AN INVESTIGATION OF DUST EMISSION USING CHEMICAL COMPOSITION ANALYSIS METHOD

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AN INVESTIGATION OF DUST EMISSION USING CHEMICAL COMPOSITION ANALYSIS METHOD

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ABSTRACT

This study is an investigation of dust emission sources, especially fine particulate matter, at Na-Phra-Lan, Chalermphrakiat district, Saraburi province, Thailand, by using the chemical composition analysis method. This is the technique to determine the major source contributors in atmosphere. The fraction of chemical species contained in an emission from each source type shows source profile and their concentrations which can be used to calculate the relative contribution from different sources to ambient particulate matter levels by using the chemical mass balancing technique called CMB model.

The gravimetric and chemical composition of fine particulate matter, especially PM_{10} emitters, were analyzed to determine the PM_{10} source profiles while the samples of fine particulate matter of atmospheric aerosol of Khung-Khow-Khew, Na-Phra-Lan and Ban Nhong-Jan at Chalermphrakiat district, were collected and analyzed to determine the chemical composition, from June, 2005 to March, 2006. Samples were collected on Teflon and Quartz fiber filters then analyzed for elemental composition, water soluble ions and carbon species by using X-ray fluorescence, ion chromatography and organic elemental analysis, respectively.

The results of this study showed the significant sources of contribution at Na-Phra-Lan, Chalermphrakiat district, dramatically expressed by white cement plants, quarry and crushing plants, Portland cement plants, biomass burning, diesel vehicles and motorcycles at 71.87, 13.62, 9.72, 1.84, 1.22 and 0.15 percent, respectively. Unknown sources was 1.58 percent.

The dominant chemical composition found in Na-Phra-Lan, Chalermphrakiat district, Saraburi province, was Ca, S, Si, Fe, SO_4^+ and Ca^{2+} at 25.11, 13.68, 9.61, 5.82, 5.78 and 4.01 percent respectively. The cement groups found Ca, Si ,S and Fe as major chemical components at 58.03, 18.6, 13.50 and 3.61 percent, respectively. It can be concluded that cement groups were the major source contributors in the study area.

KEY WORDS: CHEMICAL MASS BALANCE MODEL/ PM_{10} / EMISSION CONTRIBUTOR / EMISSION INVESTIGATION / DUST EMISSION

91 pp.

การสืบค้นแหล่งกำเนิดของฝุ่นโดยวิธีการวิเคราะห์องค์ประกอบ
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บทคัดย่อ

การสืบค้นแหล่งที่มาของฝุ่นละออง โดยเฉพาะฝุ่นละอองขนาดเล็กในพื้นที่หน้าพระลาน อำเภอเฉลิมพระเกียรติ จังหวัดสระบุรี โดยวิธีการวิเคราะห์องค์ประกอบทางเคมี ในการวิเคราะห์หาแหล่งกำเนิดหลักที่เป็นที่มาของฝุ่นละอองที่พบในบรรยากาศ โดยสัดส่วนขององค์ประกอบทางเคมีที่ได้จากแหล่งกำเนิดฝุ่นละอองใน แต่ละประเภทจะมีลักษณะแตกต่างกันและเป็นตัวแทนโครงสร้างลักษณะองค์ประกอบทางเคมีของแหล่งกำเนิดนั้น ซึ่งเป็นข้อมูลพื้นฐานในการคำนวณหาความสัมพันธ์การกระจายตัวของฝุ่นละอองจากแหล่งกำเนิดประเภทต่างๆสู่บรรยากาศเพื่อหาแหล่งกำเนิดฝุ่นละอองหลักในพื้นที่ศึกษาโดยใช้แบบจำลองสมดุลมวลทางเคมี

น้ำหนักฝุ่นและองค์ประกอบทางเคมีของฝุ่นละอองขนาดเล็กจากแหล่งกำเนิดฝุ่นโดยเฉพาะ PM_{10} ได้นำมาวิเคราะห์เพื่อจัดทำโครงสร้างลักษณะองค์ประกอบทางเคมีของแหล่งกำเนิดในแต่ละประเภท รวมทั้งการเก็บตัวอย่างและวิเคราะห์องค์ประกอบทางเคมีของฝุ่นละอองขนาดเล็กในบรรยากาศของพื้นที่คุ้งเขาเขียว, หน้าพระลาน และบ้านหนองจาน ของอำเภอเฉลิมพระเกียรติ ระหว่างเดือนมิถุนายน 2548 ถึงเดือนมีนาคม 2549 โดยใช้กระดาษกรองชนิด Teflon และ Quartz ในการเก็บตัวอย่างฝุ่นละอองและวิเคราะห์องค์ประกอบทางเคมี ได้แก่ ธาตุองค์ประกอบ, ไอออนละลายน้ำ และคาร์บอน โดยใช้เครื่องมือวิเคราะห์ตามลำดับดังนี้คือ X-ray fluorescence, ion chromatography และ organic elemental analysis

ผลการศึกษาพบว่า แหล่งกำเนิดฝุ่นละอองขนาดเล็กที่มีนัยสำคัญสำหรับพื้นที่หน้าพระลาน อำเภอเฉลิมพระเกียรติ ได้แก่ อุตสาหกรรมปูนขาว, โรงโม่ บด และย่อยหิน, อุตสาหกรรมปูนเทา, การเผาวัชพืช, เครื่องยนต์ดีเซล และรถมอเตอร์ไซด์ ในสัดส่วน 71.87, 13.62, 9.72, 1.84, 1.22 และ 0.15 % ตามลำดับ ทั้งนี้ไม่สามารถระบุแหล่งกำเนิดฝุ่นละอองขนาดเล็กที่มีผลต่อพื้นที่ศึกษาได้ 1.58%

โดยสรุป องค์ประกอบทางเคมีหลักที่พบในพื้นที่หน้าพระลาน อำเภอเฉลิมพระเกียรติ จังหวัดสระบุรี ได้แก่ Ca, S, Si, Fe, SO_4^+ และ Ca^{2+} ในสัดส่วน 25.11, 13.68, 9.61, 5.82, 5.78 และ 4.01% ตามลำดับ ซึ่งสอดคล้องกับผลการวิเคราะห์องค์ประกอบทางเคมีของกลุ่มอุตสาหกรรมปูน พบ Ca, Si, S และ Fe เป็นองค์ประกอบหลักทางเคมีในสัดส่วน 58.03, 18.60, 13.50 และ 3.61 % ตามลำดับ ซึ่งอุตสาหกรรมปูนจัดเป็นแหล่งกำเนิดหลักของฝุ่นละอองขนาดเล็กในพื้นที่ศึกษา

91 หน้า

CONTENTS

Page

ACKNOWLEDGEMENTS iii

ABSTRACT iv

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER I **INTRODUCTION**

Background and rationale 1

Research objectives 2

Scope of this study 2

Variables 3

Definitions 3

Expected outcomes and benefits 3

Conceptual framework 4

CHAPTER II **LITERATURE REVIEW**

Air pollution 5

Type of pollutant 5

Receptor model 7

Literature site 10

CHAPTER III **MATERIALS AND METHODS**

Methods 15

Materials 16

Data collection and measurement 16

Fine particulate matter (PM_{10}) collection 16

Chemical composition analysis of PM_{10} 23

Chemical mass balance (CMB) 27

Performance indicators for acceptance of results 28

CONTENTS (continued)

Page

CHAPTER IV RESULTS

The PM_{10} concentration at receptor sites 30

The characteristic and chemical composition of PM_{10} At receptor sites 33

The industrial inventory at Na-Phra-Lan, Chalermphrakiat district 38

The characteristic and chemical composition of PM_{10} of emission sources 40

The chemical characteristics comparison between sources and receptors 47

Source contribution of PM_{10} at Na-Phra-Lan, Chalermphrakiat district 51

CHAPTER V DISCUSSION

Discussion 58

CHAPTER VI CONCLUSIONS

Conclusion of this study 60

Recommendation from this study 61

REFFERENCES 63

APPENDIX 67

BIOGRAPHY 91

LIST OF TABLES

Table **Page**

2-1 Marker elements from various sources. (Hopke,P.K 1995, Garivait 1999 and Koistinen 2002) 8
3-1 PM_{10} source sampling 23
3-2 Analysis methods for chemical composition 23
4-1 The 24-hours PM_{10} concentration at Na-Phra-Lan, Chalermphrakiat district 33
4-2 Total samples for chemical composition analysis in this study 34
4-3 Summary of concentration of chemical composition at receptor sites (%) 37
4-4 Summary of industrial inventory at Na-Phra-Lan, Chalermphrakiat District 38
4-5 Summary of PM_{10} emission rate of stationary sources at Na-Phra-Lan, Chalermphrakiat District 38
4-6 Summary of traffics volume at Na-Phra-Lan, Chalermphrakiat District 39
4-7 Summary of PM_{10} emission inventory at Na-Phra-Lan, Chalermphrakiat district 40
4-8 The chemical composition of source profiles 41
4-9 Summary of major components of emission sources at Na-Phra-Lan, Chalermphrakiat district 46
4-10 Summary of dominant chemical composition at receptor sites (%) 48
4-11 Emission source contributors of PM_{10} at receptor sites 49
4-12 Total samples which run by CMB model 51
4-13 Percents of emission source contribution at Khung-Khow-Khew 52
4-14 Percents of emission source contribution at Na-Phra-Lan 52
4-15 Percents of emission source contribution at Ban Nhong-Jan 52
4-16 Percent of emission sources contribution to receptor sources 53
4-17 Summary of percent of emission sources contribution to Na-Phra-Lan, Chalermphrakiat district, Saraburi province 55
4-18 Comparison between emission inventory and CMB technique at Na-Phra-Lan, Chalermphrakiat district 57

LIST OF FIGURES

Figure **Page**

3-1 Ambient sampling locations at Na-Phra-Lan, Chalermprakiat district 17
3-2 The Khung-Khow-Khew sampling site 18
3-3 The Na-Phra-Lan sampling site 18
3-4 The Ban Nhong-Jan sampling site 19
3-5 The PM_{10} sampler (Air Metrics Mini Volume Portable Air Sampler) 20
3-6 Sample preparation for ionic analysis 25
3-7 Anions analysis condition 26
3-8 Cations analysis condition 26
3-9 The CMB equation 28
4-1 Locations of receptor sites and stationary sources 30
4-2 Trend of 24-hours PM_{10} concentration at Khung-Khow-Khew site 31
4-3 Trend of 24-hours PM_{10} concentration at Ban Nhong-Jan site 32
4-4 Trend of 24-hours PM_{10} concentration at Na-Phra-lan site 32
4-5 Chemical composition of PM_{10} at Khung-Khow-Khew site 35
4-6 Chemical composition of PM_{10} at Na-Phra-Lan site 35
4-7 Chemical composition of PM_{10} at Ban Nhong-Jan site 36
4-8 Chemical composition of Portland cement 43
4-9 Chemical composition of white cement 43
4-10 Chemical composition of quarry and crushing 44
4-11 Chemical composition of biomass burning 44
4-12 Chemical composition of diesel engine 45
4-13 Chemical composition of gasoline engine 45
4-14 Chemical composition of motorcycle 45

LIST OF FIGURES (continued)

Figure **Page**

4-15 Source locations-receptor locations-wind direction (dry-wet season) 50

4-16 Summary of emission sources contribution at receptor sites 54

4-17 Sources contribution at Na-Phra-Lan, Chaleamphrakiat district 56

CHAPTER I

INTRODUCTION

1. Background and rationale

Na-Phra-Lan, Chalermphrakiat District, Saraburi Province, has been experienced high level of air pollution, especially particulate matter less than 10 micrometer (PM_{10}) which has severe effects on public health for many decades. According to the several epidemiological evidence, fine particulate exposure causes serious detriment to human health. The investigation of fine particulate matter sources is useful to reduce air pollution especially PM_{10} which cause harm to human health.(1) ,(2), (3) ,(4) ,(5) ,(6). The activities of Quarry and rock-crushing in Na-Phra-Lan , Chalermphrakiat district area are believed to be the emission sources of PM10. Although there have had several attempts to solve this problem, but it was not success. Presently, PM_{10} level still exceed the average value of 24 hours standard (120 $\mu g/m^3$) for 124 times from 355 times of the monitoring reported by Pollution Control Department in 2004.(7) Possibly, PM_{10} might not only came from the quarries and crushing plants but also came from other sources such as cement plants, fuel combustion in motor vehicle, paved road and unpaved road dust and open-burning in cultivated areas which should be concerned as well. To determine which source types are the major contribution of ambient pollution in the receptor locations, source apportionment model is a technique to identify this situation in many countries. (8), (9)

The source apportionment is a tool to apportion the primary sources contribute particulate matter in atmosphere by using the organic molecular markers. These organic compounds collaborate with molecular composition of primary particulate emissions. The fraction of chemical species contained in an emission from each source type is source profile and their concentrations which can be used to calculate the relative contribution from different sources to ambient particulate matter levels by using the chemical mass balancing technique called CMB model. (10), (11), (12) The CMB Model can determine the source of the major contribution of the ambient pollution at the receptor to formulate air quality improvement program, which consider the possible emission control strategies of the air quality in Na-Phra-Lan, Chalermphrakiat district.

2. Research objectives

The main objective of this study is to investigate dust emission sources in Naphralan, Chalermphrakiat District, Saraburi Province. The specific objectives of this study are:

2.1 To identify the PM_{10} sources in Naphralan, Chalermphrakiat District, Saraburi Province by using the chemical composition analysis method.

2.2 To identify the composition of PM_{10} in Naphralan, Chalermphrakiat District, Saraburi Province.

2.3 To identify sources which had been underestimated in emission inventories prepared to formulate air quality improvement program.

3. Scope of this study

The scope of this study is to investigate dust emission source by collecting the fine particulate matter (PM_{10}) from particulate sources and ambient particulate in Na-Phra-Lan, Chalermphrakiat District, Saraburi Province. At least 30 samples of ambient fine particles at the receptor sites were collected and analyzed for mass concentration and chemical composition from June 2005 to March 2006. The filter samples were analyzed for elemental concentration by Wavelength Dispersive X-Ray Fluorescence (S4 Explorer Model) , carbon analysis by Organic Elemental Analysis (FlashEA^{TM} 1112 Model), NCHS method and ions analysis by Ion Chromatography (Shim-Pack IC-A3), respectively. The source collection data obtained from Pollution Control Department and literature reviews. The data sets were then analyzed by chemical mass balance model (CMB) to identify the possible sources of dust emission determined to be important contributors to ambient fine particle levels in Na-Phra-Lan, Chalermphrakiat District, Saraburi Province.

4. Variables

4.1 Independent variable: Sources of fine particulate matter (PM_{10}) in Na-Phra-Lan, Chalermphrakiat District, Saraburi Province.

4.2 Dependent variable: The chemical composition of fine particulate matter at the receptor locations.

5. Definitions

5.1 Fine particulate matter (PM_{10}) is defined as particles with an aerodynamic diameter of less than 10 micrometer.

5.2 Chemical Mass Balance (CMB) is defined as tool which uses chemical composition of particles measured at source and receptor to both define the emission source profiles, and also evaluate their contribution to a specific receptor.

5.3 Receptor location is defined as any points or areas which affect to the emission dispersion from any sources.

5.4 Source apportionment is defined as a tool which can be used to estimate source contributions to ambient air pollution levels.

5.5 Source profile is defined as profiles of the chemical and molecular composition of emission from fine particle sources.

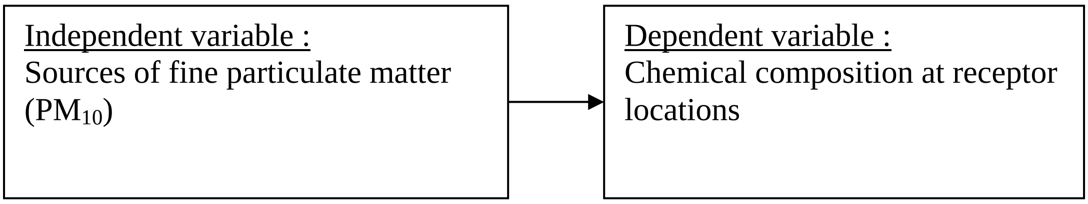
6. Expected outcomes and benefits

6.1 The chemical composition of fine particulate matter (PM_{10}) in the ambient atmospheric at Na-Phra-Lan, Chalermphrakiat District, Saraburi Province will be explored.

6.2 The source of the major contribution of the ambient pollution to the receptors and their apportionment will be determined.

6.3 The study result will provide the useful information which can be used to focus attention on improving emission inventories for sources determination to be important contributors to ambient particle levels and considered how possible emission control strategies might affect air quality.

7. Conceptual framework



CHAPTER II

LITERATURE REVIEW

1. Air Pollution (35), (36)

Air pollution: Any substance in the air comes from many different sources such as factories, vehicles, wildfires that can cause harm to humans or the environment and reducing visibility.

Air pollution : The presence in air of dust, fumes, mist, smoke, particulate matter, vapours, gases, odours, odorous substances, acids, soot, grime or any combination of them which excess of the maximum permissible concentration or level standard, as prescribed by the regulations.

2. Type of Pollutants

2.1 Particulate matter (9), (13), (14), (15), (16), (17), (18), (19)

Particulate matter (PM), is known as particle pollution, is the term for particles found in the air and can be suspended in the air for long periods of time. PM is a complex mixture of extremely small solids such as dust, fly ash, soot, smoke (particles are large and dark enough to be seen as soot or smoke) and liquid droplets such as fumes, mists, condensing vapours. The components of particle pollution include acids (for example, nitrates and sulfates), organic chemicals, metals and soil or dust particles.

2.2 Nitrogen oxides (13), (14), (15)

Nitrogen oxides (NO_x) are produced in high temperature combustion processes from the oxidation of nitrogen in the air or fuel to form nitric oxides (NO) and nitrogen dioxides (NO_2) which are known collectively as NO_x. The major mechanism for the formation of nitrogen dioxide in the atmosphere is the oxidation of nitric oxide that is the primary air pollution. Nitrogen oxides used to be the important precursors to predict or evaluate the level of both ozone and acid rain which may affect the terrestrial and aquatic ecosystems and human health. Nitrogen oxides can interact with the other components in the atmosphere to form particulate matter as well.

2.3 Sulfur dioxide (13), (15)

Sulfur dioxide is a colourless, acid gas that can produce acid rain when combines with water vapour in the atmosphere. The deposition of acid rain can damage the building and vegetable. The ambient sulfur dioxide come from stationary sources which use the fossil fuel for combustion such as coal and oil combustion, steel mills, refineries, pulp and paper mills and nonferrous smelters. Sulfur dioxide can also interact with the other compounds in the air to form PM.

2.4 Carbon monoxide (13), (15)

Carbon monoxide is a colourless, odourless and poison gas. It is produced by incomplete combustion of carbon in fuels. The major sources of carbon monoxide are from road traffics. The other major sources are industrial sources such as fuel combustion, incinerators, cement plants and wood-burning stoves. Carbon monoxide is a toxic gas that can enter the bloodstream and reduce the oxygen carrying capacity of blood.

2.5 Ozone (13), (15)

Ozone is a secondary pollutant, colourless gas produced by the reaction between nitrogen dioxide, hydrocarbons (VOC) in the presence of sunlight. Motor vehicle exhaust and industrial emissions, gasoline vapours, and chemical solvents as well as natural sources emit NO_x and VOC, that help to form ozone Ozone causes health problem because it damages lung tissue and reduce lung function and short term respiratory symptoms.

2.6 Lead (20),(21)

Lead is a metal that is found in the air in the form of fine particles with the mass median equivalent diameter of less than 1 μm. The lead emission in the atmosphere emitted from the combustion of alkyl lead additives in motor fuels. An expected 80-90% of lead in ambient air consequents from the combustion of leaded petrol. The amount of the lead in the ambient depends on the motor vehicle density and the efficiency of efforts to decrease the lead content of petrol. In term of Health effects, most critical effects are on in conditions of low-level haem biosynthesis, erythropoiesis, the nervous system and blood pressure and long-term lead exposure when the exposure is in the condition of low-level and long-term lead exposure.

2.6 Hazardous air pollutants (13), (15)

Hazardous air pollutants (HAPs) or air toxics can cause many unusual adverse effects to human health as well as cancer or birth defects. Examples of toxic air pollutants include benzene, which is found in gasoline; perchlorethlyene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries. People are most likely to be exposed to HAPs by breathing indoor or outdoor air, but they can also come into contact with chemicals that have settled out of the air and been absorbed by soil and water. Respiratory problems, such as bronchitis and asthma, are the most obvious health effects related to HAPs exposure, but HAPs also can damage the liver and nervous system and, in some cases, can cause cancer. Not everyone who is exposed to HAPs will develop harmful health effects; it depends on the amount and duration of exposure.

3. Receptor model (1), (2), (11), (12)

There are two types of mathematic models in air quality model. One is source-based model and another is receptor-based model. Source-based models or dispersion models use pollutant emissions rate estimates, meteorological transport and chemical transformation mechanisms to estimate the contribution of each source to receptor concentration. The receptor-based models use the chemical and physical characteristics of gases and particulate matter measured at source and receptor to both identify the presence of and to quantify source contributions to receptor concentration. The advantage of receptor models is that it gives a good estimation for fugitive sources which is difficult to estimate the emission rate due to insufficient applicable data.

The simple way to examine the source contribution of particulate matter at a receptor is using marker elements. Marker elements refer to one or more than one significant chemical species in the particulate matter from a certain source. For example, if the particulate matter found at receptor source has Na and Cl as dominant species, this evident refers that the significant source is likely to be marine aerosol.

Table 2-1 Marker elements from various sources. (Hopke,P.K 1995, Garivait 1999 and Koistinen 2002)

Marker elements	Sources
Na, Cl	Marine aerosol
Al, Si, K, Ca, Mn, Fe	Crustal, Road dust, Cement Industry, Stone Mill, Fly ash, Slag
C, Br, Pb	Traffic
Mn, Fe	Steel Industry
Cu, Zn, As, Sb	Non-ferrous Industry
SO_4^{2-}, NO_3^-, NH_4^+	Secondary aerosol
Ag, Cl, Cu, In, K, Pb, Sb, Zn	Incinerator
Ag, As, Cr, K, Mo, Pb, Sb, Se, S, Zn	Coal Combustion
Cr, La, Ni, Sm, S, V	Fuel oil combustion, Oil Refinery
Al, Ca, Cd, Cu, Fe, Mn, Ni	Gasoline vehicles
OC, EC, S, SO_4^{2-},NO_3^-	Diesel vehicles
Al	Gasoline vehicles with catalytic converter
Br, Pb	Gasoline vehicles without catalytic converter
Zn	Tire

Although, using marker elements as mentioned is a simple way but in the real situation there are many chemical species in particulate matter at a receptor source and the chemical species form different sources are similar to each other that makes it difficults to determine the result. Therefore, receptor models were developed to fine the source contribution in a more complex situation in the real world.

Source contribution of fine particulate matter in this project was investigated by using the receptor model. U.S.EPA. CMB8.2, the model uses the chemical and physical characteristics of particulate matter measured at various emission sources and receptors to estimate source contributions to the receptors.

Common type of receptor models are 1) Principle component analysis, PCA known as factor analysis 2)Multiple linear regression, MLR and 3) Chemical mass balance , CMB which is the fundamental receptor model.

Factor analysis used the data of chemical composition at a receptor to determine the number of significant sources. The result yielded the number of source having contributions to a receptor but could not identify source type. To fine out which sources they are, the model derives source profiles then compare to literatures concerning the characterization of various sources. Factor analysis needs more than 40 samples for proper computation.

Receptor model using chemical mass balance concept requires chemical compositions both at a receptor and sources. The output shows the presence of and quantity of sources contributions to a receptor.

Chemical mass balance receptor model expresses each receptor concentration of a chemical species in term of sum of products of source profile species and source contributions. The equation shows as follow.

$$\boxed{C_i = \sum_{J=1}^{j} F_{ij}S_j + E \qquad i=1\text{-}I}$$

Where C_i = Concentration of chemical species i measured at receptor site

F_{ij} = The fraction of chemical species i in the emission from source j

S_j = Estimation of the contribution of source j

I = Number of chemical species

J = Number of sources

E = Uncertainty

CMB model assumptions are as follows:

1. Compositions of source emissions are constant over the period of ambient and source sampling.
2. Chemical species do not react with each other.
3. All sources with a potential for contributing to the receptor have been identified and have had their emission characterized.

4. The number of species is more than or equal to the number of sources.
5. The source profiles are linearly independent of each other.
6. Measurement uncertainties are random, uncorrelated and normal distributed.

4. Literature site

Katsumi Saitoh, Koichiro Sera, Koichiro Hirano and Tadashi Shirai (22) investigated the chemical characterization of particles in winter-night smog during a period from December 1998 to January 1999 at Shinjuku in Tokyo by using an ambient particular monitoring (PM_{10} and $PM_{2.5}$). Elemental compositions in the filter samples were analysed by particle-induced X-ray emission (PIXE) analysis. 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+}) were analysed by ion chromatography. Concentrations of 22 elements in both PM_{10} and $PM_{2.5}$ samples showed that Na,Mg,Al,Si,S,Cl,K,Ca,Fe,Zn and Pb were the major components which S and Cl were the most dominant elements of PM_{10} and $PM_{2.5}$ at high concentrations. The major of ionic species composed of Cl^-, NO_3^{-},SO_4^{2-} and NH_4^+. The component proportion of carbon, the other elements (total amount of measured elements other than S and Cl) and secondary-formed particles of $PM_{2.5}$ was similar to PM_{10}. The key component was carbon particles at a low concentration and secondary-formed particles at a high concentration. The proportion of NH_4NO_3 and NH_4Cl plus HCl in secondary-formed particles at a high concentration, in particular, was as high as 90%.

Arpa Wangkiat, Narumon Withers Harvey, Shin'ichi Okamoto and Supat Wangwongwatana (23) studied chemical characteristics of fine and coarse aerosols in northern Thailand. Dichotomous air samplers were used to characterize the atmospheric aerosol of an aerodynamic diameter less than 2.5 μm and 2.5-10 μm at the top of Ban Hua Fai air monitoring station in Mae Moh area during January to April 2001. Up to 40 elements,4 ionic species and elemental and organic carbons (EC,OC) were analysed by ICP-MS, ion chromatography and CHNS/O analyzer, respectively. The average mass concentrations of fine and coarse particles were 56.29±33.74 and 25.55±8.88 $\mu g/m^3$ respectively. The majority chemical components in fine particles were EC, OC, NH_4^+,K^+,K,SO_4^{2-} and NO_3^- , in coarse particles found

EC, OC, Ca, Al, Fe, SO_4^{2-}, NO_3^- and Mg. The correlation analysis between the chemical components for fine particle mass showed OC was correlated with EC and strong correlated with K and K^+ that indicate to biomass burning and possible vehicle emission. For coarse particles, the major and minor elements such as Mg, Al, Ca, Fe, Mn, Rb, As, La and Ti were found.

Judith C. Chow,John G. Watson, Lowell L. Ashbaugh and Karen L.Magliano (24) considered the similarities and differences in PM_{10} chemical source profiles for geological dust from the San Joaquin Valley, California. The six types of geological dust included (1) urban and rural paved roads,(2) residential and agricultural unpaved roads and parking areas, (3) almond, cotton, grape, safflower and tomato fields, (4) dairy and feedlot surfaces, (5) salt-laden lake and irrigation canal drainage deposits, and (6) building and roadway construction/earthmoving soil. The geological samples were dried at 105°C, sieved through a Tyler 200 mesh screen, suspended in a chamber add sampled through size-selective inlets onto filter (PM_{10}) fit for chemical analysis. 40 elements and gravimetry on Teflon-membrane filters were analyzed by high-sensitivity XRF such as Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pb, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Th and U. The quartz filters were analyzed for gravimetry and half of quartz filter was extracted in deionized distilled water and measured for Cl^-,NO_3^{2-} and SO_4^{2-} by ion chromatography. NH_4^+ was analyzed by automated colorimetry and Na^+, K by atomic absorption spectrophotometry. A 0.5 cm^2 punch from the remaining half filter was analyzed for carbon fraction (OC, EC) by following the IMPROVE thermal/optical reflectance (TOR) protocol. Characteristic features were found among composite source profiles of six geological types. Elemental carbon and Pb marked paved road dust. Na^+, Na, S and SO_4^{2-} found in salt deposits ; OC,PO_4^{2-} ,P,K^+,K and Ca represented animal husbandry, Ti, V, Mn marked construction soil and Pb, Rd, Ti also found in construction dust, Ga,Zr,Sn and Ba were measured in some of the paved road dust profiles, As,Mo,Cd,Sb and U were found in salt deposits from canal drainage. The systematic sample composition scheme developed in the study can be used for evaluating similarities and differences for future source categorization studies.

E.Vega,V.Mugica,E.Reyes,G.S′anchez,J.C Chow and J.G Watson (25) examined chemical composition of fugitive dust emitters in Mexico City by colleting the twenty-one geological samples during 1997-1998 in and around Mexico City in the state of Hidalgo and in Texcoco Lake. Samples were a portion of the surface dust that swept from representative portions of the surface and kept in a labeled polyethylene bag previous to analysis. Geological material samples consisted of unpaved and paved roads, agricultural soil, dried lake, asphalt cement, landfill, gravel and tezontle soil. The sieved material was balanced in the chamber and sampled through size-selective inlets onto the teflon and quartz filters for further gravimetric and chemical analyses of $PM_{2.5}$ and PM_{10} The X-ray fluorescence was used to analyse for Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Tl, Pb and U. Cl^-,NO_3^{2-} and SO_4^{2-} were analysed by ion chromatography, Na^+ and K were analysed by atomic absorption . Automated colorimetry was used for water soluble (NH_4^+) and IMPROVE thermal/optical reflectance method for organic carbon (OC) and elemental carbon (EC). The result showed that the $PM_{2.5}$ fraction constituted 23% of the PM_{10} total mass for most of the geological source profiles, except for unpaved road and tezontle soil where the percentage of $PM_{2.5}$ in PM_{10} was 11% and for the dried lake and cement was 32%. $PM_{2.5}$ and PM_{10} chemical abundances for a given source type were similar for most species. Cement and crushed gravel profiles had the highest Ca abundances. The tezontle soil found Fe abundances and it was the highest of all the profiles.

Lowell L. Ashbaugh and et al (26) interested in soil sample collection and analysis for the fugitive dust characterization study. The soil types were selected and represented of soil in the San Joaquin Valley as it could emit fugitive dust. Dust sources were assigned priorities based on the amount of dust-generating activity and amount of dust expected to be generated by that activity during the fall period when the concentration of atmospheric dust is highest. The soil sources consisted of field planted in cotton, almond, tomato, grape’s afflower,dairy and feedlot facilities, paved and unpaved roads in urban and rural, agricultural staging area, disturbed land with salt buildup, and construction areas where the topsoil had been removed. All samples were characterized by particle size (percent sand, slit and clay), dry slit content which used in EPA-recommended fugitive dust emission factor, carbon and nitrogen content and potential to emit both $PM_{2.5}$ and PM_{10}. The study showed the soil characteristics of soil texture, particle size distribution, dry slit content,PM_{10} index and $PM_{2.5}$ index and carbon and nitrogen content. The PM_{10} index and $PM_{2.5}$ index are a measure of soil's potential to emit $PM_{2.5}$ and PM_{10} respectively. In this case the PM_{10} index and $PM_{2.5}$ index are strongly related to the sand or clay content of the soil that may be a high emitter of airborne dust if the soil is disturbed.

Nakron Tippayawong and Alect Lee (13) studied concentrations and elemental analysis of airborne particulate matter in Chiang Mai,Thailand. Samples were collected at four sites in Chiang Mai that represented of urban, rural, industrial and residential area by a low volume sampler over ten hours (0800-1800) period as a daytime average between October 2003-April 2004. The instrument measured airborne particulate mass concentrations using infrared light scattering technique (800 nm wavelength).The amount of scatter is proportional to the mass concentration and measured by the photodetector. The elemental analysis was analysed by atomic absorption spectroscopy for Al,Fe,Pb,Zn,Cd,Cr and Ni and by flame photometer for Ca,Na and K respectively. The result indicated that ambient air in Chiang Mai had high TSP loading in range of 50-370 $\mu g/m^3$. The elemental composition analysis showed that TSP seemed come from re-suspended soil and road dust, local industrial and construction sites as well as biomass burning.

G.S.W.Hagler and company (27) considered of source areas and chemical composition of fine particulate matter in Pearl River Delta region of China, an area encompassing the major cities of Hong Kong, Shenzhen and Guangzhou. The 24 hours $PM_{2.5}$ samplers were performed every sixth day for four months (October 2002, December 2002, March 2003 and June 2003) at three sites located in Hong Kong and four sites located in Guangdong province to represent background concentrations, urban sources and receptor sites downwind of the major urban sources. Major ion concentrations (SO_4^{2-}, NO_3^- and Cl^-) were analyzed by ion chromatography, NH_4^+ was measured by indophynol colorimetric analysis, trace elements were performed via X-ray fluorescence (XRF) analysis, elemental carbon and organic carbon were determined by using the NIOSH protocol of thermal evolution and combustion and daily surface winds were analyzed to estimate influential source locations. The concentration of PM2.5 for four months average ranged from 37-71 $\mu g/m^3$ in Guangdong province and from 29-34 $\mu g/m^3$ in Hong Kong. Despite the variability in concentration throughout the region, the general chemical make-up of the $PM_{2.5}$ is very similar among seven sites. The surrounding area of Guangzhou is indicated as a major source area influencing regional concentrations of $PM_{2.5}$ at sites immediately downwind of Guangzhou. The area near Guangzhou is also observed to heavily impact downwind concentrations of lead (combustion of fossil fuel) and potassium (biomass burning). Elemental carbon observed to be strongly influenced by local sources with highest levels found in urban regions. Guangzhou also stand out as a significant regional of organic mass , adding 8.5-14.5 $\mu g/m^3$ to downwind concentrations.

S.C. Lee and et al (28) studied PM_{10} and $PM_{2.5}$ characteristics in roadside environment of Hong Kong. The samples were collected with two collocated Partisol-Plus Model 2025 Sequential Air Sampler at the Hong Kong Polytechnic University (PU) Roadside Station air-quality monitoring site located near Victoria Harbor where the road is busiest cross-harbor roads in Hong Kong in January – May 2004. Organic carbon and elemental carbon were analyzed with a Desert Research Institute (DRI) Model 2001 Thermal/optical carbon analyzer with the IMPROVE thermal/optical reflectance (TOR) protocol. The study showed that carbonaceous aerosols were major components in fine particles, 45.7% for PM_{10} and 44.4% for $PM_{2.5}$. Particle mass and organic compound showed higher concentrations in winter than spring due to the contribution of continental aerosol pollutants brought in by long-range transport.

CHAPTER III

MATERIALS AND METHODS

The study consists of PM_{10} sampling in ambient air and emission sources, chemical composition analysis on both ambient and source samples and source apportionment analysis by a receptor model.

PM_{10} ambient air sampling employed Minivol Air Sampler which is a small portable and run on batteries therefore it can be conveniently moved to an area without electricity. All samplers were calibrated using a Primary Flow Meter before and after use. The sampling period covered wet and dry season.(June 2005 to March 2006)

There were 3 ambient air sampling sites in this study namely, 1) Khung-Khow-Khew 2) Na-Phra-Lan and 3) Ban Nhong-Jan. All sites represent mixed industrial and residential area, heavy traffic, intensive industrial area and agricultural area, respectively as showed in figure 3-1.

2 types of filters were Teflon and Quartz which used for sampling and analysis on both of ambient and source samples.

Teflon filters were used to analyze metallic and non-metallic elements including Al, Ba, Ca, Cl, Co, Cr, Cu, Fe, K, Mg, Mn, Na, P, S, Si, Ti, V, and Zn by X-ray Fluorescence (XRF).

Quartz filters were divided to 2 parts for analyze Organic Carbon and Elemental Carbon by organic elemental analysis namely OEA Analyzer. The left of the filter was then put into deionized water to dissolve the collected PM_{10} for analysis of soluble ionic species. An ionic species such as SO_4^{2-},NO_3^-, Cl^-, Na and K were analyzed by Ion Chromatography method.

1. Methods

This study was an analytical research of the investigation of dust emission source at Na-Phra-Lan, Chalermphrakiat District, Saraburi Province by using the chemical composition analysis method to calculate the relative contribution from difference emission sources to ambient particulate matter levels by using the chemical mass balancing technique called CMB model. The several fine particulate matter sources in this area included quarry and rock-crushing industrial areas, cement plants, fuel combustion in motor vehicle and open-burning in cultivated areas. Samples of ambient fine particles (PM_{10}) were collected for mass concentration and chemical composition analysis from June 2005 to March 2006 at 3 receptor locations which were Khung-Khow-Khew, Na-Phra-Lan and Ban Nhong-Jan respectively.

2. Materials

2.1 PM_{10} ambient air sampler

2.1.1 Two sets of Air Metrics Mini Volume Portable Air Sampler with flow rate at 5 litre/min.

2.1.2 Filters. One set used a 47-mm diameter Teflon filter, another used a 47-mm diameter Quartz-fibre filter. Quartz-fibre filter used for carbonaceous analysis which had been heat treated at 550 degree C for five hours to minimise their carbon black for organic carbon (OC) and element carbon (EC) respectively included ionic species. The particulate samples collected by Teflon filters were used for elemental analysis.

2.2 Chemical composition analyzer

2.2.1 Elemental analysis by Wavelength Dispersive X-Ray Fluorescence (S4 Explorer Model). The elemental species were measured in term of Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Cu, Zn and Ba.

2.2.2 Carbon analysis by Organic Elemental Analysis (FlashEA^{TM} 1112 Model), NCHS method. The elemental species were measured in term of organic carbon (OC) and elemental carbon (EC).

2.2.3 Ions analysis by Ion Chromatography (Shim-Pack IC-A3). The elemental species were measured in term of anions (Cl^-, NO_3^-, SO_4^-) and cations (NH_4^+, Na^+, K^+).

3. Data collection and measurement

3.1 Fine particulate matter (PM_{10}) collection

3.1.1 Ambient sampling

1.) Sampling location

The investigation of dust emission sources at Na-Phra-Lan, Chalermphrakiat District, Saraburi Province was managed at Khung-Khow-Khew , Na-Phra-Lan , Ban Nhong-Jan as shown in figure 3-1.

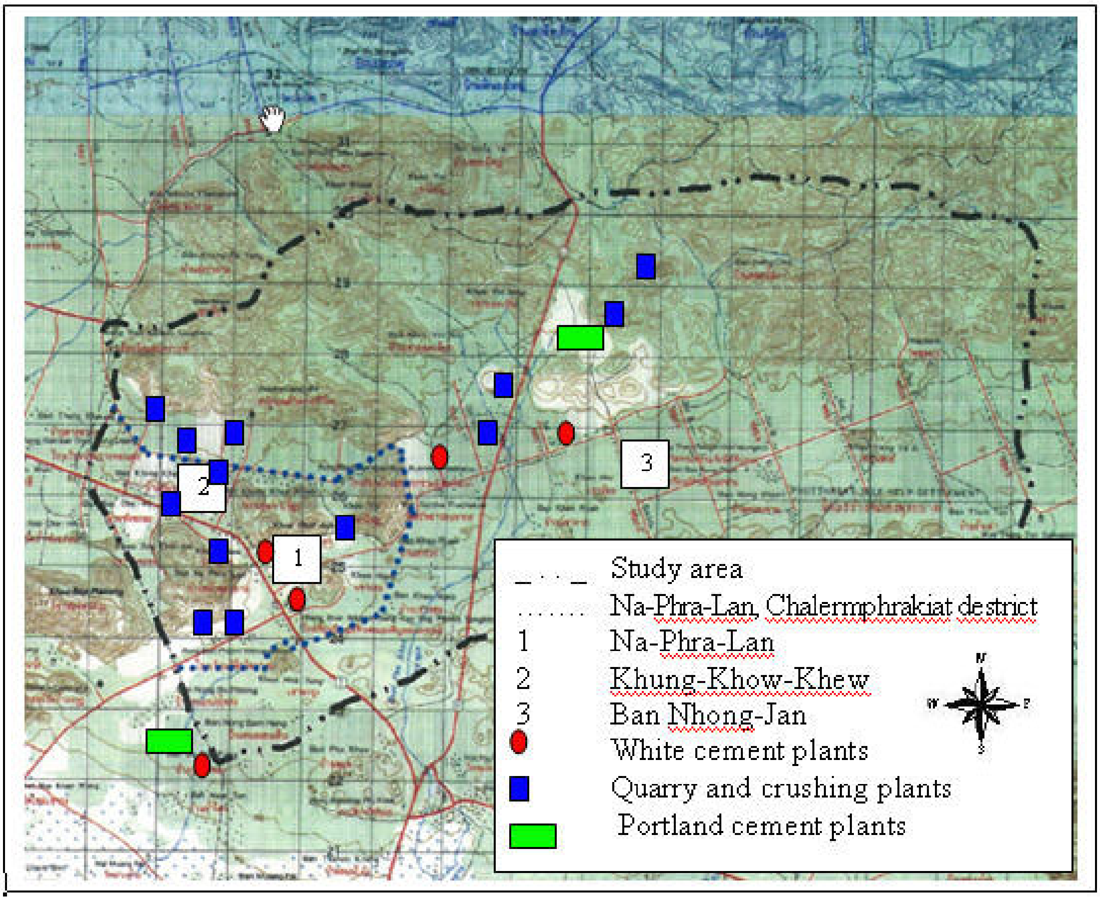


Figure 3-1 Ambient sampling locations at Na-Phra-Lan, Chalermprakiat district.

Khung-Khow-Khew, The sampling location was Khung-Khow-Khew school located around 400 meters away from phahonyothin road and closed the areas of quarry and crushing plants and white cement plants. Most of the vehicles in this area were heavy-duty truck and light-duty truck as well. The sampling site was located on the football field at Khung-khow-khew school as shown in figure 3-2.

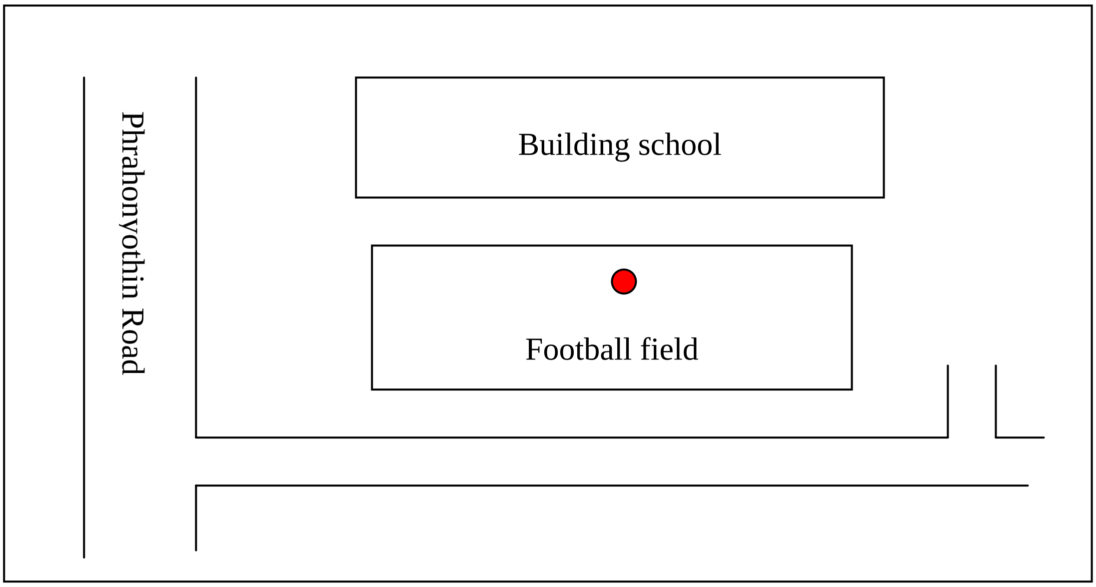


Figure 3-2 The Khung-Khow-Khew sampling site

Na-Phra-Lan, the sampling site was located at Na-Phra-Lan school which very closed to phahonyothin road and was not far from group of Portland cement and white cement plants. The sampling site was on the air quality monitoring station of pollution control department. There are some buildings and trees close to the site as shown in figure 3-3.

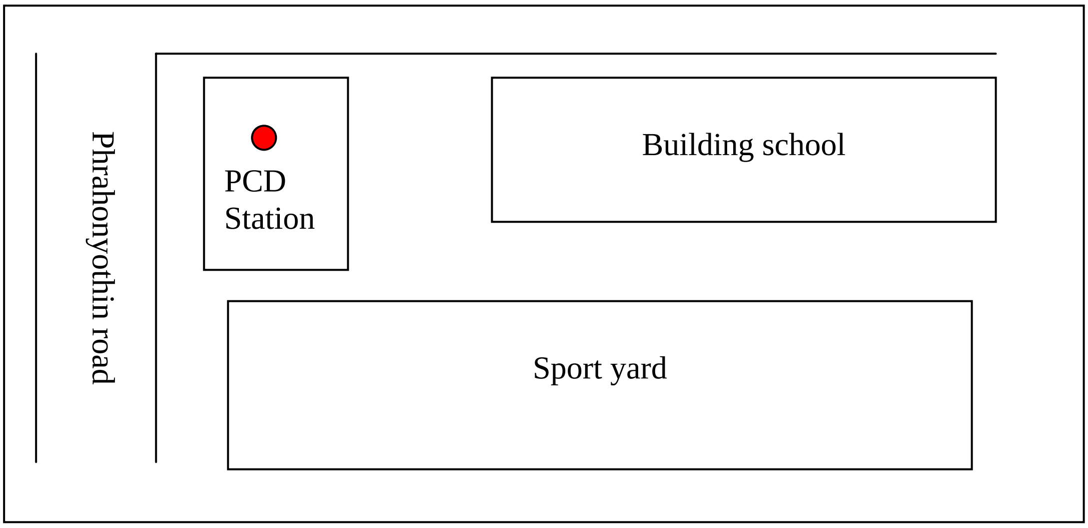


Figure 3-3 The Na-Phra-Lan sampling site

Ban Nhong-Jan, the sampling site was located at the Ban Nhong-Jan school near the local road. The landuse around the site was agriculture areas, low density of buildings and low traffic volume. However, small industries such as lime and white cement plants were contributed around this site but low density as shown in figure 3-4.

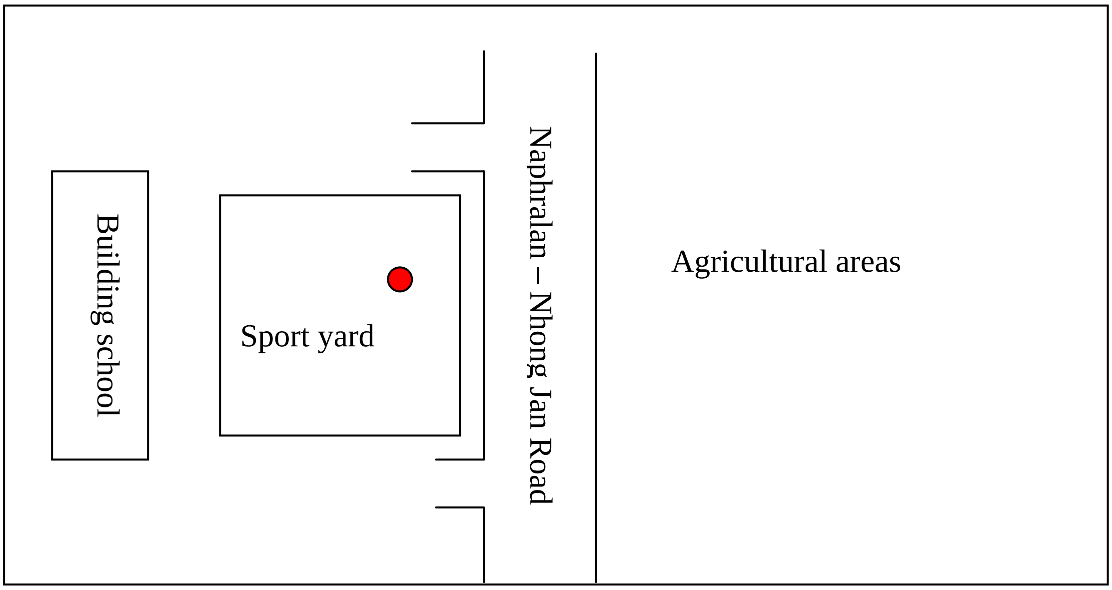


Figure 3-4 The Ban Nhong-Jan sampling site

2) Sampling period

The samples were collected for twenty-four hours every 3 days among June 2005 and March 2006, wet and dry season period for Thailand.

3) Methodology

Two sets of samplers using Air Metrics Mini Volume Portable Air Sampler with flow rate at 5 litre/min for ambient collection were placed on the top of the Pollution Control Department air monitoring station about 2.5 metres above the ground at the receptor locations and reference site except the receptor site at Khung-Khow-Khew school placed the samplers on the stand at the same height of the air monitoring station. One set of the samplers used a 47-mm diameter Teflon filter, another used a 47-mm diameter Quartz-fibre filter. Teflon filters were used for elemental analysis while quartz-fibre filter used for carbonaceous analysis and ionic species analysis respectively as showed in figure 3-5.

Figure 3-5 The PM_{10} sampler (Air Metrics Mini Volume Portable Air Sampler)

4) Sampling quality control

(1) Quality control of sampling equipment

The sampling equipment was the Mini-volumn air sampler must be calibrated with a primary flow calibrator, check and record equipment function and air flow at the sampling sites. The equipment also needed to be cleaned and checked for proper functioning.

(2) A field blank was collected for every 10 samples to control filter contamination.

(3) Quality control for gravimetric.

The filters must be weighted at laboratory and needed to be equilibrated at least 24 hours. Pre and post weight used for calculating mass of particulate matter.

(3.1) Weighting equipments

- Micro-Balance 6 digits (Mattler Toledo UMT5)
- Teflon and quartz filter 47 mm diameter with pore size 0.5 micrometer were used for particulate sampling.
- Desiccators and silica gel.

- Forceps.
- Dust-free hand gloves.
- Polyethylene casket.

(3.2) Filter preparing.

Quartz filter needed to be baked at 550°C for five hours before equilibrate in a desiccator containing silica gel at least 24 hours.

(3.3) Weighting

Before sampling

- Weigh 100 and 200 mg standard weight that was kept in a desiccator
- Weigh blank filters
- Weigh sampling filters that were kept in the polyethylene casket
- The weighting process of each filter must be done 3 times. The average value was used and recorded as a pre-weight value. The filters were kept in polyethylene casket, one filter per casket.
- Put the filter in Mini-volume air sampler at the sampling sites.

After sampling

At the sampling site, the equipment must to be checked and recorded the function and air flow rate before changing the filter. The filters were kept in the caskets and placed them in a desiccator for 24 hours before weighting.

- The weighting process involved weighting two types of filters, three times for each filter. The average value was used for post weight value.
- During weighting, forcep was used to hold the filters and hand-gloves needed to be worn.
- The filters were kept in the polyethylene casket and wrapped with parafilm.

5) Weight calculation (31)

(1) Air volume calculation

$$V_{act} = Q_{act}T$$

When V_{act} = Actual air sampled at ambient temperature and pressure, m^3

Q_{act}= Average sample flow rate at ambient temperature and pressure, m^3 per minute

T = Sampling duration, minutes

(2) Air volume at standard condition

$V_{std} = V_{act}(P_{act}/P_{std})(T_{std}/T_{act})$

When V_{std} = Air sampled at standard condition, m^3

V_{act} = Actual air sampled, m^3

P_{std} = Atmospheric pressure at standard condition, inchs Hg

P_{act} = Actual atmospheric pressure, inches Hg

T_{std} = Ambient temperature at standard condition, K

T_{act} = Actual ambient temperature, K

Particulates concentration at standard condition means air volume that calculated at standard condition, 25 C or 298 K and atmospheric pressure at 760 mmHg or 29.93 inches Hg.

(3) Concentration calculation

$PM_{10} = [(W_f – W_i)x10^3]/V_{std}$

When PM_{10} = Particulates concentration, $\mu g/m^3$

W_f,W_i = Filter weight after before sampling, mg

10^3 = Conversion factor from mg to μg

V_{std} = Air sampled at standard condition, m^3

3.1.2 Source sampling

The fine particulate matter sources in this area included quarry and crushing plants, cement plants, fuel combustion in motor vehicle and open-burning in cultivated areas.

The PM_{10} source sampling of this study consisted of 2 samples of portland cement plants, 2 samples of white cement plants and one sample of quarry and crushing plants as shown in table 3-1. These samples collected on teflon filters and quartz-fibre filter conducted the analysis of chemical compositions of particulates

The additional source profiles such as exhaust gases of vehicles, biomass burning were secondary data from literature reviews.

Table 3-1 PM_{10} source sampling

Source type	Sources	No. of samples	Methodology
Portland cement plant	Clinker cooler Cement mill	2	Stack sampling techniques
White cement plant	White cement kiln 1 White cement kiln 2	2	Stack sampling techniques
Quarry and crushing	Process	1	Mini - volume portable air sampler techniques
Total		5	-

3.2 Chemical composition analysis of PM_{10}

The total filters were determined the total mass deposit by gravimetric analysis. The filters were weighted by using a microbalance to the nearest 1 µg under controlled condition for twenty-four hours in an electronic chamber at 50±2 % RH and 22±2 degree C before and after sampling. To cover the filter after conditioning or weighting were completed, the small petri dishes were used and laboratory blank filters were routinely weighted to control the weighting condition. The filers were stored in the refrigerator awaiting use up or chemical analysis. Table 3-2 shows elemental composition related to analytical methods operate in this study.

Table 3-2 Analysis methods for chemical composition

Chemical analysis methods	Elemental composition
Wavelength Dispersive X-Ray Fluorescence (S4 Explorer Model)	Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ba
NCHS method	Organic carbon (OC), Elemental carbon (EC)
Ion Chromatography (Shim-Pack IC-A3)	anions (Cl^-, NO_3^-, SO_4^-) cations (NH_4^+, Na^+, K^+,Mg^{2+},Ca^{2+})

3.2.1 Elemental analysis

The elemental composition was measured by Wavelength Dispersive X-Ray Fluorescence (S4 Explorer Model) at Office of Atom for Peace, Bangkok, Thailand.

The Wavelength Dispersive X-Ray Fluorescence (WDXRF) is a particular wavelength of fluorescent X-rays focused by a crystal onto the detector. The entire spectrum is collected as the crystal is rotated. WDXRF gives a very high resolution spectrum and allows for very low limits of detection. The measurement values were provided in as mass per unit filter area ($\mu g/cm^2$ filter) then converted to an effective ambient mass concentration.

3.2.2 Carbonaceous analysis

The organic and elemental carbons were performed at the Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi by Organic Elemental Analysis, NCHS method using the ThermoFinnigan model FlashEA^{TM} 1112.

Carbon was determined by O_2 combustion of disks punched from the filters. Each sample was swept with He in a closed system with added oxygen, with a Cu reducing tube in the case of N to avoid the N blank caused by occluded air. Samples were then partially evacuated and He was admitted. The result of total carbon were determined by Cu-analysed radio-frequency combustion and assay of the evolved CO_2 analyser equipped with the Non-Dispersive Infrared detector (NDIR).

Four quartz-fibre filter disks (5 mm diameter) were punched out from each quartz-fibre filter. Two disks were combusted at 550 degree C in He-rich atmosphere to determine organic carbon (OC). The other two were combusted at 950 degree C in He and O_2 atmosphere to determine total carbon (TC). The elemental carbon (EC) was then calculated by subtracting OC from TC.

3.2.3 Ionic species analysis

After punching out the quartz-fibre filter for carbon analysis, the residual filter material was then analysed for ion species using Ion chromatography that performed at the Faculty of Resources and Environment, Kasetsart University, Si Racha Campus. The sample preparation, the condition of anions and cations analysis shows as the figure 3-6, 3-7 and figure 3-8 respectively.

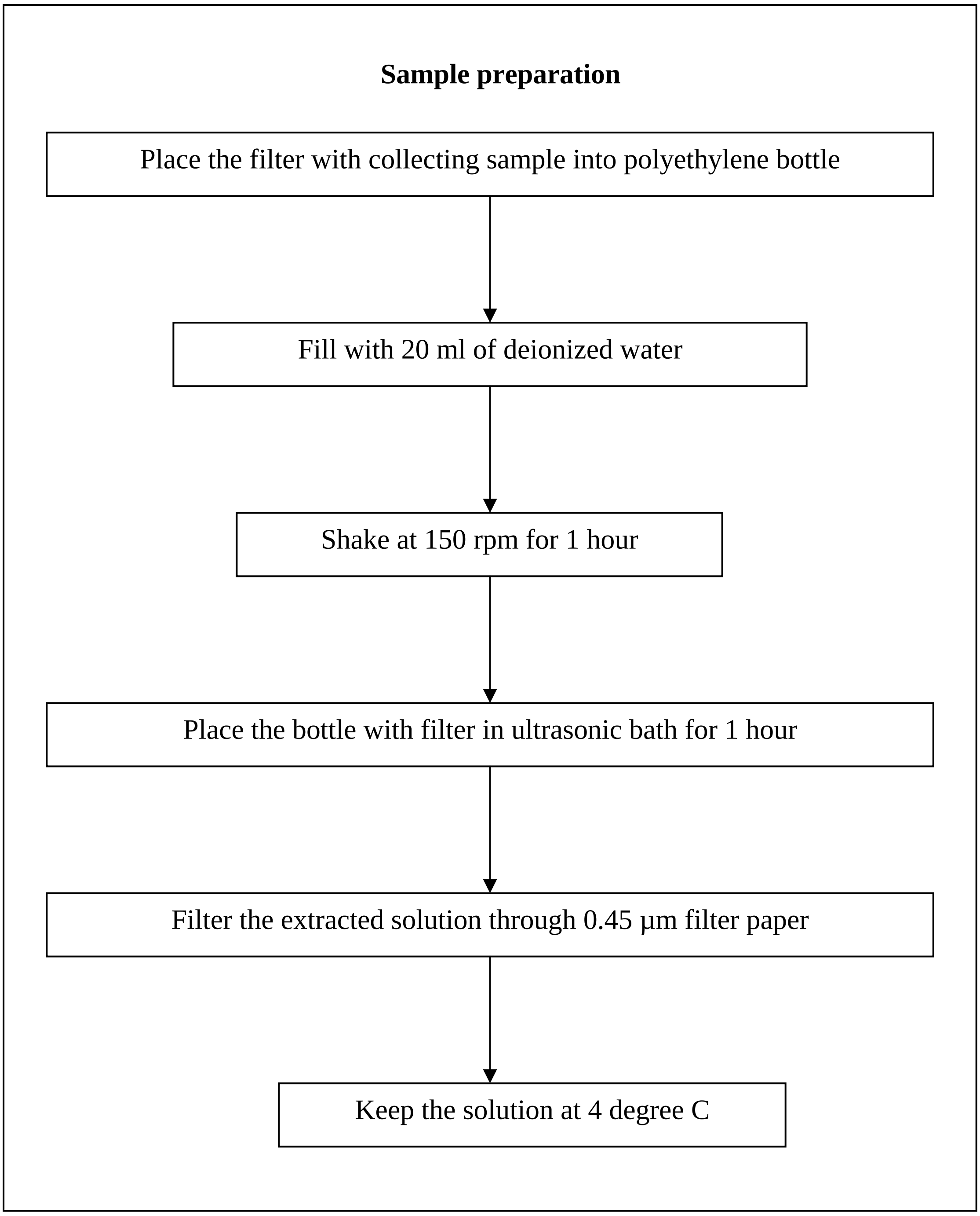


Figure 3-6 Sample preparation for ionic analysis

Condition of anions analysis

Column : Shim-pack IC-A3

Mobile phase : Boric acid 50 mM, p-hydroxybenzobic acid 8mM
And *bis* (2-hydroxyethyl) aminotris (hydroxymethy)
Methane 3.2 mM

Flow rate : 1.2 ml/min

Detector : conductivity detector at 40 degree C

Injection volume: 30 micro litres

Figure 3-7 Anions analysis condition

Condition of cations analysis

Column : Shim-pack IC-A3

Mobile phase : 2.5 mmol Oxalic acid

Flow rate : 1.5 ml/min

Detector : conductivity detector at 40 degree C

Injection volume: 30 micro litres

Figure 3-8 Cations analysis condition

3.2.4 Quality control

Quality control for the elemental analysis by wavelength dispersive X-ray fluorescence (S4 Explorer Model) at the Atom for Peace, Bangkok employed calibration of the instrument with Standard Reference Material 2783 of National Institute of Standards and Technology (Air Particulate on Filter Media), U.S.A.

Quality control for the organic and elemental carbons analysis at the Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi employed calibration of instrument by using the L-Aspartic acid standard solution contained of 10.52%N, 36.09%C and 5.3%H.

Quality control for the ionic species analysis at the Faculty of Resources and Environment, Kasetsart University, Sriracha Campus employed calibration of the instrument by using calibration curve of standard solution. Standard solution is freshly prepared. The calibration results must meet the R^2 of 0.99 before starting analyzing ions concentrations.

As the procedure mentioned above, all analytical works have to do analytical blank. The analytical blanks were filters from the same lot of filters used in sampling works. The concentration of all elements found on analytical works was used as background concentration of filters.

3.3 Chemical Mass Balance (CMB)

To determine which source types are the major contribution of the ambient pollution to the receptors, the chemical mass balance technique or CMB model is used for the investigation. The fractional amount of chemical species contained in the emission from each source type and their concentrations can be used for calculating the dust contribution from different sources to atmosphere.

The CMB model is a type of receptor models. It consists of a solution to linear equations that express each receptor chemical concentration as a linear sum of products of source profile abundances and source contributions. For each run of CMB, the model fits speciated data from a specified group of sources to corresponding data from a particular receptors (samples). The source profile abundances and the receptor concentrations supply as input data to CMB. The output consists of the amount contributed by each source type to each chemical species. The CMB equation shown in figure 3-9

CMB equation

$$C_I = F_{i1}S_1 + F_{i2}S_2 + . . + F_{ij}S_j. . + F_{ij}S_j \qquad I = 1…I , j = 1…J$$

Where :

C_I = Concentration of species I measured at a receptor site (ug/m^3)
F_{ij} = Fraction of species i in emissions from source j (ug/ug)
S_j = Estimate of the contribution of source j
I = Number of chemical species
J = Number of source types

Figure 3-9 The CMB equation

3.4 Performance Indicators for acceptance of results (12)

The R^2 is the fraction of the variance in the measured concentrations which explained by the variance in the calculated species concentration. The R^2 ranges from zero to one.

The chi-square is the weighted sum of squares of the differences between the calculated and measured fitting species concentration. Preferably, the chi-square would equal zero. A value less than 1 means a very good fit to the data, a value between 1 and 2 are acceptable. Chi-square value greater than 4 points toward that one or more species concentration are not well explained by the source contribution estimates.

Percent mass is the percent ratio of the sum of the model calculated source contribution estimates to the measured mass concentration should equal 100 ± 20%.

CHAPTER IV

RESULTS

This chapter is describing the result of study by addressing 1) The PM_{10} concentration of receptor sites. 2) The characteristic and chemical composition of PM_{10} at receptor sites. 3) The industrial inventory at Na-Phra-Lan, Chalermphrakiat District 4) The characteristic and chemical composition of PM_{10} from sources. 5) The chemical characteristics comparison between sources and receptors and 6) Sources contribution of PM_{10} in Na-Phra-Lan district.

As mentioned in previous chapters, there were 3 sites in this study, namely Khung-Khow-Khew , Ban Nhong-Jan and Na-Phra-Lan. The PM-10 collection took palace during June 2005 to March 2006. Basically, In the study area, around 50 Km^2, there were appropriately 40 Quarry and rock crushing plants (With stack and without stack), Three portland cement plants (With stack), Two white cement plants (With stack) and more than ten were white cement plants without stack. The rests were mobile sources, other industries and biomass burning. The weather conditions of that during sampling was dry and mainly prevailing wind blowing from the North. Khung-Khow-Khew was surrounded with quarry plants and 400 meters away from Phahol Yothin road (main road). Ban Nhong-Jan was an agricultural area which was mainly corn field, rice paddy fields and sun flower fields. Na-Phra-Lan was located near to Phahol Yothin road, and there were cement plants, quarry and crushing plants located surround this area. Figure 4-1 shows location of receptor sites and emission sources (With stack) in the study. Most of the emission sources in this study were located in the north and north- west.

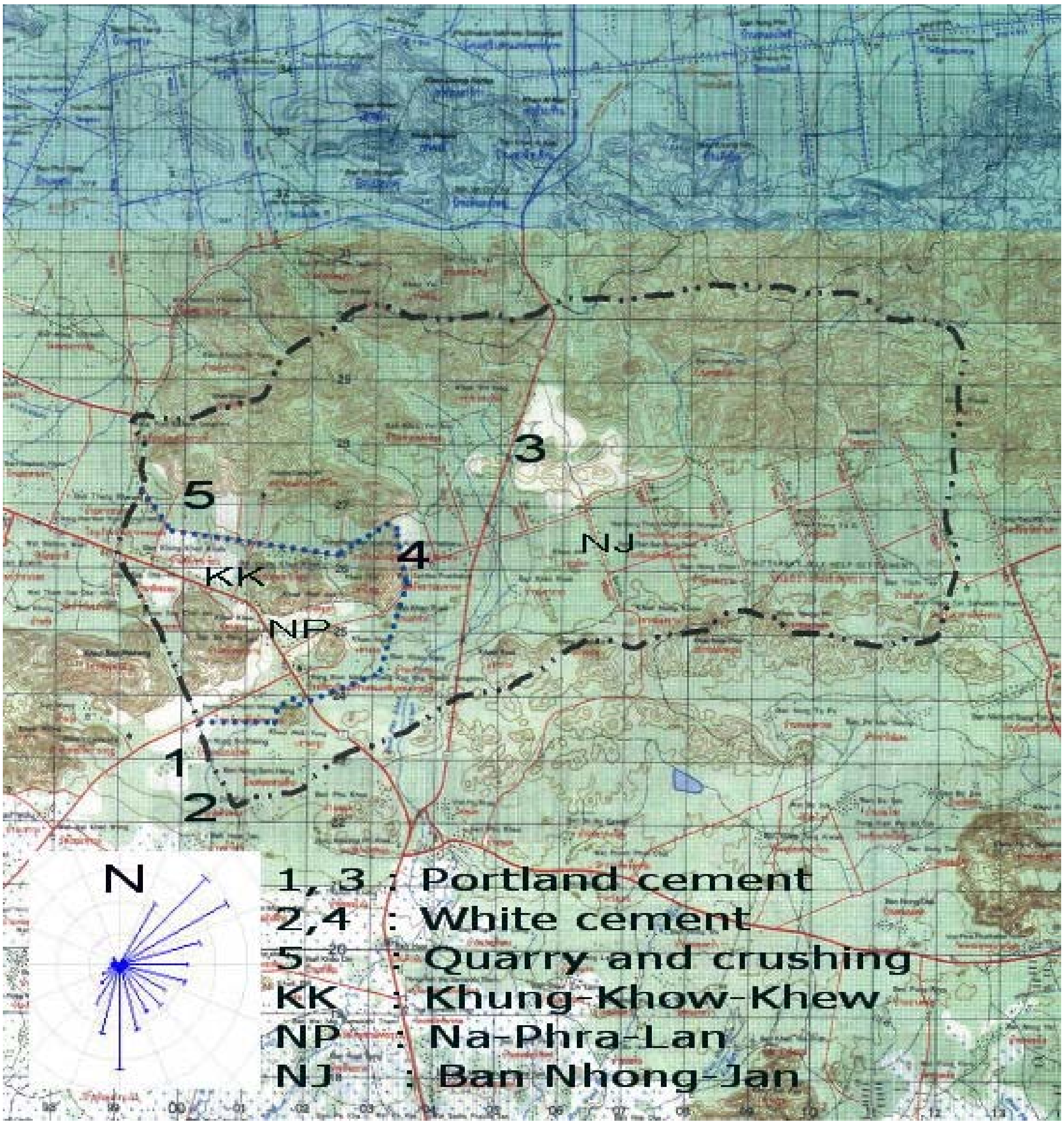


Figure 4-1 Locations of receptor sites and stationary sources

1. The PM_{10} concentration at receptor sites

The result of 24-hours PM_{10} concentration of 3 receptor sites in rain and dry season period at Na-Phra-Lan district area were 22.492-289.208 $\mu g/m^3$ The maximum concentration was 289.208 $\mu g/m^3$ at Khung-Khow-Khew site. The minimum concentration was 22.492 $\mu g/m^3$ at Ban Nhong-Jan site.

Khung-Khow-khew, there were 64 samples of 24-hours PM_{10} concentration collected between June 2005 to March 2006. Trend of 24-hours PM_{10} concentration for this site showed that most of high PM_{10} concentration appeared during October

2005 and January 2006 as showed in Figure 4-2. The maximum concentration was 289.208 µg/m^3 and the minimum concentration was 27.132 µg/m^3. The averaged PM$_{10}$ concentration was 134.456 µg/m^3 as showed in Table 4-1.

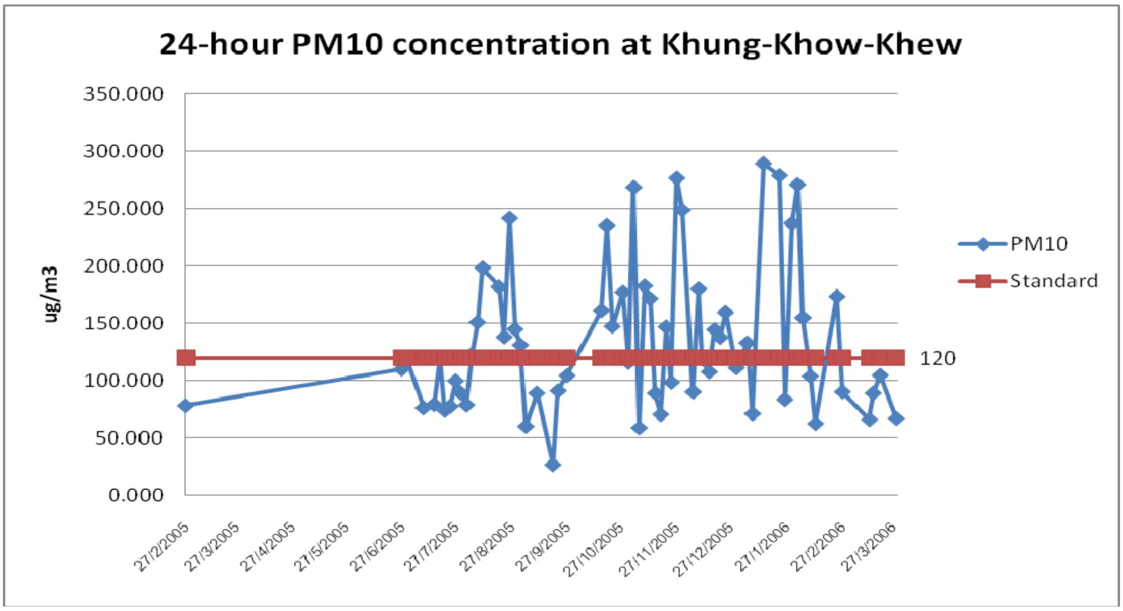


Figure 4-2 Trend of 24-hours PM$_{10}$ concentration at Khung-Khow-Khew site

Ban Nhong-Jan, there were 56 samples of 24-hours PM$_{10}$ concentration collected between June 2005 to March 2006. Trend of 24-hours PM$_{10}$ concentration for this site showed that there was not much difference as showed in Figure 4-3. The maximum concentration was 118.97 µg/m^3 and the minimum concentration was 22.492 µg/m^3. The averaged PM$_{10}$ concentration was 55.767 µg/m^3 as showed in Table 4-1.

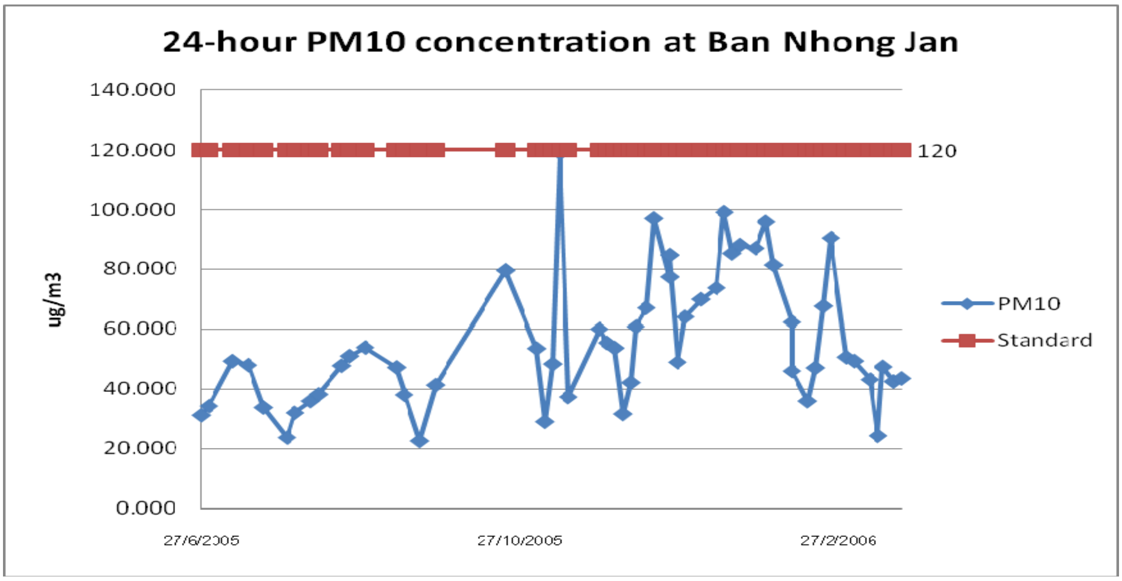


Figure 4-3 Trend of 24-hours PM_{10} concentration at Ban Nhong-Jan site

Na-Phra-Lan, there were 60 samples of 24-hours PM_{10} concentration collected between June 2005 to March 2006. Trend of 24-hours PM_{10} concentration for this site showed that most of high PM_{10} concentration appeared during July 2005 and January 2006 as showed in Figure 4-4. The maximum concentration was 272.531 μg/m^3 and the minimum concentration was 61.896 μg/m^3. The averaged PM_{10} concentration was 145.832 μg/m^3 as showed in Table 4-1.

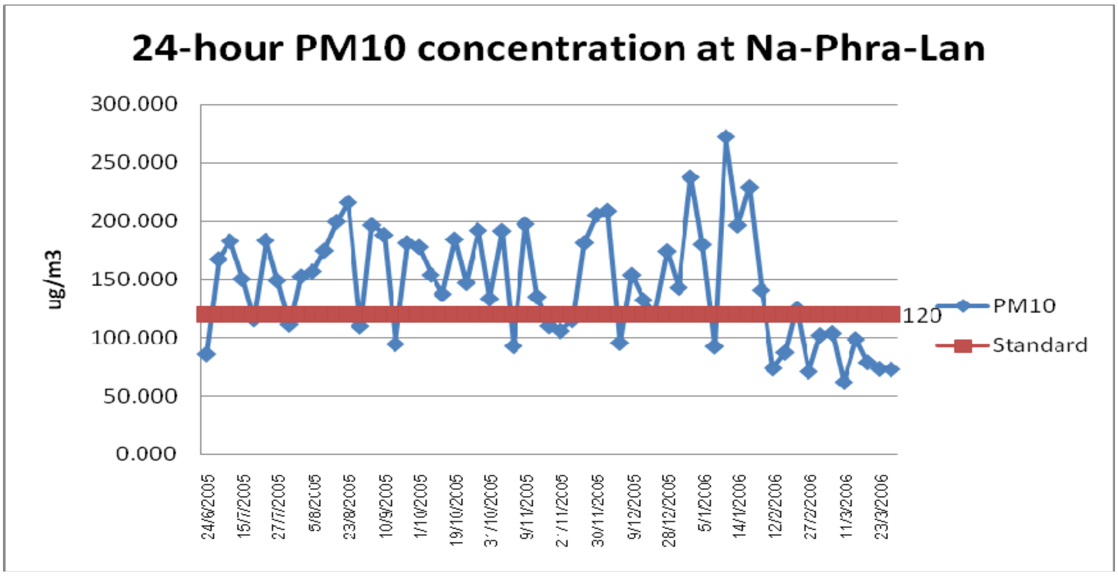


Figure 4-4 Trend of 24-hours PM_{10} concentration at Na-Phra-lan site

Table 4-1 The 24-hours PM_{10} concentration at Na-Phra-Lan, Chalermphrakiat district.

Location	No. of samples	24-hours PM_{10} concentration ($\mu g/m^3$)		
		Minimum	Maximum	Average
Khung-Khow-Khew	64	27.132	289.208	134.456
Na-Phra-Lan	60	61.896	272.531	145.832
Ban Nhong-Jan	56	22.492	118.970	55.767

The 24-hours PM_{10} concentration at Khung-Khow-khew and Na-Phra-Lan site were often exceed the PM_{10} ambient air standard. According to Na-Phra-Lan area, there are numerous Quarry and rock crushing plants surround these areas, and the Phahol Yothin road is very close to the sites as well. However, the trend of PM_{10} concentration was continuously decrease due to the implementations of the Pollution Control Department to solve this problem in Na-Phra-Lan district area continuously, for example :big cleaning day activities.

2.The characteristic and chemical composition of PM_{10} at receptor sites

The chemical composition analysis of 24-hours PM_{10} in ambient air at the 3 receptor sites during June 2005 to March 2006 consisted of 28 chemical species which were 18 metallic and non-metallic elements, namely Sodium(Na), Magnesium(Mg), Aluminium(Al), Silicon (Si), Phosphorus(P), Titanium(Ti), Vanadium(V), Chromium(Cr), Iron(Fe), Sulfur(S), Chlorine(Cl), Potassium(K), Calcium (Ca), Cobalt(Co), Copper(Cu), Zinc(Zn), Barium(Ba), Manganese (Mn), organic carbon (OC), elemental carbon (EC) and 8 water-soluble ionic species (Soluble sulfate ion (SO_4^{2-}), Soluble nitrate ion (NO_3^-), Soluble chloride ion (Cl^-),Soluble sodium ion (Na^+),Soluble potassium ion (K^+), Soluble ammonium ion (NH_4^+), Soluble calcium ion(Ca^{2+}) and Soluble magnesium ion(Mg^{2+})).

In term of chemical composition analysis, quality assurance and quality control were the mass balance between total mass of PM_{10} and total mass of chemical components. In this study, the criteria was total mass of chemical components that was not different from total mass of PM_{10} within ± 15% as showed in table 4-2.

Table 4-2 Total samples for chemical composition analysis in this study.

Areas	Total PM_{10} samples	Total samples for chemical analysis	Criteria
Khung-Khow-Khew	64	15	total mass of chemical components was not different from total mass of PM_{10} within ± 15%
Na-Phra-Lan	60	10	
Ban Nhong-Jan	55	24	

The results of the PM_{10} chemical composition analysis for 3 receptor sites were described as the followings;

Khung-Khaw-Khew, there were 64 samples which were collected and 15 samples were analyzed for chemical composition. In order to identify characteristics of chemical composition of $PM_{10,}$ the mass balance of total PM_{10} mass should be equal to total mass of elements which was recovery the sample . The analysis results showed the mainly proportion of chemical composition by having Ca, S, Si, Fe and Ca^+ at 38.67, 8.51, 8.17,5.73 and 5.17 percents, respectively.

Na-Pha-lan, similarly to Khung-Khow-Khew and Ban Nhong-Jan site, 60 samples were collected and 10 samples were complete for analysis in order to identify chemical composition whether what major species in this site were. Ca, S, Si, Fe, Ca^{2+} and SO_4^{2-} were major compositions at 27.26, 12.68, 9.46, 6.25, 6.06 and 5.30 percents, respectively for Na-Phra-Lan site.

Ban Nhong-Jan, there were 56 samples and 24 samples were complete for analysis in order to identify chemical composition in this site. Major proportions of chemical composition at Ban Nhong-Jan site were S, Si, Na^+, Ca, SO_4^{2-} and Fe at 19.83, 11.20, 9.55, 9.4, 8.23 and 5.49 percents, respectively.

According to Table 4-2, the PM_{10} chemical composition analysis of Khung-Khow-Khew site was similar to Na-Phra-Lan site especially an element of Ca, Si, S, Fe and Ca^{2+}. Both Ca and Si element were high portion in ambient air of Khung-Khow-Khew and Na-Phra-Lan sites at 38.67 and 8.17 percents for Khung-Khow-Khew, 27.26 and 9.46 percents for Na-Phra-Lan sites, respectively. Na^+ and SO_4^{2-} were the highest percents at Ban Nhong-Jan at 9.55 and 8.23 percents, respectively.

Ban Nhong-Jan found Na^+, SO_4^{2-}, Cl^- and K higher than Khung-Khow-Khew and Na-Phra-Lan site.

OC and EC at Ban Nhong-Jan site were similar to Khung-Khow-Khew and Na-Phra-Lan site.

Figure 4-5 – 4-7 showed the percentage of chemical composition at Khung-Khow-Khew, Na-Phra-Lan and Ban Nhong-Jan, respectively.

Summary of the chemical composition of 3 receptor sites showed as table 4-3.

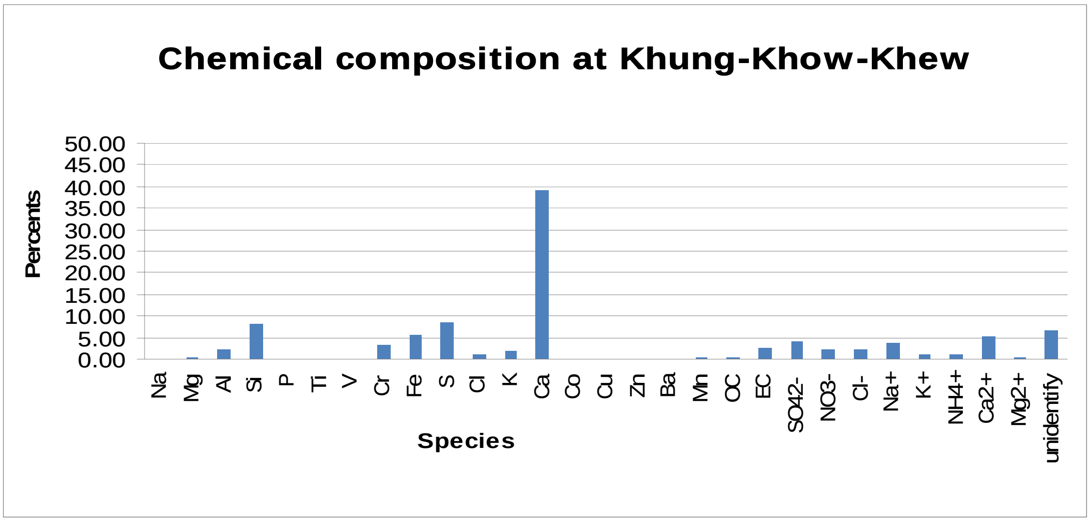


Figure 4-5 Chemical composition of PM_{10} at Khung-Khow-Khew site.

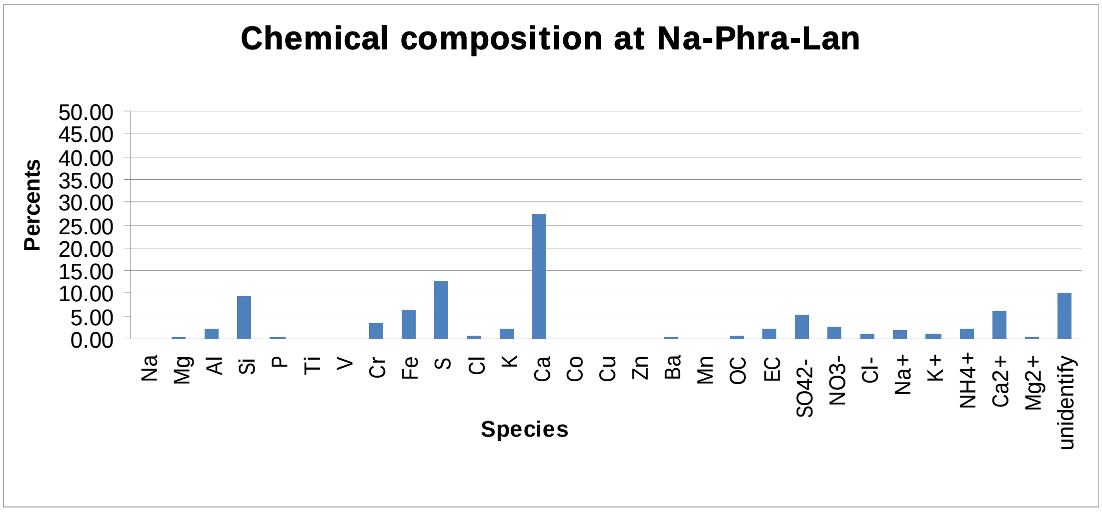


Figure 4-6 Chemical composition of PM_{10} at Na-Phra-Lan site.

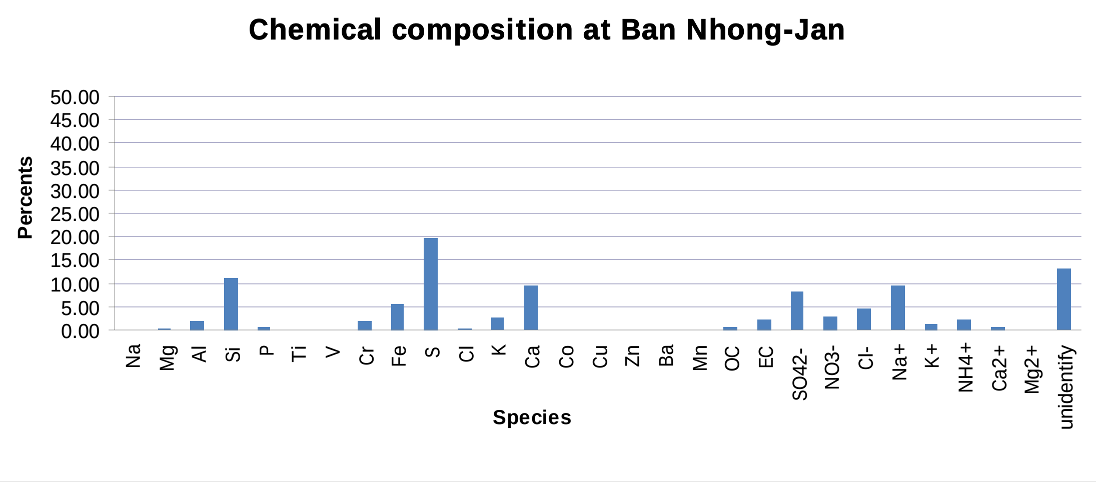


Figure 4-7 Chemical composition of PM_{10} at Ban Nhong-Jan site.

Table 4-3 Summary of concentration of chemical composition at receptor sites (%)

Parameters	Percents of chemical composition (%)			
	Khung-Khow-Khew	Na-Phra-Lan	Ban Nhong-Jan	Average
1.Na	0.02	0.04	0.04	0.03
2.Mg	0.35	0.38	0.30	0.34
3.Al	2.07	2.19	1.99	2.08
4.Si	8.17	9.46	11.20	9.61
5.P	0.18	0.54	0.51	0.41
6.Ti	0.03	0.10	0.00	0.04
7.V	0.06	0.05	0.15	0.09
8.Cr	3.39	3.46	1.85	2.90
9.Fe	5.73	6.25	5.49	5.82
10.S	8.52	12.68	19.83	13.68
11.Cl	0.88	0.74	0.28	0.63
12.K	1.90	2.33	2.60	2.28
13.Ca	38.67	27.26	9.40	25.11
14.Co	0.00	0.00	0.00	0.00
15.Cu	0.01	0.17	0.01	0.06
16.Zn	0.03	0.04	0.05	0.04
17.Ba	0.00	0.55	0.00	0.18
18.Mn	0.23	0.13	0.04	0.13
19.OC	0.25	0.62	0.58	0.48
20.EC	2.45	2.39	2.44	2.43
21.SO_4^{2-}	3.82	5.30	8.23	5.78
22.NO_3^-	2.25	2.45	2.98	2.56
23.Cl^-	2.06	1.13	4.71	2.63
24.Na^+	3.57	1.71	9.55	4.94
25.K^+	0.99	1.31	1.27	1.19
26.NH_4^+	0.91	2.4	2.36	1.89
27.Ca^{2+}	5.17	6.06	0.79	4.01
28.Mg^{2+}	0.27	0.26	0.08	0.20
29. Unidentify	8.01	9.99	13.29	10.43
Total	100	100	100	100

3.The industrial inventory at Na-Phra-Lan, Chalermphrakiat District

3.1 Stationary sources and area sources

The field survey of emission inventory for this study found total 45 industries in 3 industry types at Na-Phra-Lan, Chalermpphrakiat District in 2005 which consisted of three portland cement plants, two white cement plants and forty quarry and crushing plants.

All 45 industries could be able to divide into 2 groups as stationary sources and area sources. The stationary sources were Portland cement plants, White cement plants and Quarry and crushing plant with stacks. The second group was Quarry and crushing plants without stacks as the area sources in this study. Table 4-4 and table 4-5 described the summary of industrial inventory and PM_{10} emission rate at Na-Phra-Lan, Chalermpphrakiat District.

Table 4-4 Summary of industrial inventory at Na-Phra-Lan, Chalermphrakiat District.

Stationary sources			Area sources
Portland cement	White cement	Quarry and crushing with stacks	Quarry and crushing without stacks
3	2	3	37
Total = 8			Total = 37

Table 4-5 Summary of PM_{10} emission rates of stationary sources at Na-Phra-Lan, Chalermphrakiat District.

Source types	PM_{10} emission rate (g/sec)	PM_{10} emission rate (Ton/year)	Proportion (%)
Portland cement	5.50	173.4	26
White cement	14.06	443.4	67
Quarry and crushing (with stack)	1.38	43.5	7
Total	20.94	660.3	100

The PM_{10} emission rate of white cement plant was the major contributor in this area while the PM_{10} emission rate of the quarry and crushing plants was 7 percents.

The PM_{10} emission rate of quarry and crushing plants without stack and no pollution control equipments was 33.7 g/sec. (1,063.8 ton/year). It was calculated by emission factors of US.EPA. AP-42, (1992).

3.2 Biomass burning

In this area, most of the agricultural plants were corn fields, rice paddy fields and sunflower fields. The PM_{10} emission rate calculated by emission factors of US.EPA. AP-42, (1992) showed 98.4 ton/year. However, the biomass burning activities decreased from the past due to people understand the disadvantages of these activities affected to their products.

3.3 Mobile sources

From the mobile sources inventory at Na-Phra-Lan, Chalermphrakiat District showed traffics volume as table 4-6.

The PM_{10} concentration in the ambient at road side were 114-141 ug/m^3 and 164-260 ug/m^3 for Phrahonyothin road and Khung-Khow-Khew road respectively.

Table 4-6 Summary of traffics volume at Na-Phra-Lan, Chalermphrakiat District.

Vehicle types	Average traffic volume per day			
	Main road No. 1 Phrahonyathin Rd. (Saraburi - Phu-care)	Main road No. 21 (Phu-care – Phu-care bridge)	Main road No. 3034 (Naphralan – Ban kro)	Main road No. 3385 (Napralan – Nhong Jan)
Station (KM)	12 + 000	0 + 300	5 + 000	7 + 000
Car < 7 P	5,554	3,534	733	267
Car > 7 P	3,027	1,134	1,722	234
Light Bus	176	113	45	18
Medium Bus	135	28	59	10
Heavy Bus	566	239	51	4
Light Truck	12,202	8,638	345	89
Medium Truck	1,528	827	362	45
Heavy Truck	5,251	2,772	1,441	170
Full Trailer	4,622	2,393	1,176	101
Semi Trailer	1,922	873	823	43
TOTAL	34,969	20,551	6,757	981
Motorcycle	842	532	1,040	280

Note : Data inventory in year 2004

However, summary of PM_{10} emission rate of mobile sources at Na-Phra-Lan, Chalermphrakiat district calculated by emission factor of US.EPA. AP-42 (2003) was 1,329.5 ton/year.

Summary of total PM_{10} emission inventory at Na-Phra-Lan, Chalermphrakiat district showed as table 4-7.

Table 4-7 Summary of PM_{10} emission inventory at Na-Phra-Lan, Chalermphrakiat district

Source types	PM_{10} emission rate (Ton/year)	Proportion (%)
Portland cement	173.4	5.50
White cement	443.4	14.07
Quarry and crushing	1107.3	35.13
Biomass	98.4	3.12
Vehicle	1329.5	42.18
Total	3152.0	100

4.The characteristic and chemical composition of PM_{10} of emission sources

The dominant chemical compositions are the indicators of the PM_{10} emission sources in ambient air at the receptor sites. For example, if the particulate matter found at receptor site has Na and Cl as dominant species, this evident refers that the significant emission source is likely to be marine aerosol.

In this study, 2 emission sources types which consisted of Portland cement, white cement were characterized but quarry and crushing plant used the secondary data from US.EPA.due to its characteristics was incomplete as source profiles .Source profiles of diesel engines, gasoline engines, motorcycle, biomass burning were explored from Source apportionment of fine particulate matter in Samutprakan province report as showed in table 4-8.

Table 4-8 The chemical composition of source profiles.

Parameters	Mass fraction (ug/ug)						
	Portland cement	White cement	Quarry & crushing	Diesel engines	Gasoline engines	Motorcycle	Biomass burning
Na	0.00000	0.00000	0.00334	0.00000	0.00000	0.00000	0.00095
Mg	0.01126	0.00106	0.00700	0.00000	0.00000	0.00000	0.00043
Al	0.05757	0.01325	0.02523	0.00000	0.00000	0.00000	0.00133
Si	0.31268	0.05947	0.36580	0.00000	0.00000	0.00000	0.00000
P	0.01406	0.00000	0.00035	0.00004	0.00061	0.00000	0.00000
Ti	0.00000	0.00000	0.00150	0.00083	0.00082	0.00379	0.00000
V	0.00000	0.00000	-	0.00189	0.00000	0.00516	0.00000
Cr	0.00000	0.05520	-	0.03080	0.00850	0.03860	0.00012
Fe	0.00289	0.06938	0.00981	0.06850	0.02480	0.04130	0.00203
S	0.18198	0.08808	0.00028	0.00930	0.00720	0.00120	0.00000
Cl	0.16955	0.05188	-	0.00035	0.00070	0.00050	0.00000
K	0.02162	0.01402	0.01087	0.00000	0.00000	0.00000	0.01487
Ca	0.58403	0.57662	0.03933	0.00000	0.00000	0.00000	0.00293
Co	0.00006	0.00000	-	0.01290	0.00250	0.02080	0.00000
Cu	0.00000	0.00032	-	0.00012	0.00170	0.03560	0.00004
Zn	0.00194	0.00086	-	0.00110	0.00220	0.04630	0.00250
Ba	0.00000	0.00000	0.00045	0.00210	0.00000	0.01050	0.00000
Mn	0.00365	0.00235	-	0.00000	0.00000	0.00000	0.00000
OC	0.00000	0.00000	-	0.15070	0.31390	0.40450	0.31341
EC	0.00639	0.01554	0.01373	0.67170	0.17380	0.12070	0.33723
SO_4^{2-}	0.02593	0.03177	-	0.00000	0.02140	0.00000	0.00074
NO_3^-	0.00000	0.02126	-	0.00000	0.00000	0.00000	0.00003
Cl^-	0.01051	0.01103	-	0.00000	0.00000	0.00000	0.00000
Na^+	0.00453	0.06387	-	0.00000	0.00000	0.00000	0.00000
K^+	0.02290	0.00864	-	0.00000	0.00000	0.00000	0.00000
NH_4^+	0.00872	0.00000	-	0.00000	0.00530	0.00000	0.00049
Ca^{2+}	0.14677	0.00000	-	0.00000	0.00000	0.00000	0.00000
Mg^{2+}	0.00470	0.00000	-	0.00000	0.00000	0.00000	0.00000

1) Portland cement plant , the major proportion species of this source for metallic and non-metallic element were Ca, Si, S and Cl as 58.40, 31.26, 18.19 and 16.95 percents, respectively. Organic and Elemental Carbon analysis for this source was EC as the dominant component by 0.63 percents. The water soluble expressed 14.67, 2.59, 2.29 and 1.05 percent by for Ca^{2+}, SO_4^{2-} , K^+ and Cl^- respectively. Trend of chemical composition for portland cement plant were showed as figure 4-8.

2) White cement plant, as figure 4-9 showed the major proportion species of this source for metallic and non-metallic element were Ca, S, Fe, Si and Cr at 57.66, 8.80, 6.93, 5.94 and 5.52 percents respectively. EC showed 1.55% as the major component for Organic and Elemental Carbon analysis. Na^+, SO_4^{2-}, NO_3^- and Cl^- were 6.38, 3.17, 2.12 and 1.10 percents, respectively.

3) Quarry and Crushing plant, the metallic and non-metallic element analysis found that Si, Ca, Al and K were the major component at 36.58, 3.93, 2.52 and 1.08 percents respectively. EC was the dominant species of Organic and Elemental Carbon analysis of this source at 1.37 percents as showed in figure 4-10.

4) Biomass burning, EC and OC were the major components at 33.72 and 31.34 percents respectively. K was found at 1.48 percents as described in figure 4-11.

5) Diesel engines, expressed EC and OC as the major components at 67.17 and 15.07 percents respectively. However, Fe, Cr and Co also appeared at 6.85, 3.08 and 1.29 percents respectively.Figure 4-12 expressed chemical composition of this source.

6) Gasoline engines, showed OC and EC were the dominant species for this source at 31.39 and 17.38 percents respectively. There was SO_4^{2-} as ionic species appeared at 2.14 percents. Fe was found at 2.48 percents as showed in figure 4-13.

7) Motorcycle, OC and EC were the major species at 40.45 and 12.07 percents respectively. Zn, Fe, Cr, Cu, Co and Ba were at 4.63, 4.13, 3.86, 3.56, 2.08 and 1.05 percents respectively. Water soluble was not expressed as show in figure 4-14.

Summary of dominant species of source profiles of Na-Phra-Lan, Chalermphrakiat district concluded in table 4-9.

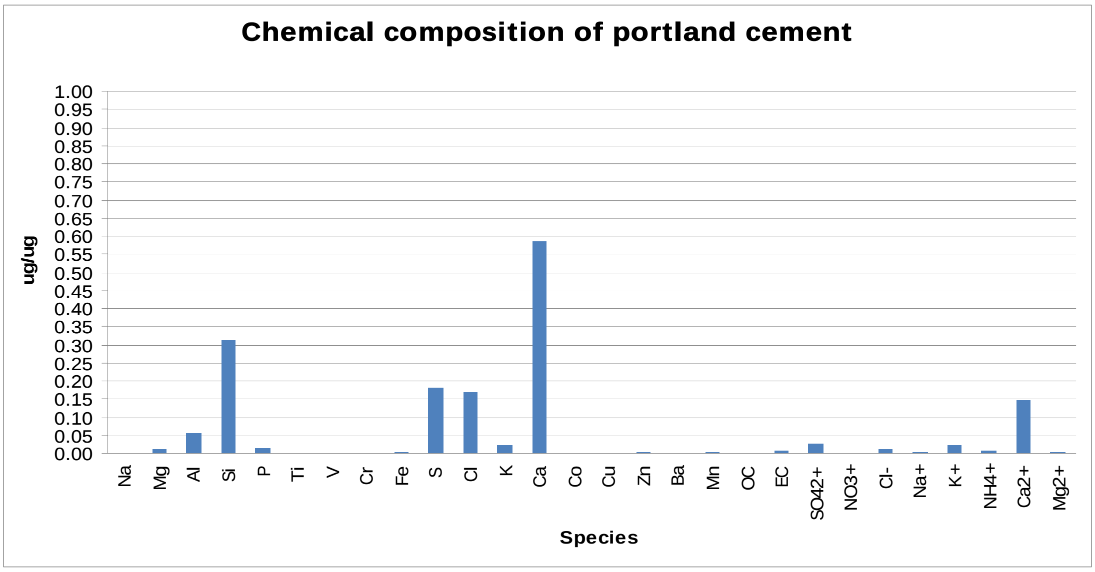


Figure 4-8 Chemical composition of Portland cement.

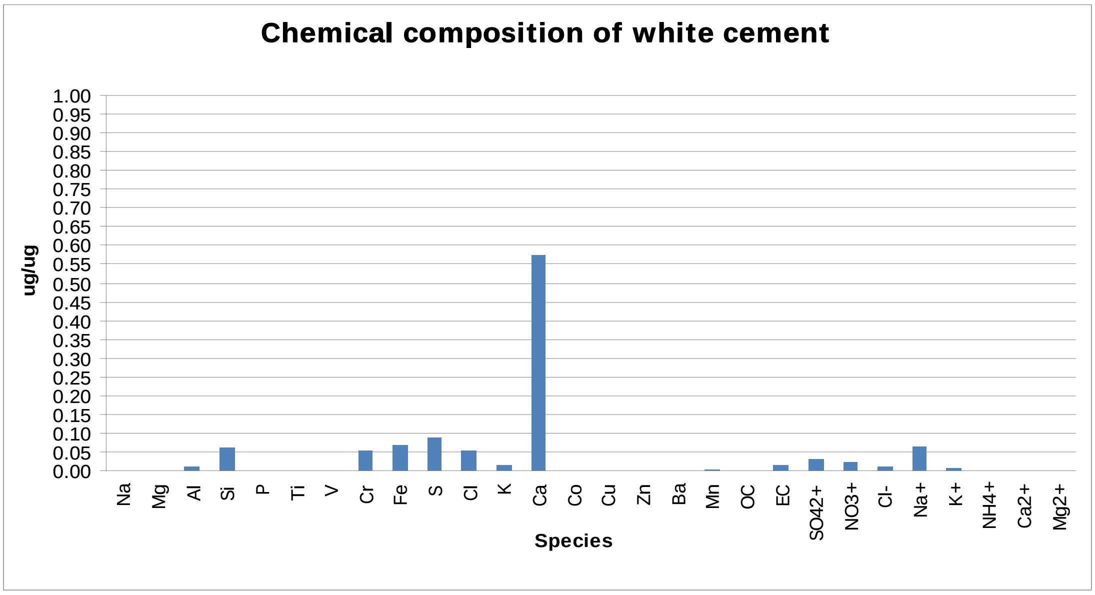


Figure 4-9 Chemical composition of white cement.

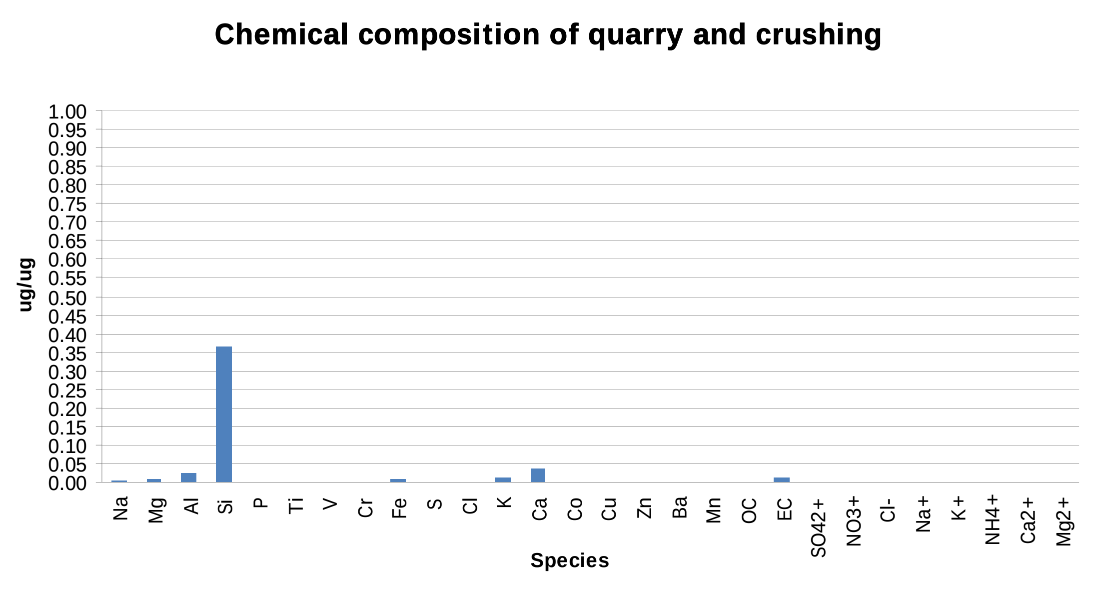


Figure 4-10 Chemical composition of quarry and crushing.

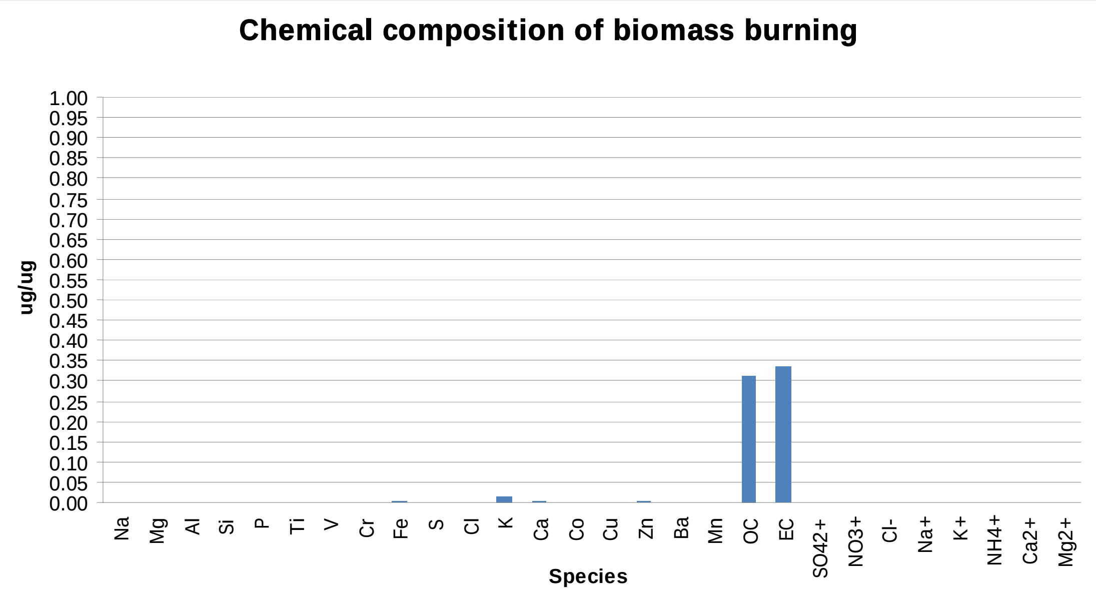


Figure 4-11 Chemical composition of biomass burning.

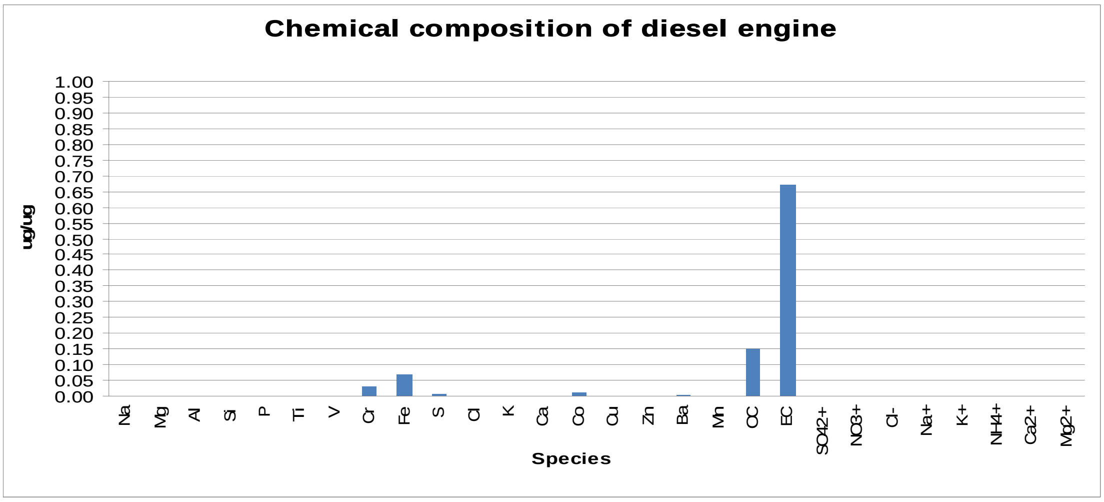


Figure 4-12 Chemical composition of diesel engine.

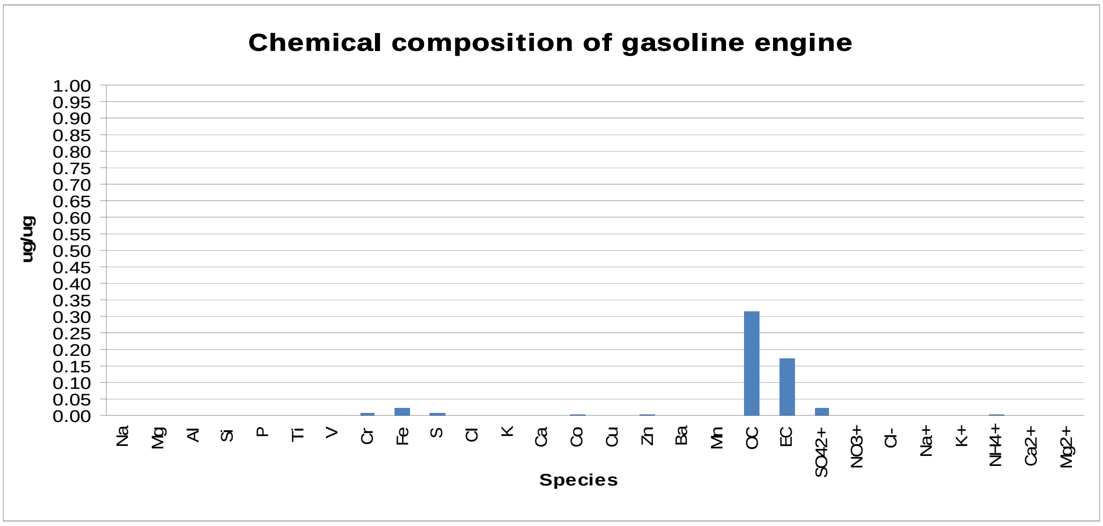


Figure 4-13 Chemical composition of gasoline engine.

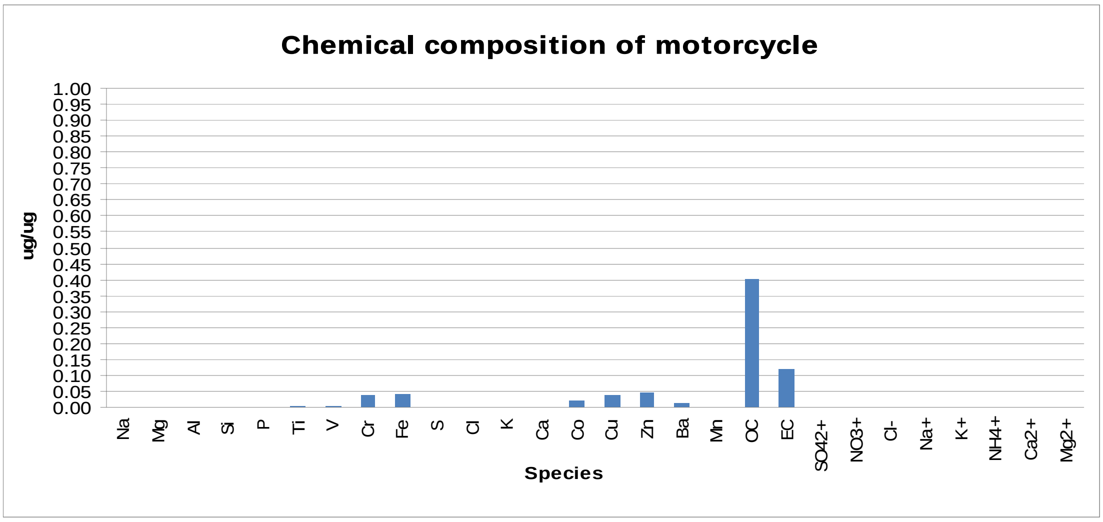


Figure 4-14 Chemical composition of motorcycle.

Table 4-9 Summary of major components of emission sources at Na-Phra-Lan, Chalermphrakiat district.

Species	Source types						
	Portland cement	White cement	Quarry & crushing	Biomass burning	Diesel engines	Gasoline engines	Motorcycle
Na							
Mg	*						
Al	*	*	*				
Si	*	*	*				
P	*						
Ti							
V							
Cr		*			*		*
Fe		*			*	*	*
S	*	*					
Cl	*	*					
K	*	*	*	*			
Ca	*	*	*				
Co					*		*
Cu							*
Zn							*
Ba							*
Mn							
OC				*	*	*	*
EC		*	*	*	*	*	*
SO_4^{2-}	*	*				*	
NO_3^-		*					
Cl^-	*	*					
Na^+		*					
K^+	*						
NH_4^+	*						
Ca^{2+}	*						
Mg^{2+}							

The chemical characteristics relation in Table 4-9 showed outcome of the marker species or major components of emission sources as the following;

Portland cement had Mg, P, K^+, NH_4^+ and Ca^{2+} as the marker species while white cement showed Cr, Fe, NO_3^- and Na^+ as the marker species. Al, Si, K, Ca and EC were marker species for Quarry and crushing which were also found in portland cement and white cement. However, S was not found in quarry and crushing because there was not combustion process for this source type (Table 4-6). The marker species of Biomass burning were K, OC and EC. Diesel engine had Co as the marker species while gasoline engine had SO_4^{2-} as marker species. The marker species for motorcycle were Cu, Zn and Ba, respectively.

5. The chemical characteristics compariron between sources and receptors

In accordance with the chemical characteristics of PM_{10} measured at emission sources and receptor sites, the simple way to observe the source contribution of particulate matter at a receptor use marker elements that refer to one or more than one significant chemical species in the particulate matter from a confident source.

According to table 4-3, it showed the dominant species (≥ 5%) which were found in receptor sites as expressed in table 4-10.

Table 4-10 Summary of dominant chemical composition at receptor sites (%)

Parameters	Percents of chemical composition (%)		
	Khung-Khow-Khew	Na-Phra-Lan	Ban Nhong-Jan
1.Na	0.02	0.04	0.04
2.Mg	0.35	0.38	0.30
3.Al	2.07	2.19	1.99
4.Si	8.17	9.46	11.20
5.P	0.18	0.54	0.51
6.Ti	0.03	0.10	0.00
7.V	0.06	0.05	0.15
8.Cr	3.39	3.46	1.85
9.Fe	5.73	6.25	5.49
10.S	8.52	12.68	19.83
11.Cl	0.88	0.74	0.28
12.K	1.90	2.33	2.60
13.Ca	38.67	27.26	9.40
14.Co	0.00	0.00	0.00
15.Cu	0.01	0.17	0.01
16.Zn	0.03	0.04	0.05
17.Ba	0.00	0.55	0.00
18.Mn	0.23	0.13	0.04
19.OC	0.25	0.62	0.58
20.EC	2.45	2.39	2.44
21.SO_4^{2-}	3.82	5.30	8.23
22.NO_3^-	2.25	2.45	2.98
23.Cl^-	2.06	1.13	4.71
24.Na^+	3.57	1.71	9.55
25.K^+	0.99	1.31	1.27
26.NH_4^+	0.91	2.4	2.36
27.Ca^{2+}	5.17	6.06	0.79
28.Mg^{2+}	0.27	0.26	0.08
29. Unidentify	8.01	9.99	13.29
Total	100	100	100

From the result analysis, the emission sources affected to each receptor sites which were described as table 4-11.

Table 4-11 Emission source contributors of PM_{10} at receptor sites

Receptors	Emission source contributors
Khung-Khow-Khew	1. Portland cement 2. White cement 3. Quarry and crushing
Na-Phra-Lan	1. Portland cement 2. White cement 3. Quarry and crushing
Ban Nhong-Jan	1. Portland cement 2. White cement 3. Quarry and crushing

According to table 4-11, it would be possible to accept the result since Khung-Khow-Khew was located in downwind for dry and wet season, and small quarry and crushing plants(with and without stack), portland cements, white cements (with stack and without stack) were located around this site. The traffic volume was also high in this area (based on the inventory data bases).

In part of Na-Phra-Lan area, it located close to emission sources such as portland cements, white cements, and the traffic volume was high in this area (based on inventory data bases). It also was not far from mining around this area. However, the effects from quarry and crushing plants to Na-Phra-Lan might not be strong as Khung-Khow-Khew area due to the small number of quarry and crushing plants and their locations was far from these plants.

Ban Nhong-Jan also affected the emissions, especially PM_{10}. Although it was located far from the major sources (with stack). However, there were some of small quarry and crushing plants and white cement plants located around the area and closed to mine as well. Considering to the wind direction, Ban Nhong-Jan was located downwind either dry or wet season, so it would be possible to report that this area was also affected by those sources. Figure 4-15 showed location of receptors with wind direction.

Although, using major elements as mentioned is a simple way to locate the emission source contributors but in the real situation there are many chemical species in particulate matter at a receptor source and the chemical species form different sources are similar to each other. It is difficult to determine the result. Therefore, receptor models were developed to find the source contribution for complicated situation in the real world.

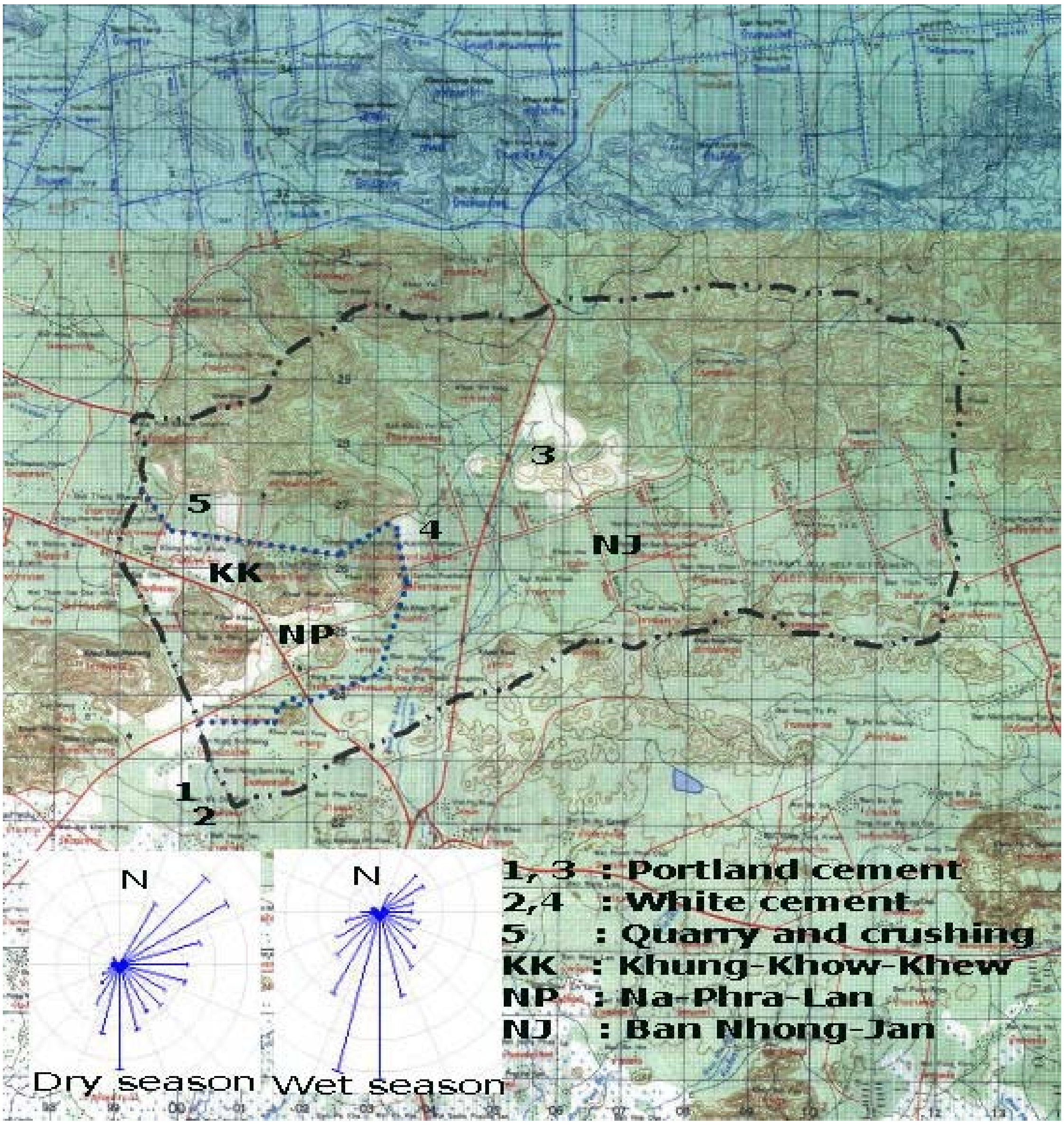


Figure 4-15 Source locations-receptor locations-wind direction (dry-wet season)

6.Source contribution of PM_{10} in Na-Phra-Lan ,Chalermphrakiat district

Source contribution of PM_{10} in this study was investigated by using the receptor model. U.S.EPA. CMB8.2, the model uses the chemical and physical characteristics of particulate matter measured at various emission sources and receptors to estimate source contributions to those receptors.

Receptor model using chemical mass balance concept requires chemical compositions both at a receptor and sources. The output shows the presence of and quantity of sources contributions to a receptor.

According to table 4-1, total samples for chemical composition analysis at the receptor sites were calculated by CMB model to estimate emission sources contribution to the receptor sites. Table 4-12 showed total samples which ran by CMB model.

Table 4-12 Total samples which ran by CMB model.

Areas	Total PM_{10} samples	Total chemical composition analyzed samples	Total samples which ran by CMB model
Khunk-Khow-Khew	64	15	7
Na-Phra-Lan	60	10	7
Ban Nhong-Jan	56	24	7

The results from CMB model showed as table 4-13, 4-14 and 4-15,. respectively.

Table 4-13 Percents of emission source contribution at Khung-Khow-Khew

Date	Source contribution (%)								
	Portland cement	White cement	Quarry & crushing	Diesel engines	Motorcycle	Unknown	R^2	χ^2	%mass
23/8/05	-	46.32	50.46	-	3.22	-	0.96	1.87	93.0
15/11/05	-	34.65	65.35	-	-	-	0.98	1.42	100.5
30/1/06	23.18	75.62	-	0.58	-	0.62	0.92	3.79	94.0
27/2/06	-	84.98	15.02	-	-	-	0.88	3.87	117.9
14/3/06	-	49.57	50.43	-	-	-	0.93	2.41	115.8
16/3/06	-	66.96	33.04	-	-	-	0.94	2.25	120.5
20/3/06	20.96	62.38	-	-	-	16.66	0.91	3.82	100.2
Average	6.31	60.07	30.61	0.08	0.46	2.47	-	-	-

Table 4-14 Percents of emission source contribution at Na-Phra-Lan

Date	Source contribution (%)							
	Portland cement	White cement	Quarry & crushing	Diesel engines	Unknown	R^2	χ^2	%mass
18/11/05	24.29	69.28	-	6.43	-	0.95	3.34	91.6
26/1/06	23.69	64.15	-	12.16	-	0.94	3.08	102.8
15/2/06	22.44	75.92	-	1.64	-	0.92	3.56	107.3
27/2/06	21.00	79.00	-	-	-	0.93	2.73	117.9
14/3/06	15.12	42.99	39.90	1.99	-	0.92	4.01	99.9
20/3/06	-	68.17	31.83	-	-	0.96	2.39	122.8
26/3/06	14.74	82.35	-	2.92	-	0.92	3.63	119.7
Average	17.33	68.84	10.25	3.59	-	-	-	-

Table 4-15 Percents of emission source contribution at Ban Nhong-Jan

Date	Source contribution (%)						
	Portland cement	White cement	Biomass burning	Unknown	R^2	χ^2	%mass
21/7/05	-	95.64	0.06	4.3	0.98	1.72	97.7
23/8/05	-	94.26	5.74	-	0.98	0.63	110.0
15/11/05	-	85.68	14.32	-	0.91	3.89	93.3
27/12/05	18.25	76.20	5.55	-	1.0	0.0	88.9
30/12/05	20.35	66.76	12.89	-	1.0	0.0	102.0
14/3/06	-	90.86	0.06	9.08	0.97	1.69	111.4
29/3/06	-	97.43	0.06	2.51	0.96	1.92	113.5
Average	5.51	86.69	5.53	2.27	-	-	-

1) Emission sources contributed to receptor sites.

Khung-Khow-Khew: Major emission sources contribution significantly emitted from white cement, quarry and crushing, portland cement, motorcycle and diesel engine with 60.07, 30.61, 6.31, 0.46 and 0.08 percents respectively. An unknown source contribution was 2.47 percents.

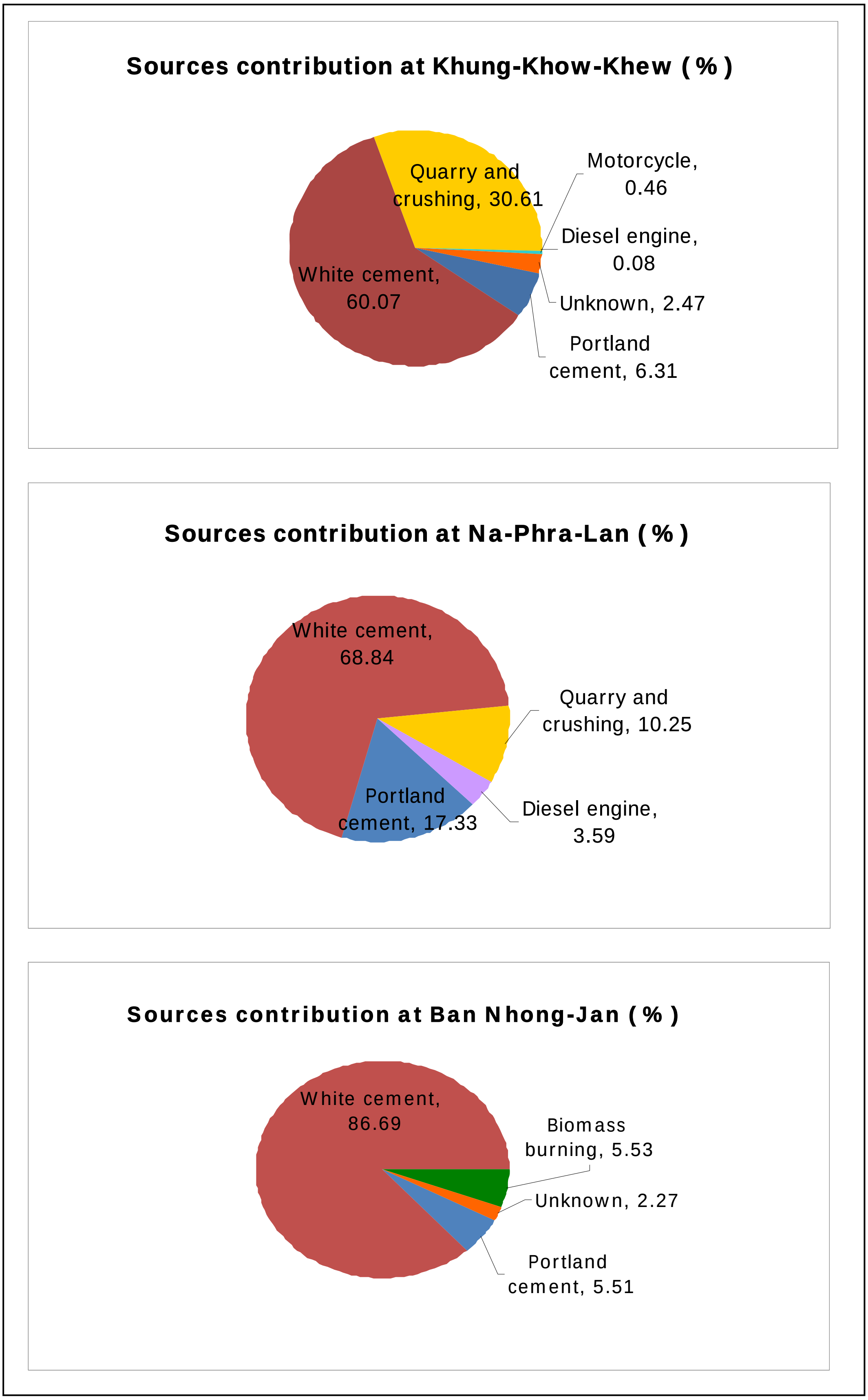
Na-Phra-Lan: Key sources contributions were white cement, portland cement, quarry and crushing plant and diesel engine at 68.84, 17.33, 10.25 and 3.59 percents, respectively.

Ban Nhong-Jan: The significant sources contribution dramatically expressed by white cement, biomass burning and portland cement at 86.69, 5.53 and 5.51 percents respectively. An unidentified source was 2.27 percents.

Table 4-16 and figure 4-16 expressed summary of emission sources contribution of each receptor sites.

Table 4-16 Percent of emission sources contribution to receptor sources

Emission sources	Source contributions (%)		
	Khung-Khow-Khew	Na-Phra-Lan	Ban Nhong-Jan
Portland cement	6.31	17.33	5.51
White cement	60.07	68.84	86.69
Quarry and crushing	30.61	10.25	-
Biomass burning	-	-	5.53
Diesel engine	0.08	3.59	-
Motorcycle	0.46	-	-
Unknown sources	2.47	-	2.27
Total	100.00	100.00	100.00



Sources contribution at Khung-Khow-Khew (%)

Sources contribution at Na-Phra-Lan (%)

Sources contribution at Ban Nhong-Jan (%)

Figure 4-16 Summary of emission sources contribution at receptor sites

Considering about wind direction in Na-Phra-Lan, Chaleamphrakiat district area with the summary on emission sources contribution in table 4-11, especially portland cement plants, white cement plants and quarry and crushing plants which affected to them, so the receptors were acceptable and appropriate in a particular situation due to the wind roses. It showed that these receptors were located downwind of the study area either dry or wet season as showed in figure 4-15.

The average results of 3 receptors showed that major PM_{10} source contributions in Na-Phra-Lan, Chalermphrakiat district, Saraburi provice came from white cement, quarry and crushing, portland cement, biomass burning diesel engine and motorcycle at 71.87, 13.62, 9.72, 1.84, 1.22 and 0.15 percents, respectively. An unidentified source was 1.58 percents.

Table 4-17 and figure 4-17 showed the sources contribution of PM_{10} in Na-Phra-Lan, Chaleamphrakiat district, Saraburi provice.

Table 4-17 Summary of emission sources contribution to Na-Phra-Lan, Chalermphrakiat district, Saraburi province

Emission sources	Source contributions (%)			
	Khung-Khow-Khew	Na-Phra-Lan	Ban Nhong-Jan	Average
Portland cement	6.31	17.33	5.51	9.72
White cement	60.07	68.84	86.69	71.87
Quarry and crushing	30.61	10.25	-	13.62
Biomass burning	-	-	5.53	1.84
Diesel engine	0.08	3.59	-	1.22
Motorcycle	0.46	-	-	0.15
Unknown sources	2.47	-	2.27	1.58
Total	100	100	100	100

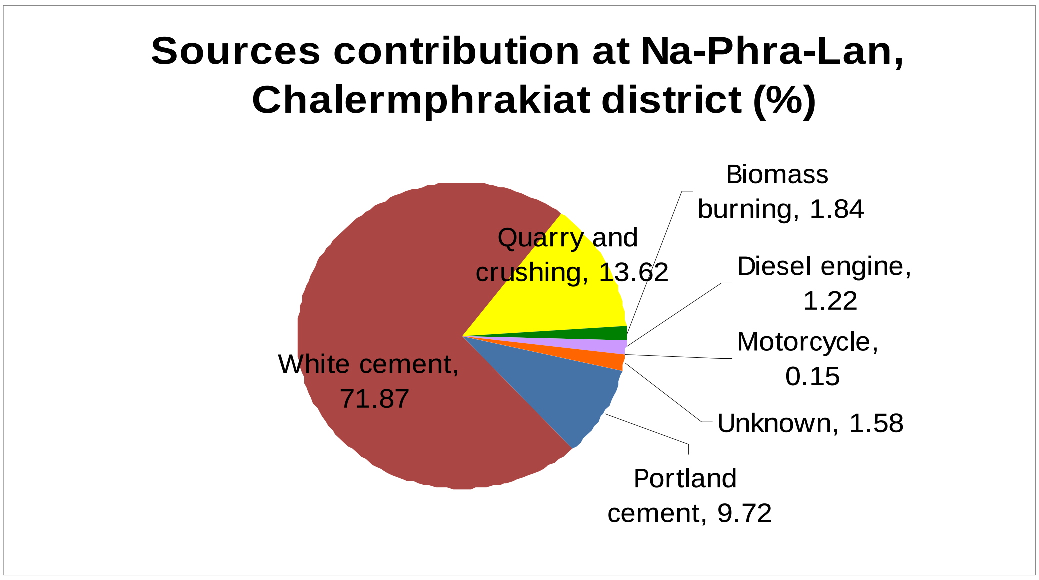


Figure 4-17 Sources contribution at Na-Phra-Lan, Chaleamphrakiat district

2) Comparison between emission inventory and CMB technique in case of fugitive emission source.

In comparison between CMB model and emission inventory technique, emission factor was used for emission inventory technique by obtaining secondary data for calculation. CMB model uses linear equations to express each receptor chemical concentration as a linear sum of actual emission data of source profile abundances to calculate emission concentration at receptor site In case of fugitive emission, CMB model should be recommended to use as technique for emission calculation in conjunction with emission factor to also improve the best emission inventory as showed in table 4-18.

Table 4-18 Comparison between emission inventory and CMB technique at Na-Phra-Lan, Chalermphrakiat district.

Source types	Percents of proportion (%)	
	Emission inventory	CMB technique
Portland cement	5.50	9.72
White cement	14.07	71.87
Quarry and crushing	35.13	13.62
Biomass burning	3.12	1.84
Vehicles	42.18	1.37
Unknown	-	1.58
Total	100	100

CHAPTER V

DISCUSSION

There are 2 techniques to be expressed in this section for analyzing the emission source contributor in the study area. Firstly, simple technique, by comparing chemical composition between receptor sites and emission sources, is a tool to look at which emission source plays as a contributor to the receptors of this study. Secondly, CMB model technique use as advance tool to clarify which emission sources are the major source contributor to the receptor sites.

1. In simple technique, as shown in table 4-8, 4-9 and 4-10, emission sources contribute to either Khung-Khow-Khew, Na-Pha-Lan or Ban Nhong-Jan were portland cement, white cement, quarry and crushing, biomass burning and vehicles according to chemical species of emission sources found in those receptor areas. However, simple technique cannot point out which emission sources were a major contributor of this area. In air quality management, major contributor of each area and proportion of each emission sources have to be known in order to establish an appropriate air quality strategy to combat air pollution. Totally, a simple technique cannot give best practice to assist us to make much more comprehensive air quality strategy plan. However, this simple technique likes a first step to be very useful for looking for number of emission sources which will be focused on more details of the study.

2. In advance technique, CMB model was introduced in this study to give comprehensive data sets to identify sources apportionment. In table 4-11 and figure 4.15, we found that majority contributor for all receptor sites were white cement, quarry and crushing and portland cement except Ban Nhong-Jan. It was not found quarry and crushing as one of emission source contributor in the area. However, vehicles such as diesel engine and motorcycle were found some contribution to Khung-Khow-Khew and Na-Phra-Lan, while Ban Nhong-Jan found biomass burning as the third of emission source contribution in the area. The effect of quarry and

crushing at Na-Phra-Lan was not strong as much as Khung-Khow-Khew due to the Na-Phra-Lan location was not in the center of quarry and crushing activities as Khung-Khow-Khew location.

3. In table 4-12, we found that majority contributors for Na-Phra-Lan, Chalermphrakiat district area were white cement, quarry and crushing and portland cement at 71.87, 13.60 and 9.72 percents, respectively. Similarly, emission inventory report of this area pointed out that white cement, portland cement and quarry and crushing in the study area are major of PM_{10} contributors at 67, 26 and 7 percents, respectively. This can confirm that air quality strategy plan to combat particulate matter in this area should focus on these emission sources for first priority.

4.In comparison between CMB model and emission inventory technique, emission factor was used for emission inventory technique by obtaining secondary data for calculation. CMB model uses linear equations to express each receptor chemical concentration as a linear sum of actual emission data of source profile abundances to calculate emission concentration at receptor site In case of fugitive emission, CMB model should be recommended to use as technique for emission calculation in conjunction with emission factor to also improve the best emission inventory.

5. To create a completed source profiles to represent identified contributors is necessary to get more 90 percent recovery the chemical composition in the sample from all sites. In case of high percents of unknown in the result, it might be lost the trace elements which would be the marker species as the characteristic for these sources.

6. In case of unknown source contributors, these would be other activities such as soil dust, road dust which were not collected to create source profiles in this study.

CHAPTER VI

CONCLUSIONS

Conclusions of this study

1. The sources of PM_{10} at Na-Phra-Lan, Chaleamphrakiat district.

Relation to the result of chemical composition analysis from sources contribution in this study area found that the major sources types such as Portland cement plants, white cement plants and quarry and crushing plants had major chemical components(Ca, Si ,Al and K). However, each source type has had their emission characteristic which could help to identify sources contributor to the receptor area. Portland cement had Mg, P, K^+, NH_4^+ and Ca^{2+} as the marker species of chemical composition while white cement showed Cr, Fe, NO_3^- and Na^+ as the marker species. Al, Si, K, Ca and EC were marker species for Quarry and crushing which were also found in portland cement and white cement. However, S was not found in quarry and crushing due to there was not combustion process for this source type (Table 4-6). The marker species of Biomass burning were K, OC and EC. Diesel engine had Co as the marker species while gasoline engine had SO_4^{2-} as marker species. The marker species for motorcycle were Cu, Zn and Ba, respectively.

The summary of PM_{10} sources in Na-Phra-Lan, Chaleamphrakiat district were white cement plants, quarry and crushing plants, Portland cement plants, biomass burning, diesel vehicle and motorcycle at 71.87, 13.62, 9.72, 1.84, 1.22 and 0.15 percents, respectively.

2. The chemical composition in Na-Phra-Lan, Chaleamphrakiat district.

The result of PM_{10} chemical composition analysis of 3 receptor sites in Na-Phra-Lan, Chalermphrakiat district, Saraburi province found that the PM_{10} chemical composition analysis of Khung-Khow-Khew area was similar to Na-Phra-Lan area especially Ca, Si, S, Fe and Ca^{2+}. Both of Ca and Si element were high in atmosphere of Khung-Khow-Khew and Na-Phra-Lan areas at 38.67 and 8.17 percents for Khung-Khow-Khew, 27.26 and 9.46 percents for Na-Phra-Lan areas respectively. Na^+ and SO_4^{2-} were the highest percents at Ban Nhong-Jan at 9.55 and 8.23 percents, respectively.

Ban Nhong-Jan found Na^+, SO_4^{2-}, Cl^- , K and S higher than Khung-Khow-Khew and Na-Phra-Lan site.

OC and EC at Ban Nhong-Jan site were similar to Khung-Khow-Khew and Na-Phra-Lan site.

The summary of dominant chemical composition found in Na-Phra-Lan, Chalermphrakiat district were Ca, S, Si, Fe, SO_4^+ and Ca^{2+} at 25.11, 13.68, 9.61, 5.82, 5.78 and 4.01 percents respectively which represented to cement groups. It found Ca, Si ,S and Fe as major chemical components at 58.03, 18.6, 13.50 and 3.61% respectively. Cement groups were also the major sources contributors in the study area.

Recommendations of this study

As mentioned in previous chapter, Chemical Mass Balance model is very useful to identify source of air pollutants, including particle matter, volatile organic compounds and so on. However, usage of this model would also consider or focus on these recommendations in order to minimize limitation of model and other factors which can lead to misunderstand situation of the study. In this study, recommendations could be listed as the followings;

1. Usage of model result without other information to point out sources apportionment, especially emission inventory of study area, can lead to establish an inappropriate policy to combat air pollution in the study area. Emission inventory data can be a supporter to confirm CMB model whether result of this model corporate with number of emission sources in the area. Within sources apportionment, emission inventory should be recommended and done together with CMB model.

2. Limitation of instrument to analyze chemical composition of sample, basically, species should be analyzed directly by their own technique. In this study, there was not an instrument to analyze elemental carbon directly, elemental carbon was obtained by analyzing total carbon and organic carbon, and calculated elemental carbon from their

difference. So that took a long path to have a best fit operating condition for analysis that could lead to inaccuracy.

3. In case of fugitive emission, CMB model should be recommended to use as technique for emission calculation in conjunction with emission factor to also improve the best emission inventory.

4. Limitation of CMB model, as mentioned in earlier, CMB model uses statistical technique by paring chemical species between emission sources and receptors to specify what emission sources play a major role to air quality over atmosphere. In fact, pollutants dispersion depends on several factors, particularly in meteorological data, stack high of emission sources and distance between emission sources and receptors. These factors can effect to ground level concentration of particle in this study. In order to determine whether which emission sources is a real major contributor, dispersion model and meteorological model are useful in conjunction with CMB analysis to determine where contributions might have come from which are very useful to identify more accuracy and improve their weakness.

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APPENDIX

APPENDIX A

LIST OF CHEMICAL SPECIES

Specie names	**Analytical Technique**
TMAC	Total Mass by gravimeter
NAXF	Sodium by XRF
MGXF	Magnesium by XRF
ALXF	Aluminum by XRF
SIXF	Silicon by XRF
PXF	Phosphorus by XRF
TIXF	Titanium by XRF
VXF	Vanadium by XRF
CRXF	Chromium by XRF
FEXF	Iron by XRF
SXF	Sulfur by XRF
CLXF	Chlorine by XRF
KXF	Potassium by XRF
CAXF	Calcium by XRF
COXF	Cobalt by XRF
CUXF	Copper by XRF
ZNXF	Zinc by XRF
BAXF	Barium by XRF
MNXF	Manganese by XRF
OCTC	Organic carbon by TOC
ECTC	Elemental carbon by TOC
SO4I	Soluble sulfate ion by IC
NO3I	Soluble nitrate ion by IC
CLI	Soluble chloride ion by IC
NAI	Soluble sodium ion by AA
KI	Soluble potassium ion by IC
NH4I	Soluble ammonium ion by UV
CA2I	Soluble calcium ion by IC
MG2I	Soluble magnesium ion by IC

APPENDIX B

LIST OF EMISSION SOURCES

Code names	**Emission sources**
SR001	Portland cement plant
SR002	White cement plant
SR003	Quarry and crushing plant
SR004	Biomass burning
SR005	Heavy-duty truck
SR006	Light-duty truck
SR007	Gasoline vehicle
SR008	Motorcycle

APPENDIX C

CMB MODEL

```
                 Chemical Mass Balance Version EPA-CMB8.2
                         Report Date: 10/8/2008

SAMPLE:                        OPTIONS:                    INPUT FILES:

SITE:        HJ47020           BRITT & LUECKE:       No       INsr.IN8..txt
SAMPLE DATE:   7/21/05         SOURCE ELIMINATION: No             PR.sel
DURATION:      24              BEST FIT:           No             SP.sel
START HOUR:    0                                                  AD1.sel
SIZE:        FINE                                                 AD.csv
                                                                  PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

    R SQUARE        0.98                % MASS          97.7
  CHI SQUARE        1.72        DEGREES FREEDOM          1


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)   Std Err     Tstat
----------------------------------------------------
YES SR002  LDUST     31.52313    5.38992    5.84854
YES SR004  QDUST      1.43299    1.57528    0.90967
YES SR005  BIOMC      0.01898    0.00829    2.29039
YES SR007  MDUST     -0.01543    0.00486   -3.17071

----------------------------------------------------
                 32.95967

MEASURED CONCENTRATION FOR SIZE: FINE
     33.7+-    3.4
```

```
              Chemical Mass Balance Version EPA-CMB8.2
                     Report Date: 9/10/2008

SAMPLE:                  OPTIONS:                          INPUT FILES:

SITE:        HJ47021     BRITT & LUECKE:        No              INsr2f1.IN8.txt
SAMPLE DATE:   23/8/05   SOURCE ELIMINATION:      No                     PR.sel
DURATION:      24        BEST FIT:            No                         SP.sel
START HOUR:    0                                                      AD2f1.sel
SIZE:        FINE                                                     AD2f1.csv
                                                                         PR.csv
Species Array: 10
Sources Array: 10

FITTING STATISTICS:

      R SQUARE      0.98                   % MASS         110.0
   CHI SQUARE      0.63         DEGREES FREEDOM          2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
-------------------------------------------------
YES SR002  LDUST      52.88340    6.87777    7.68903
YES SR005  BIOMC       3.22028    0.71819    4.48390

-------------------------------------------------
                 56.10368

MEASURED CONCENTRATION FOR SIZE: FINE
     51.0+-     5.1
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                        Report Date: 10/8/2008

SAMPLE:                  OPTIONS:                          INPUT FILES:

SITE:        HJ47029     BRITT & LUECKE:       No                INsr.IN8..txt
SAMPLE DATE:   11/15/05  SOURCE ELIMINATION:     No                   PR.sel
DURATION:     24          BEST FIT:            No                     SP.sel
START HOUR:    0                                                     AD1.sel
SIZE:        FINE                                                     AD.csv
                                                                      PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

     R SQUARE     0.91                   % MASS          93.3
   CHI SQUARE     3.89          DEGREES FREEDOM           2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR002  LDUST      29.76523    3.96319    7.51042
YES SR005  BIOMC       4.97314    1.09563    4.53906

--------------------------------------------------
                  34.73837

MEASURED CONCENTRATION FOR SIZE: FINE
     37.2+-    3.7
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                           Report Date: 10/9/2008

SAMPLE:                     OPTIONS:                          INPUT FILES:

SITE:        HJ47057        BRITT & LUECKE:       No            INsr2f1.IN8.txt
SAMPLE DATE:   27/12/05 SOURCE ELIMINATION:     No                     PR.sel
DURATION:      24           BEST FIT:             No                   SP.sel
START HOUR:    0                                                    AD2f1.sel
SIZE:        FINE                                                   AD2f1.csv
                                                                       PR.csv
Species Array: 7
Sources Array: 8

FITTING STATISTICS:

       R SQUARE      1.00                % MASS              88.9
    CHI SQUARE      0.00          DEGREES FREEDOM        0


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)  Std Err     Tstat
----------------------------------------------------

YES SR001 CDUST       7.93938      2.15333   3.68703
YES SR002 LDUST      33.15353      7.41446   4.47147
YES SR005 BIOMC       2.41364      0.77783   3.10305
 ----------------------------------------------------
                  43.50655

MEASURED CONCENTRATION FOR SIZE: FINE
     48.9    4.9
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                          Report Date: 10/9/2008

SAMPLE:                   OPTIONS:                          INPUT FILES:

SITE:       HJ47058       BRITT & LUECKE:       No             INsr2f1.IN8.txt
SAMPLE DATE:   30/12/05   SOURCE ELIMINATION:      No                   PR.sel
DURATION:      24         BEST FIT:             No                      SP.sel
START HOUR:    0                                                     AD2f1.sel
SIZE:       FINE                                                     AD2f1.csv
                                                                        PR.csv
Species Array: 7
Sources Array: 8

FITTING STATISTICS:

        R SQUARE     1.00             % MASS            102.0
     CHI SQUARE     0.00        DEGREES FREEDOM        0


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)  Std Err    Tstat
---------------------------------------------------
YES SR001 CDUST     13.28927    3.42426  3.88092
YES SR002 LDUST     43.60962    9.75325  4.47129
YES SR005 BIOMC      8.41822     2.08245  4.04245


---------------------------------------------------
            65.31711

MEASURED CONCENTRATION FOR SIZE: FINE
   64.0+--   6.4
```

```
                Chemical Mass Balance Version EPA-CMB8
                       Report Date: 10/8/2008

SAMPLE:                 OPTIONS:                          INPUT FILES:

SITE:        HJ47064    BRITT & LUECKE:        No           INsr.IN8..txt
SAMPLE DATE:  3/14/06   SOURCE ELIMINATION:     No                 PR.sel
DURATION:      24       BEST FIT:            No                    SP.sel
START HOUR:    0                                                  AD1.sel
SIZE:        FINE                                                  AD.csv
                                                                   PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

     R SQUARE     0.97             % MASS            111.4
   CHI SQUARE     1.69       DEGREES FREEDOM          2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err     Tstat
--------------------------------------------------
YES SR002  LDUST     24.51784    3.34712    7.32505
YES SR004  QDUST      2.46489    1.27418    1.93449
YES SR005  BIOMC      0.01549    0.00657    2.35675
YES SR007  MDUST     -0.01256    0.00376   -3.34434

--------------------------------------------------
                 26.98566

MEASURED CONCENTRATION FOR SIZE: FINE
    24.2+-    2.4
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                             Report Date: 10/8/2008

SAMPLE:                  OPTIONS:                              INPUT FILES:

SITE:        HJ47008     BRITT & LUECKE:        No                 INsr.IN8..txt
SAMPLE DATE:   3/29/06    SOURCE ELIMINATION:     No                      PR.sel
DURATION:      24        BEST FIT:              No                        SP.sel
START HOUR:    0                                                         AD1.sel
SIZE:        FINE                                                         AD.csv
                                                                          PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

      R SQUARE     0.96              % MASS              113.5
    CHI SQUARE     1.92          DEGREES FREEDOM           2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
---------------------------------------------------
YES SR002  LDUST     74.46320   10.17710    7.31674
YES SR004  QDUST      1.95330    3.37614     0.57856
YES SR005  BIOMC      0.04426    0.01908     2.31986
YES SR007  MDUST     -0.03623    0.01101    -3.28965

---------------------------------------------------
                 76.42453

MEASURED CONCENTRATION FOR SIZE: FINE
                                      67.4+-    6.7
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                           Report Date: 10/9/2008

SAMPLE:                   OPTIONS:                          INPUT FILES:

SITE:        KK47015      BRITT & LUECKE:        No          INsr2f1.IN8.txt
SAMPLE DATE:   23/8/05    SOURCE ELIMINATION:    No                   PR.sel
DURATION:      24         BEST FIT:              No                   SP.sel
START HOUR:    0                                                  AD2f1.sel
SIZE:        FINE                                                 AD2f1.csv
                                                                     PR.csv
Species Array: 7
Sources Array: 2

FITTING STATISTICS:

      R SQUARE     0.96              % MASS               93.0
    CHI SQUARE     1.87         DEGREES FREEDOM            3


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)  Std Err     Tstat
--------------------------------------------------
YES SR002 LDUST     59.50706     7.72587    7.70231
YES SR004 QDUST     64.82858    11.64152   5.56874
YES SR007 MDUST      4.14114     0.92362   4.48359


--------------------------------------------------
              128.47678

MEASURED CONCENTRATION FOR SIZE: FINE
   138.2+-   13.8
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                         Report Date: 8/10/2008

SAMPLE:                      OPTIONS:                     INPUT FILES:

SITE:        KK47006          BRITT & LUECKE:       No        INsr.IN8..txt
SAMPLE DATE:   11/15/05       SOURCE ELIMINATION:      No            PR.sel
DURATION:      24            BEST FIT:             No                SP.sel
START HOUR:    0                                                    AD1.sel
SIZE:        FINE                                                    AD.csv
                                                                     PR.csv
Species Array: 10
Sources Array: 6

FITTING STATISTICS:

      R SQUARE     0.98              % MASS             100.5
    CHI SQUARE     1.42        DEGREES FREEDOM            2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err     Tstat
--------------------------------------------------
YES SR002  LDUST     31.12934     7.38550    4.21493
YES SR004  QDUST     58.70124    10.50936    5.58561
YES SR005  BIOMC     -0.00283     0.00075   -3.76842

--------------------------------------------------
                 89.82775

MEASURED CONCENTRATION FOR SIZE: FINE
    89.4+-    8.9
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                           Report Date: 8/10/2008

SAMPLE:                    OPTIONS:                          INPUT FILES:

SITE:          KK47009     BRITT & LUECKE:         No             INsr.IN8..txt
SAMPLE DATE:   1/30/06     SOURCE ELIMINATION:      No                  PR.sel
DURATION:       24         BEST FIT:               No                   SP.sel
START HOUR:    0                                                       AD1.sel
SIZE:          FINE                                                     AD.csv
                                                                        PR.csv
Species Array: 8
Sources Array: 2

FITTING STATISTICS:

      R SQUARE     0.92                % MASS              94.0
   CHI SQUARE      3.79         DEGREES FREEDOM             5


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR001  CDUST      51.69284   10.50728    4.91972
YES SR002  LDUST     168.67407   24.19379    6.97179
YES SR003  DDDT        2.68380    1.29396    2.07410

--------------------------------------------------
                 223.05070

MEASURED CONCENTRATION FOR SIZE: FINE
   237.2+-    23.7
```

```
              Chemical Mass Balance Version EPA-CMB8.2
                     Report Date: 8/10/2008

SAMPLE:                   OPTIONS:                     INPUT FILES:

SITE:        KK47018      BRITT & LUECKE:      No             INsr.IN8..txt
SAMPLE DATE:   2/27/06     SOURCE ELIMINATION:    No                 PR.sel
DURATION:     24          BEST FIT:            No                    SP.sel
START HOUR:    0                                                    AD1.sel
SIZE:        FINE                                                    AD.csv
                                                                     PR.csv
Species Array: 9
Sources Array: 8

FITTING STATISTICS:

     R SQUARE     0.88             % MASS            117.9
   CHI SQUARE     3.87        DEGREES FREEDOM         10


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err     Tstat
--------------------------------------------------
YES SR002  LDUST     90.73239    7.03142   12.90386
YES SR004  QDUST     16.04285    3.97220    4.03878

--------------------------------------------------
                106.77524

MEASURED CONCENTRATION FOR SIZE: FINE
    90.5+-    9.1
```

```
                  Chemical Mass Balance Version EPA-CMB8.2
                         Report Date: 10/8/2008

SAMPLE:                    OPTIONS:                          INPUT FILES:

SITE:         KK47019      BRITT & LUECKE:        No          INsr.IN8..txt
SAMPLE DATE:   3/14/06     SOURCE ELIMINATION:      No             PR.sel
DURATION:      24          BEST FIT:              No                SP.sel
START HOUR:    0                                                   AD1.sel
SIZE:         FINE                                                  AD.csv
                                                                    PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

      R SQUARE     0.93              % MASS              115.8
   CHI SQUARE      2.41        DEGREES FREEDOM          8


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR002  LDUST      38.12020    3.21119   11.87107
YES SR004  QDUST     38.78397    6.20440      6.25104

--------------------------------------------------
                76.90417

MEASURED CONCENTRATION FOR SIZE: FINE
    66.4+-    6.6
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                           Report Date: 8/10/2008

SAMPLE:                   OPTIONS:                          INPUT FILES:

SITE:         KK47020     BRITT & LUECKE:        No             INsr.IN8..txt
SAMPLE DATE:   3/16/06    SOURCE ELIMINATION:      No                  PR.sel
DURATION:      24         BEST FIT:              No                    SP.sel
START HOUR:    0                                                      AD1.sel
SIZE:         FINE                                                     AD.csv
                                                                       PR.csv
Species Array: 9
Sources Array: 8

FITTING STATISTICS:

       R SQUARE      0.94               % MASS              120.5
    CHI SQUARE      2.25           DEGREES FREEDOM          6


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
---------------------------------------------------
YES SR002  LDUST      72.14491    7.49792    9.62199
YES SR004  QDUST      35.60607    7.48979    4.75395

---------------------------------------------------
                 107.75098

MEASURED CONCENTRATION FOR SIZE: FINE
     89.4+-     8.9
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                        Report Date: 8/10/2008

SAMPLE:                    OPTIONS:                      INPUT FILES:

SITE:       KK47021        BRITT & LUECKE:        No            INsr.IN8..txt
SAMPLE DATE:   3/20/06     SOURCE ELIMINATION:      No                 PR.sel
DURATION:     24           BEST FIT:              No                   SP.sel
START HOUR:    0                                                      AD1.sel
SIZE:       FINE                                                       AD.csv
                                                                       PR.csv
Species Array: 8
Sources Array: 9

FITTING STATISTICS:

      R SQUARE      0.91             % MASS             100.2
   CHI SQUARE      3.82        DEGREES FREEDOM         7


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
------------------------------------------------
YES SR001  CDUST      22.03776    6.02192    3.65959
YES SR002  LDUST      65.59081    6.98432    9.39115
YES SR004  QDUST      17.51831  11.68389    1.49936

------------------------------------------------
               105.14687

MEASURED CONCENTRATION FOR SIZE: FINE
   105.0+-    10.5
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                        Report Date: 10/9/2008

SAMPLE:                    OPTIONS:                          INPUT FILES:

SITE:        NP47045       BRITT & LUECKE:        No        INsr2f1.IN8.txt
SAMPLE DATE:   18/11/05   SOURCE ELIMINATION:      No                PR.sel
DURATION:      24          BEST FIT:              No                 SP.sel
START HOUR:    0                                                  AD2f1.sel
SIZE:        FINE                                                 AD2f1.csv
                                                                     PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

       R SQUARE      0.95              % MASS              91.6
    CHI SQUARE      3.34         DEGREES FREEDOM          2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)  Std Err     Tstat
---------------------------------------------------
YES SR001 CDUST      24.44727   4.91511   4.97390
YES SR002 LDUST      69.73566  12.23082   5.70163
YES SR003 DDDT        6.47323   1.44774   4.47128


---------------------------------------------------
                100.65617

MEASURED CONCENTRATION FOR SIZE: FINE
   109.9+-   11.0
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                           Report Date: 10/8/2008

SAMPLE:                     OPTIONS:                         INPUT FILES:

SITE:       NP47007        BRITT & LUECKE:       No              INsr.IN8..txt
SAMPLE DATE:   1/26/06     SOURCE ELIMINATION:      No                  PR.sel
DURATION:      24          BEST FIT:            No                      SP.sel
START HOUR:    0                                                       AD1.sel
SIZE:       FINE                                                        AD.csv
                                                                        PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

      R SQUARE      0.94                % MASS              102.8
   CHI SQUARE      3.08           DEGREES FREEDOM         4


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
---------------------------------------------------
YES SR001  CDUST      34.29493    6.45520    5.31276
YES SR002  LDUST      92.85986   16.18318    5.73805
YES SR003  DDDT      17.59694     3.92984    4.47777

---------------------------------------------------
                  144.75172

MEASURED CONCENTRATION FOR SIZE: FINE
   140.8+-    14.1
```

```
                  Chemical Mass Balance Version EPA-CMB8.2
                          Report Date: 10/8/2008

SAMPLE:                   OPTIONS:                         INPUT FILES:

SITE:        NP47008      BRITT & LUECKE:       No                INsr.IN8..txt
SAMPLE DATE:   2/15/06    SOURCE ELIMINATION:      No                    PR.sel
DURATION:      24         BEST FIT:             No                       SP.sel
START HOUR:    0                                                        AD1.sel
SIZE:        FINE                                                        AD.csv
                                                                         PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

     R SQUARE     0.92              % MASS               107.3
   CHI SQUARE     3.56         DEGREES FREEDOM             8


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR001  CDUST      21.02864    3.56729    5.89485
YES SR002  LDUST      71.14846    8.00302    8.89021
YES SR003  DDDT        1.53954    0.59083    2.60571

--------------------------------------------------
                   93.71664

MEASURED CONCENTRATION FOR SIZE: FINE
    87.3+-    8.7
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                        Report Date: 10/8/2008

SAMPLE:                    OPTIONS:                        INPUT FILES:

SITE:        NP47010       BRITT & LUECKE:       No              INsr.IN8..txt
SAMPLE DATE:  2/27/06      SOURCE ELIMINATION:      No                  PR.sel
DURATION:      24          BEST FIT:          No                        SP.sel
START HOUR:    0                                                       AD1.sel
SIZE:        FINE                                                      AD.csv
                                                                        PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

     R SQUARE     0.93            % MASS              117.9
   CHI SQUARE     2.73        DEGREES FREEDOM           6


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR001  CDUST      17.54919    3.52341    4.98074
YES SR002  LDUST      66.00657    7.95924    8.29307
YES SR003  DDDT       -0.00547    0.00149   -3.67918

--------------------------------------------------
              83.55029

MEASURED CONCENTRATION FOR SIZE: FINE
    70.9+-    7.1
```

```
                 Chemical Mass Balance Version EPA-CMB8.2
                        Report Date: 10/8/2008

SAMPLE:                    OPTIONS:                          INPUT FILES:

SITE:       NP47013        BRITT & LUECKE:       No              INsr.IN8..txt
SAMPLE DATE:   3/14/06     SOURCE ELIMINATION:     No                   PR.sel
DURATION:     24           BEST FIT:          No                        SP.sel
START HOUR:    0                                                       AD1.sel
SIZE:       FINE                                                        AD.csv
                                                                        PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

      R SQUARE     0.92              % MASS            99.9
   CHI SQUARE     4.01         DEGREES FREEDOM         7


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
---------------------------------------------------
YES SR001  CDUST      14.87995    4.68759    3.17433
YES SR002  LDUST      42.31593    5.16460    8.19346
YES SR003  DDDT        1.96486    0.63752    3.08204
YES SR004  QDUST      39.28190   11.19797    3.50795

---------------------------------------------------
                  98.44263

MEASURED CONCENTRATION FOR SIZE: FINE
    98.6+-    9.9
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                           Report Date: 10/8/2008

SAMPLE:                   OPTIONS:                          INPUT FILES:

SITE:        NP47020      BRITT & LUECKE:        No             INsr.IN8..txt
SAMPLE DATE:   3/20/06    SOURCE ELIMINATION:      No                  PR.sel
DURATION:      24         BEST FIT:             No                     SP.sel
START HOUR:    0                                                      AD1.sel
SIZE:        FINE                                                      AD.csv
                                                                       PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

      R SQUARE     0.96               % MASS             122.8
   CHI SQUARE      2.39          DEGREES FREEDOM           2


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR002  LDUST      66.00538   11.63286    5.67404
YES SR004  QDUST      30.82634    7.16279     4.30368

--------------------------------------------------
                  96.83172

MEASURED CONCENTRATION FOR SIZE: FINE
     78.9+-     7.9
```

```
                    Chemical Mass Balance Version EPA-CMB8.2
                            Report Date: 10/8/2008

SAMPLE:                  OPTIONS:                              INPUT FILES:

SITE:        NP47022     BRITT & LUECKE:       No                INSr.IN8..txt
SAMPLE DATE:   3/26/06   SOURCE ELIMINATION:     No                     PR.sel
DURATION:      24        BEST FIT:             No                       SP.sel
START HOUR:    0                                                       AD1.sel
SIZE:        FINE                                                       AD.csv
                                                                        PR.csv
Species Array: 7
Sources Array: 1

FITTING STATISTICS:

      R SQUARE      0.92              % MASS            119.7
   CHI SQUARE      3.63         DEGREES FREEDOM           7


SOURCE CONTRIBUTION ESTIMATES:

SOURCE
EST CODE   NAME     SCE(ug/m3)    Std Err      Tstat
--------------------------------------------------
YES SR001  CDUST      12.85451    3.00004    4.28478
YES SR002  LDUST      71.83512    8.70889    8.24848
YES SR003  DDDT        2.54434    0.77411    3.28681

--------------------------------------------------
                   87.23396

MEASURED CONCENTRATION FOR SIZE: FINE
    72.9+-    7.3
```

BIOGRAPHY

NAME	Ms. Chuennadda Chulamanee
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