 128.91 cm^2)
		75		28.5	5.4	
		25	PVC	33.9	6.9	
		75		33.3	6.8	
Sun 1 Mar 2020		25	PTFE	31.6	5.8	
		75		34.1	6.4	
		25	PVC	28.1	5.7	
		75		31.3	6.4	
Mon 2 Mar 2020		25	PTFE	0.0	0.0	
		75		0.0	0.0	
		25	PVC	42.4	8.6	
		75		35.3	7.2	
Tue 3 Mar 2020		25	PTFE	38.0	7.0	
		75		41.7	7.8	
		25	PVC	35.3	7.2	
		75		31.7	6.5	
Wed 4 Mar 2020		25	PTFE	38.2	7.2	
		75		52.0	9.6	
		25	PVC	38.0	7.7	
		75		44.3	9.0	
Mon 18 May 2020	SCI 025	25	Glass Fiber filter	141.8	1.1	
				167.2	1.3	
				153.8	1.2	
				148.3	1.2	
		75		154.3	1.2	
				176.5	1.4	
				164.5	1.3	
				157.6	1.2	
Avg ± SD	SCI 025	25	PTFE	-	5.0 ± 2.50	
		75		-	5.0 ± 3.41	
		25	PVC	-	6.1 ± 2.04	
		75		-	5.8 ± 2.26	
		25	Glass Fiber filter	-	1.2 ± 0.08	
		75		-	1.3 ± 1.00	

Table 4.2 Laboratory analysis data

Date	site	Altitude (m)	Weight Difference (Pre-Post) (mg)			Avg Flow Rate (Q) (L/min)	Sample Time (min)
			PM2.5	PM10-2.5	PM10		
Thu 23 Jan 2020	Main entrance	1.5	0.0059	0.0122	0.0181	3.0566	240
Wed 29 Jan 2020	SCI 025	25	0.0512	0.0517	0.1029	2.6421	322
			0.0396	0.0418	0.0814	2.9385	209
		75	0.0517	0.0314	0.0831	2.9905	480
			0.0428	0.0266	0.0694	2.9729	348
Thu 30 Jan 2020		25	0.0744	0.042	0.1164	3.009	444
			0.0802	0.0565	0.1367	2.9687	480
		75	0.0317	0.0495	0.0812	2.9649	480
			0.0405	0.0535	0.094	2.9715	480
Fri 31 Jan 2020		25	0.072	0.0409	0.1129	3.2237	480
			0.072	0.0397	0.1117	2.9614	480
		75	0.0895	0.0432	0.1327	2.9779	480
			0.0819	0.0485	0.1304	2.9015	480
Sat 29 Feb 2020		25	0.012	0.0505	0.0625	3.0635	363
			0.0173	0.0525	0.0698	2.9591	480
		75	0.0343	0.0594	0.0937	2.8617	480
			0.0321	0.0515	0.0836	2.9764	480
Sun 1 Mar 2020		25	0.012	0.0193	0.0313	3.0393	209
			0.018	0.0426	0.0606	3.0258	400
		75	0.0426	0.0423	0.0849	2.7458	384
			0.0593	0.0441	0.1034	3.0241	480
Mon 2 Mar 2020		25	0.0077	0.0243	0.032	3.0629	131
			0.0183	0.0488	0.0671	3.0269	319
		75	0.0317	0.0372	0.0689	3.013	384
			0.0451	0.0437	0.0888	2.992	480
Tue 3 Mar 2020		25	0.0296	0.0513	0.0809	2.7333	480
			0.0259	0.0484	0.0743	2.9228	480
		75	0.0352	0.0503	0.0855	2.9177	375
			0.0439	0.0597	0.1036	2.9648	480
Wed 4 Mar 2020		25	0.0493	6.1774	6.2267	3.0677	480
			0.0428	6.1309	6.1737	3.0248	480
		75	0.048	0.0454	0.0934	2.9932	400
			0.0583	0.0569	0.1152	3.0254	480
Thu 5 Mar 2020		25	0.1331	0.0119	0.145	2.9463	480
			0.0415	0.0078	0.0493	2.9996	480
		75	0.0245	0.0203	0.0448	2.9853	372
			0.0275	0.0229	0.0504	3.0115	480

Table 4.3 Concentration of fine particulate matter and altitude.

Date	Site	Altitude (m)	PMs Concentration (μg/m³)						
			PM 2.5	Avg PM2.5	PM 10-2.5	Avg PM10-2.5	PM10	Avg PM10	PM1
Thu 25 Jan 2018	CCP	1.5	44.24	45.00 ± 19.99	24.12	18.43 ± 7.65	68.37	63.47 ± 25.77	-
Sat 27 Jan 2018			14.77		13.12		27.89		-
Tue 30 Jan 2018			15.67		10.46		26.13		-
Thu 1 Feb 2018			43.78		8.42		52.51		-
Sat 3 Feb 2018			55.23		19.10		74.33		-
Tue 6 Feb 2018			59.99		16.40		76.39		-
Thu 15 Feb 2018			67.17		28.12		95.30		-
Sat 17 Feb 2018			59.11		27.73		86.84		-
Thu 23 Jan 2020	Main entrance	1.5	14.45	16.18 ± 2.22	8.86	8.04 ± 0.72	23.31	24.22 ± 1.70	-
			15.4		7.77		23.17		
			18.68		7.5		26.18		
Wed 29 Jan 2020		25	60.18	62.33 ± 3.04	60.77	64.42 ± 5.16	120.95	126.75 ± 8.2	-
			64.48		68.07		132.55		
		75	36.02	38.7 ± 3.78	21.88	23.8 ± 2.71	57.9	62.49 ± 6.49	-
			41.37		25.71		67.08		
Thu 30 Jan 2020		25	55.69	55.99 ± 0.42	31.44	35.55 ± 5.81	87.13	91.53 ± 6.22	-
			56.28		39.65		95.93		
		75	22.27	25.24 ± 4.33	34.78	36.15 ± 1.93	57.05	61.48 ± 6.26	-
			28.4		37.51		65.91		
Fri 31 Jan 2020		25	46.53	48.59 ± 2.91	26.43	27.18 ± 1.06	72.96	75.77 ± 3.97	-
			50.65		27.93		78.58		
		75	62.61	60.71 ± 2.69	30.22	32.52 ± 3.25	92.83	93.23 ± 0.57	-
			58.81		34.82		93.63		
Mon 24 Feb 2020		25		-		-		-	67
Tue 25 Feb 2020		75		-		-		-	100
Wed 26 Feb 2020		25		-		-		-	62
Thu 27 Feb 2020		75		-		-		-	62
Fri 28 Feb 2020		25		-		-		-	50

Date	Site	Altitude (m)	PMs Concentration (µg/m^3)						
			PM 2.5	Avg PM2.5	PM 10-2.5	Avg PM10-2.5	PM10	Avg PM10	PM1
Sat 29 Feb 2020		25	10.79	11.49	45.41	41.19	56.2	52.67	-
			12.18	± 0.98	36.96	± 5.98	49.14	± 4.99	
		75	24.97	29.46	39.97	38.01	64.94	61.73	37
			22.47	± 6.35	36.05	± 2.77	58.52	± 4.54	
Sun 1 Mar 2020		25	18.89	16.88	30.38	32.79	49.27	49.67	-
			14.87	±2.84	35.2	± 3.41	50.07	± 0.57	
		75	40.4	40.63	40.12	35.25	80.52	76.03	-
			40.85	± 0.32	30.38	± 6.89	71.23	± 6.36	
Mon 2 Mar 2020		25	19.19	19.07	60.57	55.55	79.76	74.63	-
			18.95	± 0.17	50.54	± 7.09	69.49	± 7.26	
		75	27.4	29.4	32.15	31.29	59.55	60.69	-
			31.4	±2.83	30.43	± 1.22	61.83	± 1.61	
Tue 3 Mar 2020		25	22.56	20.51	39.1	36.8 ±	61.66	57.31	-
			18.46	± 2.9	34.5	3.25	52.96	± 6.15	
		75	32.17	31.51	45.97	42.96	78.14	75.47	-
			30.85	± 0.93	41.95	± 2.84	72.8	± 3.78	
Wed 4 Mar 2020		25	33.48	31.48	37.22	40.34	70.7	71.82	-
			29.48	± 2.83	43.46	± 4.41	72.94	± 1.58	
		75	40.09	40.12	37.92	38.55	78.01	78.67	-
			40.15	± 0.04	39.18	± 0.89	79.33	± 0.93	
Thu 5 Mar 2020		25	23.41	26.12	8.41	6.92 ±	31.82	33.03	-
			28.82	± 3.83	5.42	2.11	34.24	± 1.71	
		75	22.06	20.54	18.28	17.06	40.34	37.6 ±	-
			19.02	± 2.15	15.84	± 1.73	34.86	3.87	

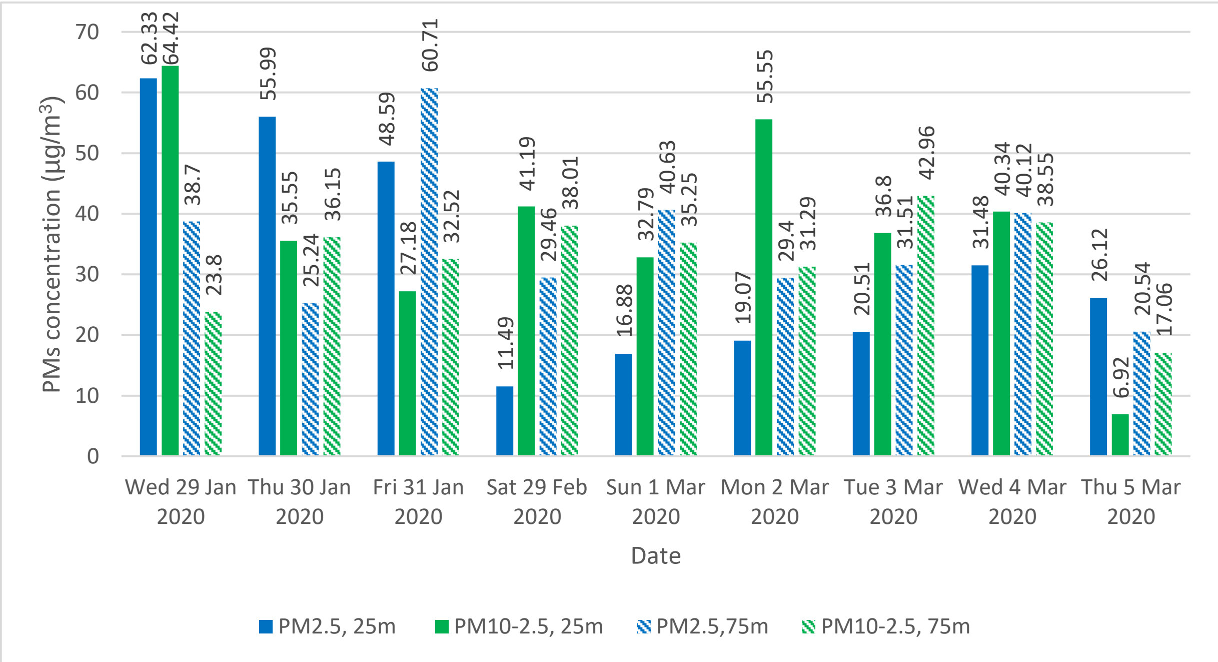

Figure 4.1 Sampling date and particulate matter concentration

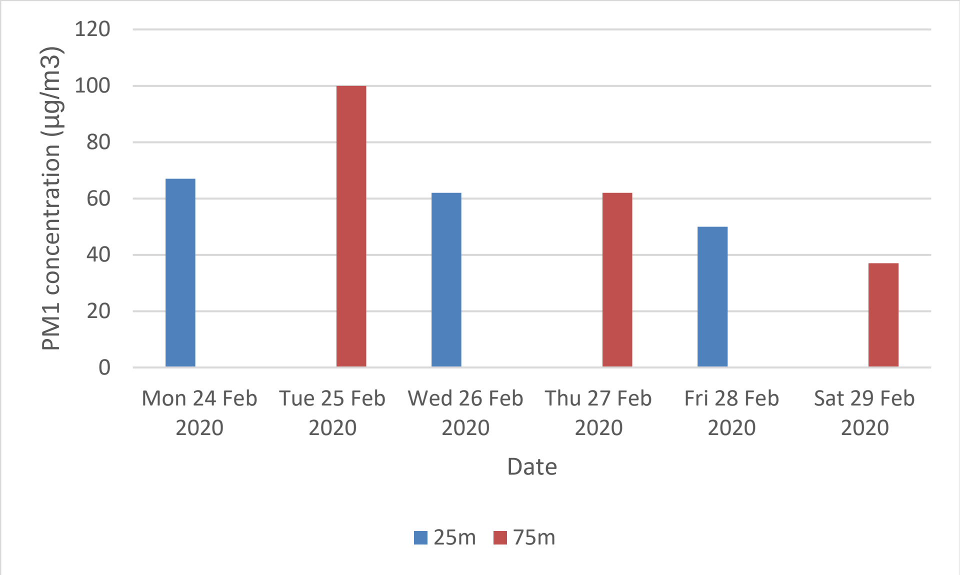

Figure 4.2 PM_1 concentration

4.2 Fine particulate matter concentration

The concentration of fine particulate matter is measured in two sampling site: Mahamakut Building and data from other areas are referenced: Chulalongkorn university Centenary park and main entrance of Chulalongkorn university. Blank filters were check weight before and after sampling with weight different 0.0037 mg on PVC fiter and -0.0107 mg on PTFE filter. From Table 4.3, it can be seen that Mahamakut Building, the average concentration of PM_1, $PM_{2.5}$ and PM_{10} is in the range 37-100, 6.92-64.42 and 33.03-126.75 µg/m^3 respectively. At the altitude of 25 meters, the minimum average concentrations of $PM_{2.5}$ and PM_{10} are 6.92 ± 2.11 and 33.03 ± 1.71 respectively, and the highest average $PM_{2.5}$ and PM_{10} concentrations are 64.42 ± 5.16 and 126.75 ± 8.21 respectively. At an altitude of 75 meters, the average concentrations of the lowest $PM_{2.5}$ and PM_{10} were 17.06 ± 1.73 and 37.6 ± 3.87 respectively, and the highest average concentration of $PM_{2.5}$ and PM_{10} was 42.96 ± 2.84 and 93.23 ± 0.57 respectively. The lowest concentration of fine particulate matter is the last day of the university examination, which may result in a decrease in the number of students, therefore the concentration of fine particulate matter is also reduced. From measuring the fine particulate matter concentration at the main entrance of Chulalongkorn university, showed that the average concentration of $PM_{2.5}$ and PM_{10} at the main entrance of Chulalongkorn university is 16.18 ± 2.22 and 24.22 ± 1.70 µg/m^3 respectively. The concentrations of $PM_{2.5}$ and PM_{10} at the Chulalongkorn university Centenary Park (reference site) are in the range 14.77- 67.17 and

26.13 - 95.30 µg/m^3, compared to the values obtained from the measurements from January in 2020 at the Mahamakut Building, which has a concentration of $PM_{2.5}$ in the range of 22.27- 64.48, which found that the concentration of $PM_{2.5}$ in the Chulalongkorn university Centenary Park is greater than the Mahamakut Building because Chulalongkorn university Centenary Park is located on the roadside where the traffic is quite dense, resulting in the $PM_{2.5}$ concentration greater than the Mahamakut Building. In addition, the concentration of fine particulate matter at each sampling point may vary depending on atmospheric conditions such as temperature, pressure, humidity and wind direction.

From figure 4.1, found that the concentration of $PM_{2.5}$ and $PM_{10-2.5}$ between January 29-31 2020 is higher than the period from 29 February - 5 March 2020, because it is a period of high air pollution in the winter, the air is not well circulated. In addition, it was found that on 2-5 March 2020, the concentration of $PM_{2.5}$ and $PM_{10-2.5}$ tends to decrease as it is the exam week. On March 2, 2020 is the first exam day, therefore the high concentration because many students come to take the exam then the value gradually decreases.

From figure 4.2, it was found that the concentrations of PM_1 on Monday to Friday were in the range of 50 – 100 µg/m^3 at all altitudes, but on weekend it was found that concentrations were lower than on weekday, thus showing that human activities have an effect on the concentration of PM_1.

Table 4.4 Meteorological parameters during measurements

Date	Altitude (m)	Temperature	Humidity	Pressure
Mon 24 Feb 2020	25	30.25	54.5	754
Tue 25 Feb 2020	75	30	62	749.75
Wed 26 Feb 2020	25	30.25	66	753
Thu 27 Feb 2020	75	30.25	69	748.25
Fri 28 Feb 2020	25	29	70.25	751.75
Sat 29 Feb 2020	25	30.25	70	750.25
	75	31.25	68.5	749.25
Sun 1 Mar 2020	25	32	71.5	751.5
	75	32	71	747.75
Mon 2 Mar 2020	25	31.5	69.25	749
	75	31.75	68.5	749.5
Tue 3 Mar 2020	25	31.25	69	749.75
	75	31.5	68.5	749.25
Wed 4 Mar 2020	25	30.75	68.5	749.5
	75	31.5	68	747.5
Thu 5 Mar 2020	25	31.75	67	750.25
	75	31.5	68.25	750.75

4.3 Correlation between PM_1 $PM_{2.5}$ $PM_{10-2.5}$ and PM_{10} and altitude

From the statistical analysis using t-test, it was found that the difference between the concentrations of PM_1, $PM_{2.5}$, $PM_{10-2.5}$ and PM_{10} and altitude were p-value of 0.854, 0.721, 0.421 and 0.788 respectively, which showed that PM_1, $PM_{2.5}$, $PM_{10-2.5}$ and PM_{10} concentration and altitude were not significantly different.

4.4 Compare with other study

Table 4.5 Comparison of average PM_1, $PM_{2.5}$ and PM_{10} from measurement with reference

Reference	Obs. Altitude (m)	Obs. season	PM_{10}	$PM_{2.5}$	PM_1
	454	Spring	34.8	30.9	28.3
		Summer	28.0	20.5	16.8
		Autumn	32.6	27.8	25.1
		Winter	38.3	33.9	31.6
		Annual mean	35.7	30.4	27.5
	121	Spring	49.5	42.3	37.9
		Summer	23.4	19.2	16.8
		Autumn	51.0	41.3	36.9
		Winter	55.6	48.9	45.9
		Annual mean	44.1	38.2	34.9
This study	25	Winter	98.02	42.38	-
	75		72.4	30.82	-
	25	Summer	56.5	35.6	-
	75		65.0	33.9	-

The concentrations of PM_1, $PM_{2.5}$ and PM_{10} were compared to previous studies conducted by measuring the concentrations of PM_1, $PM_{2.5}$ and PM_{10} at the Canton Tower in Guangzhou, China. The concentrations of $PM_{2.5}$ and PM_{10} at high altitudes are less than those at low altitudes. In contrast, during the hot season, the concentrations of $PM_{2.5}$ and PM_{10} at high altitudes are greater than those at low altitudes, but $PM_{2.5}$ concentrations at both altitudes are very similar. In this experiment, the results were the same as previous studies.

CHAPTER V

CONCLUSIONS

The concentration of fine particulate matter were measured from Mahamakut building found that the concentrations of PM_1 $PM_{2.5}$ and PM_{10} at different altitudes were not significantly different, from the experiment, PM_1 $PM_{2.5}$ and PM_{10} concentrations may not only depend on altitude, but may also depend on many factors such as wind direction, structure of the building, the environment around the sampling point and human activities.

At Mahamakut Building, fine particulate matter measurements were conducted between 29-31 January 2020 at an altitude of 25 meters showed that the highest average concentration of $PM_{2.5}$ and PM_{10} was 62.33 ± 3.04 and 126.75 ± 8.2, respectively. At altitude 75 meters showed that the highest average concentration of $PM_{2.5}$ and PM_{10} were 60.71 ± 2.96 and 93.23 ± 0.57 respectively. And during the period from 29 February to 5 March 2020 at the altitude of 25 meters, the maximum average concentration of $PM_{2.5}$ and PM_{10} was 31.48 ± 2.83 and 74.63 ± 7.62 respectively, while at the altitude of 75 meters, the highest average concentration of $PM_{2.5}$ and PM_{10} were 40.63 ± 0.32 and 78.67 ± 0.93 respectively.

The occurrence of COVID-19 pandemic cannot perform the experimental due to the Bangkok lockdown from March 18, 2020 to May 31, 2020. Additional recommendations for this study should increase the number of samples collected and continuously collected to provide enough data for analysis, resulting in more accurate and reliable results. If there is enough data, data can also be analyzed to find relationships to clearly distinguish and sampling points should be specified with a different altitude to allow for different results.

REFERENCES

Air Pollution Control District. Particulate Matter (PM) Sources. [Online]. Available from : http://www.valleyair.org/air_quality_plans/AQ_plans_PM_sources.htm [1 February 2020]

Choomanee, P., et al. Vertical Variation of Carbonaceous Aerosols within the $PM_{2.5}$ Fraction in Bangkok, Thailand. Aerosol and Air Quality Research. (2020)

Chulalongkorn University. CU Centenary Park – CU100. [Online].2017. Available online at: http://www.cu100.chula.ac.th/cu-centenary-park/ [15 March 2020]

GreenFacts. Air Pollution Particulate Matter. [Online]. 2020. Available from : https://www.greenfacts.org/en/particulate-matter-pm/level-3/01-presentation.htm#0p0 [1 February 2020]

Hong W., et al. Vertical characteristics of PM2.5 during the heating season in Tianjin, China**.** Science of the Total Environment**.** 523 (2015) 152–160.

Li, Lei., et al. Tower observed vertical distribution of PM2.5, O3 and NOx in the Pearl River Delta. Atmospheric Environment. (2020)

Panjamaporn Suwannapun, "PM_{10} $PM_{2.5}$ and PAHs exposures and health risk in urban parks of Bangkok," (Degree of Master of Science in Hazardous Substance and Environment Management, Graduate School, Chulalongkorn University, 2018)

Quang, T. N., et al. Vertical particle concentration profiles around urban office buildings. Atmospheric Chemistry and Physics. (2012)

Shengzhen Z., et al. Vertical distribution of atmospheric particulate matters within urban boundary layer in southern China: size-segregated chemical composition and secondary formation through cloud processing and heterogeneous reactions. Atmospheric Chemistry and Physics Discussions.

TSI. DUSTTRAK II AEROSOL MONITOR 8530. [Online]. Available from : https://tsi.com/products/aerosol-and-dust-monitors/dust-monitors/dusttrak-ii-aerosol-monitor-8530/ [1 February 2020]

USEPA. Particulate Matter (PM) Pollution. [Online]. 2018. Available from : https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM [1 February 2020]

WHO. Ambient (outdoor) air pollution. [Online]. 2018. Available from : https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health [1 February 2020]

Xuejiao D., et al. Vertical distribution characteristics of PM in the surface layer of Guangzhou. Particuology. 20 (2015) 3–9.

Zhang, Kun., et al. Source and vertical distribution of $PM_{2.5}$ over Shanghai during the winter of 2017. Science of the Total Environment. (2020)

ศูนย์ข้อมูลกรุงเทพมหานคร. กรุงเทพฯ ปัจจุบัน. [Online]. 2013. Available online at: http://www.bangkok.go.th/info/ [15 March 2020]

APPENDICES

1. T-test of PM_1 concentration and altitude.

Group Statistics

	Altitude	N	Mean	Std. Deviation	Std. Error Mean
PMone	25	4	44.7500	30.67436	15.33718
	75	4	49.7500	42.08226	21.04113

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PMone	Equal variances assumed	.424	.539	-.192	6	.854	-5.00000	26.03763	-68.71179	58.71179
	Equal variances not assumed			-.192	5.486	.855	-5.00000	26.03763	-70.18688	60.18688

2. T-test of $PM_{2.5}$ concentration and altitude.

Group Statistics

	Altitude	N	Mean	Std. Deviation	Std. Error Mean
PMtwofive	25	9	32.4856	18.53223	6.17741
	75	9	35.1456	11.78450	3.92817

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PMtwofive	Equal variances assumed	3.080	.098	-.363	16	.721	-2.66000	7.32058	-18.17894	12.85894
	Equal variances not assumed			-.363	13.561	.722	-2.66000	7.32058	-18.40895	13.08895

3. T-test of $PM_{10-2.5}$ concentration and altitude.

Group Statistics

	Altitude	N	Mean	Std. Deviation	Std. Error Mean
PMtentotwofive	25	9	37.8600	16.35206	5.45069
	75	9	32.8433	7.99802	2.66601

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PMtentotwofive	Equal variances assumed	1.590	.225	.827	16	.421	5.01667	6.06775	-7.84639	17.87972
	Equal variances not assumed			.827	11.621	.425	5.01667	6.06775	-8.25187	18.28520

4. T-test of PM_{10} concentration and altitude.

Group Statistics

	Altitude	N	Mean	Std. Deviation	Std. Error Mean
PMten	25	9	70.3533	27.34611	9.11537
	75	9	67.4878	15.64489	5.21496

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PMten	Equal variances assumed	1.396	.255	.273	16	.788	2.86556	10.50171	-19.39707	25.12818
	Equal variances not assumed			.273	12.730	.789	2.86556	10.50171	-19.87098	25.60209

Inlet Cap

When using the DustTrak monitor to sample environmental air, the inlet cap should be put over the instrument. This cap will keep large objects from dropping into and plugging the inlet. The cap will also keep direct light from shinning into the chamber and skewing the results.

The inlet cap can simply be pressed onto the instruments inlet.

Figure 2-6: Putting on Inlet Cap

Size-Selective Impactors

Size-selective impactors can be attached to the inlet of the DustTrak II instruments. Size-selective impactors can be used to pre-condition the size range of the particles entering the instrument. PM_1, $PM_{2.5}$, PM_4 (Respirable) and PM_{10} impactors are available. **The instrument must run at the factory default setting of 3.0 L/min for the impactors to achieve the correct cut points.**

The size-selective impactor is composed of three parts; the cap, impaction plate and bottom. Selection of the cap will determine cut size of the impactor. Each cap is labeled with the particle cut size (1 μm, 2.5 μm, 4.0 μm or 10 μm). The same impaction plate and bottom are used on all impactor sizes.

The impactor assembly is attached to the instrument in place of the inlet cap. The inlet cap does not need to be used if an impactor is being used. See Chapter 4, "Maintenance," for instructions on how to add oil to the impaction plate.

Figure 2-7: Size-Selective Impactor

Dorr-Oliver Cyclone

A Dorr-Oliver cyclone is shipped with the instrument. The Dorr-Oliver cyclone removes particles over 4.0 µm in size. The Dorr-Oliver cyclone is attached to the instrument by sliding the cyclone clip over the protruding catch. The tube from the Dorr-Oliver cyclone needs to be routed to the inlet of the instrument.

Figure 2-8: Installing Door-Oliver Cyclone

Do not use Inlet attachments (impactors or inlet cap) when using the Dorr-Oliver Cyclone. **The instrument flow rate must be changed to 1.7 L/min when using the Dorr-Oliver Cyclone in order to achieve a 4 µm (respirable) cut-point.** See the Flow Cal instructions in the Operations chapter for instructions on how to change the instruments flow rate.

Instrument Setup

The DustTrak II monitor can be connected to a computer to download data and upload sampling programs.

Connecting to the Computer

Connect the USB host port of a Microsoft Windows®-based computer to the USB device port on the side of the DustTrak monitor.

Installing TrakPro™ Data Analysis Software

TrakPro software can preprogram the DustTrak monitor, download data, view and create raw data and statistical reports, create graphs, and combine graphs with data from other TSI instruments that use TrakPro software. The following sections describe how to install the software and set up the computer.

NOTE
To use TrakPro software with the DustTrak Aerosol Monitor, the PC must be running Microsoft Windows® and the computer must have an available Universal Serial Bus (USB) port.

®Windows is a registered trademark of Microsoft Corporation.
®Microsoft and Windows are registered trademarks of Microsoft Corporation.

BIOGRAPHY

Name : Hathairat Kittipalarak

Date of birth: 8 December 1997

Place of birth: Chachoengsao

E-mail: Hathairat.kit@hotmail.com

Graduation: Bachelor of Environment Science, Chulalongkorn University 2019