FINE PARTICULATE MATTER AND AIRBORNE MICROORGANISMS IN BANGKOK

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นาย ปัณชญา พัฒนสุข

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การตรวจสอบจุลินทรีย์ในอากาศภายนอกอาคารที่มากับฝุ่นละอองขนาดเล็ก เปรียบเทียบกันในพื้นที่ของเขตเมือง ชานเมือง และริมถนนของกรุงเทพมหานคร เก็บตัวอย่างเป็นเวลา 7 วันในแต่ละพื้นที่ ระหว่างเดือนมิถุนายนถึงพฤศจิกายน ปี 2552 ด้วยเครื่องมือเก็บอากาศส่วนบุคคลที่เชื่อมติดกับหัวคัดแยกฝุ่นด้วยอัตราการไหล 1.7 ลิตร/นาที เก็บตัวอย่างฝุ่นละออง พบว่าปริมาณของฝุ่นละอองและจุลินทรีย์ในบรรยากาศทั่วไปที่เขตเมืองและชานเมืองใกล้เคียงกัน แต่แตกต่างจากบริเวณริมถนนอย่างมาก และจำนวนแบคทีเรียในอากาศที่วัดบริเวณริมถนนก็แตกต่างอย่างมีนัยสำคัญจากพื้นที่ที่เก็บตัวอย่างอื่น นอกจากนั้นแบคทีเรียที่เพาะเลี้ยงได้ส่วนมากในเขตเมืองและริมถนนเป็นแบคทีเรียแกรมบวกรูปร่างกลม ในขณะที่ในเขตชานเมืองเป็นแบคทีเรียแกรมลบรูปร่างกลม เมื่อจำแนกประเภทแบคทีเรียในอากาศด้วยพบว่าแบคทีเรียส่วนมากที่พบทุกพื้นที่ที่เก็บตัวอย่างเป็นชนิด *Pseudomonas fluorescens, Staphylococcus sciuri* และ *Bacillus pumilus* ส่วนเชื้อราในอากาศส่วนมากเป็นชนิด *Penicillium spp.* และ *Aspergillus spp.* และที่น่าสังเกตคือระดับฝุ่นละอองนั้นมีความเกี่ยวข้องกับจำนวนของจุลินทรีย์ในอากาศเฉพาะเขตชานเมืองเท่านั้น โดยพบว่าฝุ่นละอองขนาดเล็ก มีความสัมพันธ์กับจำนวนแบคทีเรียในอากาศที่ค่าสหสัมพันธ์ 0.62 ที่มีนัยสำคัญทางสถิติที่ 0.05 และจำนวนเชื้อราในอากาศที่ระดับค่าสหสัมพันธ์ 0.61 ที่มีระดับนัยสำคัญทางสถิติที่ 0.05 นอกจากนั้นค่าอุตุนิยมวิทยาต่างๆ ยังมีความสัมพันธ์เกี่ยวข้อง กับทั้งจำนวนฝุ่นละอองและจุลินทรีย์ในอากาศที่ระดับนัยสำคัญ 0.01 และ 0.05.

สาขาวิชา …การจัดการสิ่งแวดล้อม……. ลายมือชื่อนิสิต ....

ปีการศึกษา…..2552…………………... ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก…..............

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม …..............

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PHUNCHAYA PATTANASUK : FINE PARTICULATE MATTER AND AIRBORNE MICROORGANISMS IN BANGKOK. THESIS ADVISOR : ASSOC. PROF. WANIDA JINSART, Ph.D., THESIS CO-ADVISOR : HATHAIRATANA GARIVAIT, Ph.D., 174 pp.

Outdoor airborne microbial associated fine particulate matter was comparatively investigated in urban, suburban, and roadside area of Bangkok. Fine particulate matter was collected for 7 days in each site from June to November 2009. Personal air samplers equipped with cascade impactors at a flow rate of 1.7 l/min were used for air sampling. The quantities of particulate matter and airborne microorganisms at ambient urban and suburban areas are comparable, but are remarkably different from roadside area. At roadside area, and airborne bacterial concentration significantly different from other sampling sites. Most of bacterial cultures at urban and roadside area are gram positive cocci while those at suburban area are gram negative cocci. In addition, the major types of airborne bacteria found at all sampling sites are *P. fluorescens, S. sciuri*, and *B. pumilus*, and the major types of airborne fungi are *Penicillium spp.* and *Aspergillus spp.* Intriguingly, particulate matter levels are associated with the airborne microorganism concentrations only at suburban area. At this site, fine particulate matter is correlated with airborne bacteria (r=0.62, P=0.05) and airborne fungi (r=0.61, P=0.05). Moreover, meteorological parameters are significantly correlated with both particulate matter and microbial count concentrations at p = 0.01 and p = 0.05.

Field of Study : Environmental Management

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Student's Signature ....

Advisor's Signature ....

Co-Advisor's Signature ....

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CHAPTER I

INTRODUCTION

1.1 Rationale background

Atmospheric pollution, one of the major environmental problems, recently becomes an important public concern because of its adverse health effects. In last decade, increasing scientific knowledge and evidences has emphasized that ambient (outdoor) air pollution has remarkably increased in several large cities of developed and developing countries. People in those countries have more risk to be exposed to considerably increasing outdoor air pollutants, and that leads to more emergences of public health problems, especially respiratory illnesses such as asthma, chronic productive cough, and even malignant tumor in respiratory tract (Abbey et al., 1999; Pope et al., 2002).

Bangkok, the capital of Thailand, is also one of the large cities in developing countries facing the growing health and environmental problems from more severe outdoor air pollution. Recently, ambient air pollution is not only increasing in metropolitan area of Bangkok, but also in its suburban area and its nearby provinces, including Pathumthani, Nonthaburi, Nakhon Pathom, Samut Prakan, and Samut Sakhon.

Increasing particulate matter dust and associated airborne microorganisms in outdoor environments have become one of serious issues particularly from their adverse health effects. Outdoor air pollution composes of bioaerosol and non-biological particles (As shown in Figure 1.1). Bioaerosol is defined as the airborne particles of biological origin such as bacteria, fungi, virus, bacterial spores, fungal spores, pollen, allergen, and microbial metabolites (Fang et al., 2008; Morris et al., 2008; Verma and Pathak, 2008). These aerosols are considered as bioaerosol because they can be pathogenic or lead to allergy and inflammation of respiratory system and cardiovascular system (Fang et al., 2005; Gorman and Fuller, 2008; Morris et al., 2008) (As shown in Figure 1.2). The majority of bioaerosol is non-pathogenic microorganisms, which can cause diseases only in immunocompromised people such as children, pregnant women, elderly people, and patients with respiratory and cardiovascular diseases (Shaffer and Lighthart, 1997; Mopuang et al., 2006). Some of bioaerosol is pathogenic and can cause many illnesses such as headache, fatigue, nose irritation, eye irritation, and throat irritation (Fang et al., 2005; Mopuang et al., 2006; Fang et al., 2008; Verma and Pathak, 2008). Non-biological particles such as particulate matter, automobile particles, and tobacco smoke play an important role as a carrier of airborne microorganisms into lung (Fang et al., 2005; Fang et al., 2008; Morris et al., 2008). The majority routes of exposure are inhalation (Mouli et al., 2005; Fang et al., 2008; Morris et al., 2008; Verma and Pathak, 2008) and other routes, including ingestion (Mouli et al., 2005; Verma and Pathak, 2008), conjunctiva (Verma and Pathak, 2008), and skin contact (Mouli et al., 2005). The aerodynamic diameters of bioaerosol sizes may range from 0.5 to 100 µm, 0.25 µm for individual bacterial particles and 1-30 µm for fungal spores (Fang et al., 2008). Normally, most of airborne bacteria attached to the dust surface can accumulate in the upper respiratory tract, rather than penetrate into the lower respiratory tract (Fang et al., 2008; Morris et al., 2008; Verma and Pathak, 2008). However, the airborne fungi spores can deposit in both upper respiratory and lower respiratory air ways (Mouli et al., 2005; Fang et al.,2008).

Figure 1.1 Bioaerosol and non-biological particles (Brook et al.,2004)

	MAJOR SOURCES	HEALTH EFFECTS	ENVIRONMENTAL EFFECTS
SO_2	Industry	Respiratory and cardiovascular illness	Precursor to acid rain, which damages lakes, rivers, and trees; damage to cultural relics
NO_x	Vehicles; industry	Respiratory and cardiovascular illness	Nitrogen deposition leading to over-fertilization and eutrophication
PM	Vehicles; industry	Particles penetrate deep into lungs and can enter bloodstream	Visibility
CO	Vehicles	Headaches and fatigue, especially in people with weak cardiovascular health	
Lead	Vehicles (burning leaded gasoline)	Accumulates in bloodstream over time; damages nervous system	Fish/animal kills
Ozone	Formed from reaction of NO_x and VOCs	Respiratory illness	Reduced crop production and forest growth; smog precursor
VOCs	Vehicles; industrial processes	Eye and skin irritation; nausea; headaches; carcinogenic	Smog precursor

Figure 1.2 Health effects of air pollutants (earthtrends.wri.org/images/Effects-Chart.jpg)

1.2 Problem of the previous study

Most of the published studies regarding aeromicrobiology primarily emphasized on the study of bioaerosols in indoor and outdoor environments, whereas the studies on worldwide air quality in relation with health problems focused only the profiles of the particulate matter in the environments. Theoretically, the airborne microorganism can adhere to the surface of dust or particulate matter, and that potential of dust to carry the microbes (both pathogenic and non-pathogenic types) has brought the interesting notions to current researches, which combined the studies of both airborne microbial community and particulate matter in the environment together. Recently, there are a few published researches studying the bioaerosols, especially airborne microorganisms, in conjunction with the particulate matter in ambient air environment in Bangkok, Thailand. Even less is known about the microbial identity at urban, suburban, and roadside of Bangkok, and its relationship to the particulate matter in ambient air. Hence, this project focusing on the study of airborne microorganisms in conjunction with particulate matter in ambient air may provide some knowledge to aeromicrobiological field and other relevant researches.

1.3 Objectives of the study

The main objective of this project is to investigate the correlation of particulate matter associated airborne microorganisms (bacteria and fungi) with particulate matter levels and other meteorological parameters in metropolitan and nearby areas of Bangkok. The objective can be subdivided into three categories as follows:

1. To assess the potential of airborne microorganism and fine particulate matter levels at three diverse locations in Bangkok: urban, suburban and roadside.

2. To demonstrate the association between the particulate matter level and the airborne microbial counts.

3. To identify the type of the particulate matter associated airborne microorganisms.

1.4 Hypothesis

1. High levels of particulate matter are associated with airborne microbial counts.
2. Type and concentration of airborne microorganism are diverse among the area locations.
3. Meteorological parameters are associated with airborne microbial levels

1.5 Scope of the study

- **Air pollutants**: airborne bacteria, airborne fungi, fine particulate matter, and coarse particulate matter
- **Site locations**
  - Urban area - Chulalongkorn University, CU
  - Suburban area - Environmental Research and Teaching Centre, ERTC
  - Roadside area - Silom road
- **Sampling duration**: June - November, 2009
- **Identification**: Identify the majority type of microorganisms in each site.

1.6 Benefit of the study

1. The information of the airborne microorganisms and particulate matter in the atmosphere can be applied for health risk assessment and build health awareness in ambient air pollution.

2. This finding can be used as a preliminary initial data for the development of ambient bioaerosols standard in the future.

CHAPTER II

LITERATURE REVIEW

2.1 Composition of air

Air is essential for all living things on earth as live-supported gas and the planet equilibrium environment. The blanket of air around the earth is called the atmosphere. In theory, air is a mixture of gases, mainly nitrogen and oxygen, but containing much smaller amounts of water vapor, argon, and carbon dioxide, and very small amounts of other gases, as shown in Table 2.1. Air also contains suspension of particulate matter or dust, microbial spores, and several types of microorganisms. The composition of air also depends on metrological parameters in each location such as air temperature, relative humidity and wind direction (Cunningham et al., 2007).

Table 2.1: Present composition of the lower atmosphere

Composition	Present by volume (%)
Nitrogen (N_2)	78.08
Oxygen (O_2)	20.94
Argon (Ar)	0.934
Carbon dioxide (CO_2)	0.035
Neon (Ne)	0.00182
Helium (He)	0.00052
Methane (CH_4)	0.00015
Krypton (Kr)	0.00011
Hydrogen (H_2)	0.00005
Nitrous oxide (N_2O)	0.00005
Xenon (Xe)	0.000009
Particulate matter dust*	0-1,000,000 particles/ml

* Particulate matter dust include bacteria, yeast, fungi, pollen and other

* Average composition of dry, clean air (Cunningham et al., 2007)

2.2 Atmospheric pollution

Atmospheric pollution is one of the environmental problems that people are increasingly concerned because of its adverse effects to human health and daily routine. Atmospheric pollution is an introduction of particulate matter or dust, chemical substances, gases, fumes or odor in harmful amounts into the air. These air pollutants can be harmful to human health, and other organisms. In human, the major route of exposure to outdoor air pollutants is the inhalation into lungs.

In the last decades, increasing scientific evidences has indicated that the outdoor or ambient air pollution has dramatically increased in many industrialized cities around the world. In Thailand, outdoor air pollution is one of the severe problems occurring in most urban areas, suburban areas and roadside areas. Bangkok metropolitan area, the capital city of Thailand, is also one of many cities affected by air pollution at this time. Moreover, nearby region of Bangkok such as Pathumthani province are now affected by increasing air pollution. The main sources of air pollution in Pathumthani province come from vehicles, organization and open burning. Each year, millions pounds of toxic chemicals, reagents, gases, and particles from vehicles, industries, and power plants are released into air.

2.3 Classification of air pollutants

Outdoor air pollution is a complex mixture of several air pollutants. Air pollutants are known as substances in the atmosphere that can cause damage to human health and environments. Air pollutants can be categorized as primary or secondary pollutants depending on their origins. Usually, primary pollutants are substances directly released from general emission sources. The examples of primary pollutants are nitrogen oxides, sulfur oxides, carbon monoxide, carbon dioxide, particulate matter, volatile organic compounds (VOCs), toxic metals, odors, and radioactive pollutants. Secondary pollutants are not emitted directly and formed by the reaction of primary pollutants. The important examples of secondary pollutants are ground level ozone, compounds in photochemical smog (Maier et al., 1999).

2.4 Sources of air pollutants

There are two major sources of outdoor air pollutants: natural and anthropogenic emission sources. Natural outdoor air pollutants include particulate matter, microorganisms, oxides of nitrogen and sulfur from volcanic activities, ash from forest fires, organic dust from biological decomposition, natural volatile organic compounds (VOCs), and pollen from plants. Outdoor air pollutants from anthropogenic or human activities comprise gases and particulate matter from fossil fuel combustion in industries and vehicles, toxic gases and solvents from manufacturing in industrial processes, volatile organic compounds, ozone, polycyclic aromatic hydrocarbons, and dust form waste depositions. Recently, most sources of air pollution are from the human activities which release the huge number of greenhouse gases and toxic substances into the atmosphere (Maier et al., 1999).

2.5 Particulate matter and airborne microorganisms

Particulate matter is the mixture of solid and liquid particles suspended in the air. In contrast, aerosol refers to particles and the gas together. Particle size is the most important factor for determining where particles are deposited in lung. Particle sizes are classified into two groups: coarse particles and fine particles. Coarse particles (2.5-10 micrometers) deposited in the upper respiratory tract and large airways, while fine particles (less than 2.5 micrometers) may reach terminal bronchioles and alveoli. When compared with large particles, fine particles can remain suspended in the atmosphere for longer periods and be transported over longer distances (Maier et al., 1999; Fang et al.,2005; Fang et al.,2008). There are clear evidences that particulate matter is associated with respiratory illnesses, but the specific effects of some air pollutants to the pathogenesis of respiratory diseases remain unknown. Airborne microorganism distributed in ambient air is also defined as one of air pollutants, and the adverse health effects of those in ambient air are uncovered rarely.

Table 2.2: Approximate size ranges of different airborne particles*

Particle Type	Minimum Size (μm)	Maximum Size (μm)
Particles that can be inhaled	<100	100
Particles that are respirable (can reach the deep part of the lungs)	<10	10
Clay	0.02	2
Silt	2	20
Fine Sand	20	200
Coarse Sand	200	2,000
Gravel	2,000	>2,000
Smog	0.001	2
Clouds/Fog	2	70
Mist	70	200
Drizzle	200	500
Rain	500	10,000
Plant Spores	10	30
Pollen	10	100
Viruses	0.003	0.05
Bacteria	0.3	30
Human Hair	30	120
Visible to the Eye	50	>50
Gas Molecules	0.0003	0.005
Tobacco Smoke	0.01	1
Milled Flour	1	80
Nebulizer Drops	1	20
Combustion Nuclei	0.01	0.1
Metal Fumes	0.001	1
Ultrafine Particles	<0.1	0.1

* Source: Johnson, D., and Vincent, J., 2003.

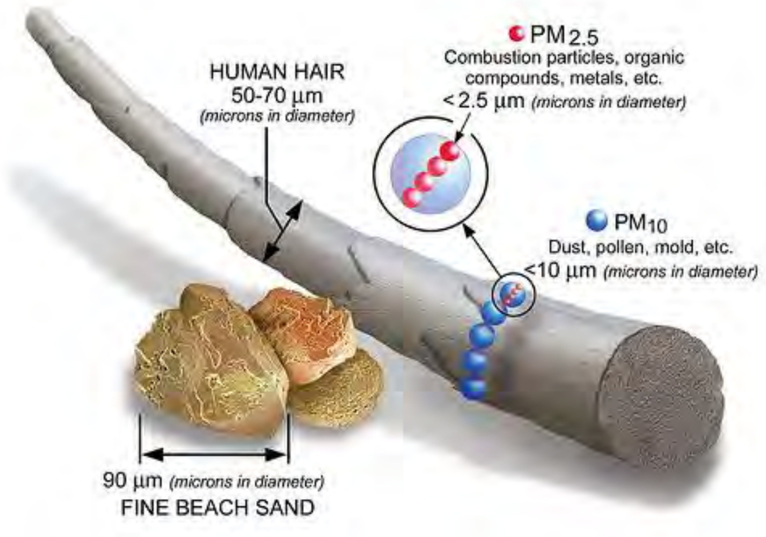


Figure 2.1 Particle size of particulate matter (www.epa.gov/airscience/quick-finder/particulate-matter.htm).

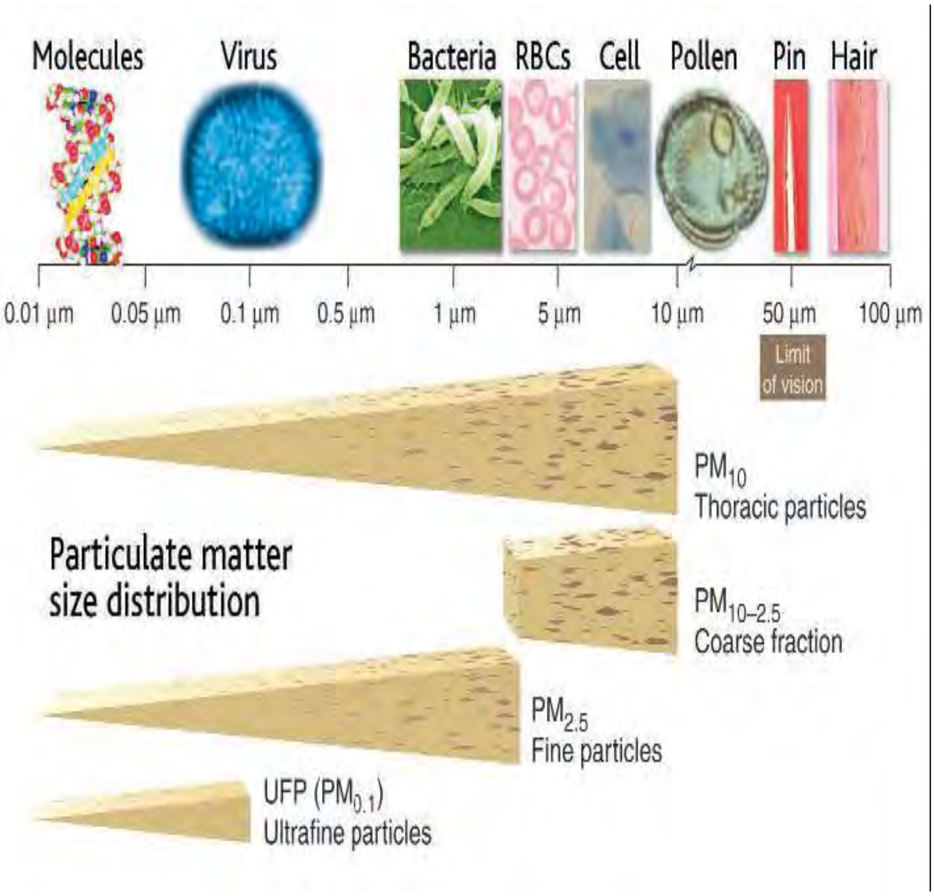


Figure 2.2 Particle size (Brook et al., 2004).

Generally, airborne microorganisms can be categories into two groups: non-pathogenic and pathogenic microorganisms. Simply, non-pathogenic normally doesn't cause disease in healthy individuals, while pathogenic microorganisms have potential to cause diseases. Some airborne bacteria and fungi are pathogenic microorganisms which can causes respiratory illnesses in human such as allergies, asthma, and severe infections of the respiratory tract (Maier et al., 1999).

2.6 Air quality standards

The Clean Air Act (CAA) requires EPA to set National Ambient Air Quality Standards (NAAQS) for six common air pollutants. The six common air pollutants are particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants have negative effects on human health and natural environments, and cause the damages on human properties. Among the six pollutants, particulate matter and ground-level ozone mostly affect to and public health concern. In Thailand, The major air pollutants standard concentrations were developed by Pollution Control Department (PCD), Ministry of Natural Resources and Environment. For PM_{10}, the 24-hour ambient air quality standard level is set at 0.12 mg/m^3 or 120 $\mu g/m^3$, and the annual ambient air quality standard level is set at 0.05 mg/m^3 or 50 $\mu g/m^3$, as shown in Table 2.3 (http://www.pcd.go.th/info_serv/en_reg_std_airsnd01.html).

Table 2.3: Air quality standards in Thailand*

Pollutants	average	Standard
1. Carbonmonoxide (CO)	1 hr	30 ppm. (34.2 mg/m^3)
	8 hr	9 ppm. (10.26 mg/m^3)
2. Nitrogen Dioxide (NO_2)	1 hr	0.17 ppm. (0.32 mg/m^3)
3. Ozone (O_3)	1 hr	0.10 ppm. (0.20 mg/m^3)
	8 hr	0.07 ppm. (0.14 mg/m^3)
4. Sulfur Dioxide (SO_2)	1 year	0.04 ppm. (0.10 mg/m^3)
	24 hr	0.12 ppm.(0.30 mg/m^3)
	1 hr	0.3 ppm.(780 µg/m^3)
5. Lead (Pb)	1 month	1.5 µg/m^3
6. Particulate Matter (< 10 µm)	24 hr	0.12 mg/m^3
	1 year	0.05 mg/m^3
7. Particulate Matter (< 100 µm)	24 hr	0.33 mg/m^3
	1 year	0.10 mg/m^3

* Source: http://www.pcd.go.th/info_serv/en_reg_std_airsnd01.html

Table 2.4: National Ambient Air Quality Standards (NAAQS) by USEPA*

Pollutant	Primary Standards Level	Primary Standards Averaging Time
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour
	35 ppm (40 mg/m^3)	1-hour
Lead	0.15 µg/m^3	Rolling 3-Month Average
	1.5 µg/m^3	Quarterly Average
Nitrogen Dioxide	0.053 ppm (100 µg/m^3)	Annual (Arithmetic Mean)
Particulate Matter (PM_{10})	150 µg/m^3	24-hour
Particulate Matter ($PM_{2.5}$)	15.0 µg/m^3	Annual (Arithmetic Mean)
	35 µg/m^3	24-hour
Ozone	0.075 ppm (2008 std)	8-hour
	0.08 ppm (1997 std)	8-hour
	0.12 ppm	1-hour
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)

* Source: http://www.epa.gov/air/criteria.html

$PM_{2.5}$ is acknowledged by WHO, USEPA, and the EU as the major pollutant of concern because of its high concentration in atmosphere and its correlation with adverse health effects. In almost all Asian countries, the standard level for $PM_{2.5}$ has not been legislated and there is now no immediate plans from Asian governments to develop $PM_{2.5}$ standard levels. Only Singapore and Bangladesh have legally determined $PM_{2.5}$ standard level, based on the old USEPA standards. For $PM_{2.5}$, the 24-hour ambient air quality standard level is set at 0.035 mg/m^3 or 35 µg/m^3, and the annual ambient air quality standard level is set at 0.015 mg/m^3 or 15 µg/m^3, as shown in Table 2.4 (http://www.epa.gov/air/criteria.html).

Outdoor air quality affects how you live and breathe. Depending on the weather conditions, the outdoor air quality is dynamic; on the other word, it can change rapidly from hour to hour or even day to day. The U.S. Environmental Protection Agency (USEPA) and others are working to make information about outdoor air quality for better understanding. This key tool used for determining air quality is the Air Quality Index, or AQI. The AQI is an index for reporting daily air quality. AQI indicates how clean or polluted your air is, and what associated health effects might be concern for you. The AQI values are determined in the range from 0 to 500, as shown in Figure 2.3 (http://www.epa.gov/air/data/help/hmonaqi.html). The higher AQI value shows the greater level of air pollution and the greater health concern. An AQI value at 100 generally represents the national air quality standard level for air pollution, which is the level that EPA has set to protect public health. AQI values below 100 are determined as the satisfactory levels. When AQI values are above 100, air quality is considered to be unhealthy to human. Each category corresponds to a different level of health concern.

Air Quality Index values	Levels of Health Concern	Colors
When the AQI is in this range:	*… air quality conditions are:*	*… as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for sensitive groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
300 to 500	Hazardous	Maroon

Figure 2.3 Air Quality Index (AQI) value (http://www.epa.gov/air/data/help/hmonaqi.html)

At the present, there is no agreement on the standard level or threshold values for bioaerosol in any countries yet. This may be due to the insufficient information regarding the distribution of bioaerosols in outdoor environments and health impact from bioaerosols. Therefore, at this time, there are no standard values of the ambient airborne microorganisms (both airborne bacteria and airborne fungi) in any country, and further investigations are immediately required for developing the outdoor bioaerosol standard or threshold levels, which may help to reduce the number of patients suffering from the adverse health effects of bioaerosols in the future.

2.7 Recent air quality in Thailand

From the report of air quality (Pollution Control Department [PCD], 2008: 6) in Thailand, the major air pollutant is particulate matter (PM_{10}) which distribute widely for a long time in Saraburi, Ratchaburi, Samut Prakan, Ayutthaya, and Bangkok.

Table 2.5: Record of air quality in Thailand (PCD, 2008: 6)

Area	2007		2008	
	Min-max	Exceed (%)	Min-max	Exceed (%)
Saraburi	17.3 - 302.2	103/702 (14.7)	13.6 - 283.0	57/704 (8.1)
Ratchaburi	12.8 - 140.7	14/330 (4.2)	15.6 - 159.0	20/354 (5.6)
Samut Prakan	10.5 - 461.5	276/1,682 (16.4)	12.2 - 249.5	84/1,715 (4.9)
Bangkok	9.8 - 242.7	92/1,970 (4.7)	8.1 - 205.4	82/2,000 (4.1)
Ayutthaya	16.7 - 221.1	15/351 (4.2)	12.9 - 205.9	13/346 (3.8)

2.8 Recent air quality in Bangkok

From PCD air quality report (PCD, 2008: 7), the major air pollutant in Bangkok is particulate matter (PM_{10}). Figure 2.4 shows the variation of PM_{10} during 1995 to 2008 in both roadside area and ambient area. For more than 14 years, in roadside area, PM_{10} levels were higher than annual NAAQS, 50 μg/m^3.

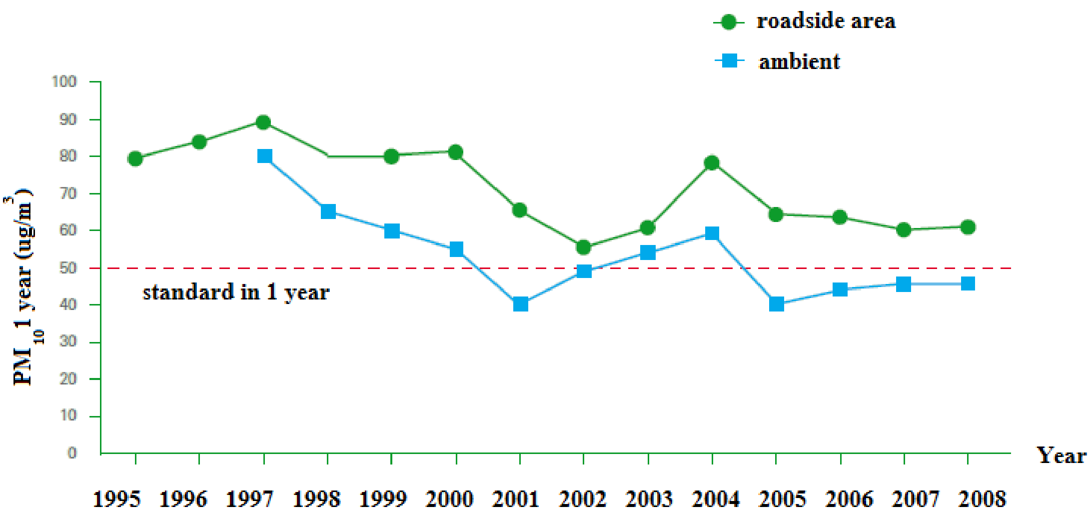


Figure 2.4 Average PM_{10} in Bangkok from 1995 to 2008 (PCD, 2008: 7)

2.9 Meteorological parameters

Meteorology is the science of the atmosphere that deals with the phenomena of the atmosphere, especially weather conditions. Meteorological parameters, including wind direction, wind speed, temperature, relative humidity, pressure and solar radiation, are natural weather phenomena that directly or indirectly affect the measurements of air quality (Ahrens, 2006a, b).

- *Temperature*: the ambient temperature is reported in term of degrees Celsius.
- *Relative Humidity*: the ratio of actual water vapor in the ambient air to the maximum amount that could occur at the same ambient air temperature. The ratio is measured as percentage.
- *Wind Speed*: the rate at which the air is moving past a stationary observer. Wind velocity is measured in Knots.
- *Wind Direction*: Wind direction is shown as the direction from which the wind is blowing. A compass scale of 0 to 360 degrees is used. North is 0 or 360 degrees, Northeast is 45 degrees, East is 90 degrees, Southeast is 135 degrees, South is 180 degrees, Southwest is 225 degrees, West is 270 degrees and Northwest is 315 degrees.
- *Solar Radiation*: This parameter is measured by using Pyranometer CM11 in watt per square meter.

2.10 Adverse health effects of particulate matter and bioaerosols in ambient air

Recently, all people around the world have more risk from short-term and long-term exposure to airborne microorganisms coming along with particulate matter because of increased human activities, especially from the influence of industrialization. People in the sensitive groups, including children, pregnant women, elderly people, patients with cardiovascular and respiratory diseases, immunocompromised persons, and patients with transplanted tissue or organ, are more likely to be affected by pathogenic airborne microorganisms as well as particulate matter in ambient air.

It is well-known that air pollutants can affect to human health in both short term and long-term, particularly health problems in respiratory and cardiovascular diseases (Langkulsen et al., 2006; Buadong et al., 2009). A lot of adverse health effects in human and other animals from the exposure to particulate matter have been identified in many publish studies. In human, effects from short-term exposure are lung inflammatory reactions, respiratory symptoms, and acute effects on the cardiovascular system, while those from long-term exposure are lower respiratory illnesses, reduced lung function, chronic obstructive pulmonary disease, lung cancer and even cardiopulmonary mortality (Abbey et al., 1999; Pope et al., 2002).

The size of the particulate matter is a main determinant of where in the respiratory tract the particle will come to rest when inhaled. Larger particles are generally filtered in the nose and throat and do not cause problems, but particulate matter smaller than 10 micrometer referred to as PM_{10}, can settle in the bronchi and lungs and cause health problems. The 10 micrometer in size of the particulate matter does not represent a strict boundary between respirable and non-respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies. Similarly, particles smaller than 2.5 micrometer referred to $PM_{2.5}$ could penetrate into the gas-exchange regions of the lung, and very small particles (< 100 nanometers) may penetrate into gas exchange region of alveolar and spread to other organs in the body. In particular, a study published in the Journal of the American Medical Association indicates that $PM_{2.5}$ leads to high plaque deposits in arteries, causing vascular inflammation and atherosclerosis — a hardening of the arteries that reduces elasticity, which can lead to heart attacks and other cardiovascular problems (Pope et al., 2002). Some published studies suggest that even short-term exposure at elevated concentrations could significantly contribute to acute heart problems.

Recently, the interest in bioaerosols in both indoor and outdoor environments has increased in last decades because several studies found that he increase in bioaerosol levels has been correlated with adverse health effects such as impaired lung function in both children and adults, increased respiratory diseases (i.e. cough), cardiovascular diseases, and even lung cancer (Mopuang et al.,2006). In addition, increased bioaerosols also may leads to the increase in hospital admission, medication usage, and even mortality or the reduction in life expectancy.

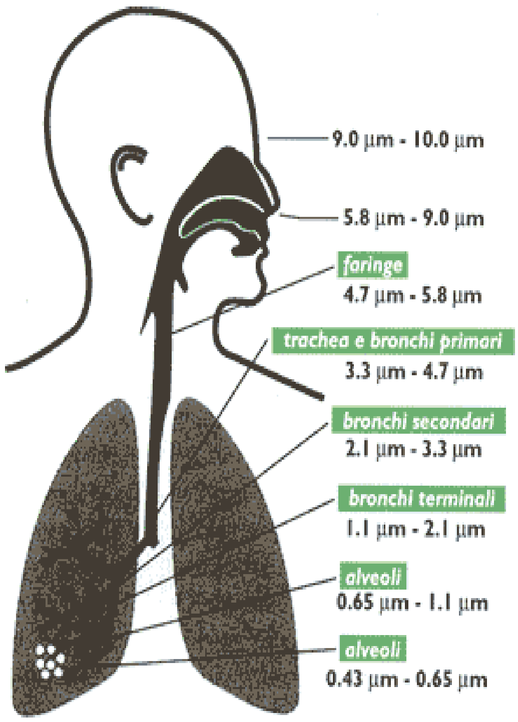


Figure 2.5 Deposition of particle sizes in respiratory tract (Brook et al.,2004)

2.11 Literature review

Buadong et al. (2009) studied the association between air pollution (PM_{10} and O_3) and the number of patients with cardiovascular diseases in central Bangkok, provided by the data from Ramathibodi, Siriraj, and Chulalongkorn hospitals. The PM_{10} data during April 2002 to December 2006 was used in a time-series analysis. They found that the exposure to PM_{10} had a positive correlation with patients suffering from cardiovascular diseases at 99% confidence.

Gorman and Fuller (2008) reported that total microbial concentrations were highest during June to August. There is no significant difference of selected fungal counts during day times. The most common airborne fungi were *Cladosporium* spp., *Penicillium* spp., *Aspergillus* spp., and *Alternaria* spp. Moreover, each type of fungi is associated with meteorological parameters.

Morris et al. (2008) investigated the types of airborne bacteria distributed in outdoor environments. They found that the number of gram positive bacteria was higher than those of gram negative bacteria (<10%), and most airborne bacteria were distributed from soil, rather than vegetation. Moreover, meteorological parameters such as temperature, relative humidity, and wind velocity affect to the concentrations of airborne bacteria in ambient air.

Mopuang et al. (2006) reported that most of bacterial cultures were gram positive cocci, while most of fungal cultures were *Aspergillus spp., Botrytis spp. and Curvalarium spp.* Some of particulate matter and microbial counts were higher than the standard level of Pollution Control Department (PM_{10} > 120 $\mu g/m^3$) and the American Conference of Governmental Industrial Hygienists (ACGIH) (Microbial counts > 1000 CFU/m^3). Moreover, they found that there was correlation between bacterial counts and fungal count, while there are no correlation between microbial counts and particulate matter.

Langkulsen et al. (2006) studied the association between air pollution and respiratory diseases at primary school in Bangkok. They found that the number of children with respiratory symptoms were higher in areas containing high air pollution than those in low air pollution area.

Fang et al. (2005) reported that the fungal concentrations in Beijing were higher than other sampling sites. They also found that there were seasonal and spatial variations of airborne microbial counts. The major type of airborne fungi was *Cladosporium* spp. Fang et al., 2008 also reported that most of culturable airborne microorganisms were culturable airborne bacteria, culturable airborne fungi and actinomycetes, respectively.

Thongsanit et al. (2003) reported that daily PM_{10} concentrations at the roadside areas with heavy traffic congestion ranged broadly from 30 to 160 $\mu g/m^3$. The highest PM_{10} level occurred during winter (November-February), which is dry season. From this study, they found that particulate matter concentrations are associated with traffic volumes and seasonal factors (temperature and rainfall).

Kumthai (2002) studied the concentration and types of airborne bacteria in heavy traffic congestion areas in Bangkok (Siam square and Rama IV road) during wet and dry seasons, and Chulalongkorn University was used to be the control site. In this study, they found that closed areas, traffic areas, people, seasonal variation and wind direction were important factors that affected to the concentrations of airborne bacteria.

Chianmongkhon (2001) studied airborne bacterial counts in many areas around Nong-kam within a radius of 1 kilometer. Seasonal variation and distance from collecting center affected to the concentrations of airborne bacteria. Moreover, meteorological parameters (wind direction and rainfall) affected to the airborne bacterial counts.

Pratumvong (1997) studied airborne bacterial counts during dry season at Or Por Ror building and Odean circle, Bangkok. They found that airborne bacteria in every stage in viable microbial particle sizing samplers (Andersen 2000 INC). The airborne bacterial counts were found to be related to the conditions in closed areas, human activities, traffic areas, and people. Meteorological parameters were also correlated to airborne bacterial count, but the correlation was not significant.

Giorgio et al. (1996) reported that there were high diversity of airborne bacteria and airborne fungi found during May to July. Airborne bacterial counts were higher than airborne fungal counts, and airborne microorganisms in Marseilles were higher than those at naturally conserved island but the difference was not significant. Moreover, meteorological parameters were correlated to the concentrations of airborne microorganisms.

Lee et al. (1972) reported that correlation between airborne bacteria and chemical pollutants such as carbon monoxide, total hydrocarbons, pollutants associated with automobile emissions in Cincinnati. Mancinelli and Shulls (1977) reported that correlation between airborne bacteria and nitrogen dioxide (+), nitric oxide (-).

Generally, the airborne microorganism concentrations in outdoor environments are varied among sampling sites. For example, In France, Giorgio et al. (1996) reported that the arithmetic mean of airborne bacteria concentrations was 791 ± 598 CFU/m^3, and those of airborne fungi concentrations was 92 ± 92 CFU/m^3. In addition, the counts of airborne microorganisms in urban area were higher than those in natural area, and the airborne bacterial counts were higher than airborne fungal counts. In USA, the average concentrations of airborne bacteria during day time was 609 CFU/m^3 at the urban site, 522 CFU/m^3 at the forest site, 242 CFU/m^3 at the rural site and 103 CFU/m^3 at the coastal site (Shaffer and Lighthart, 1997). In Beijing, China, the mean concentration of airborne bacteria was 3700 ± 210 CFU/m^3, while that of airborne fungi was 1200 ± 73 CFU/m^3 (Fang et al., 2005; Fang et al., 2008). The dominant types of airborne fungi found in Beijing were *Cladosporium* spp., *Penicillium* spp. and *Aspergillus* spp. (Fang et al.,2005; Fang et al., 2008; Verma and Pathak, 2008). In addition, seasonal variation pattern of airborne microorganisms and the size distribution were significantly different (Fang et al.,2005; Fang et al.,2008).

2.12 Heading to this research

At the present, there is no standard level for bioaerosol in any countries. This may be due to the insufficient information of the exposure and impact of bioaerosol. In this study, we aim to determine the airborne microorganism concentrations in outdoor environments of the urban, suburban, and roadside areas of Bangkok. We also want to understand the impact of atmospheric process on the airborne microbes in such environments. The result from this study will provide useful information for health risk assessment and the development of outdoor bioaerosol standard level or threshold value in the future.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Detail of selected sampling sites

Based on human activity, the sampling sites were chosen from three different locations in Bangkok and Pathumthani Province. (As shown in Figure 3.1)

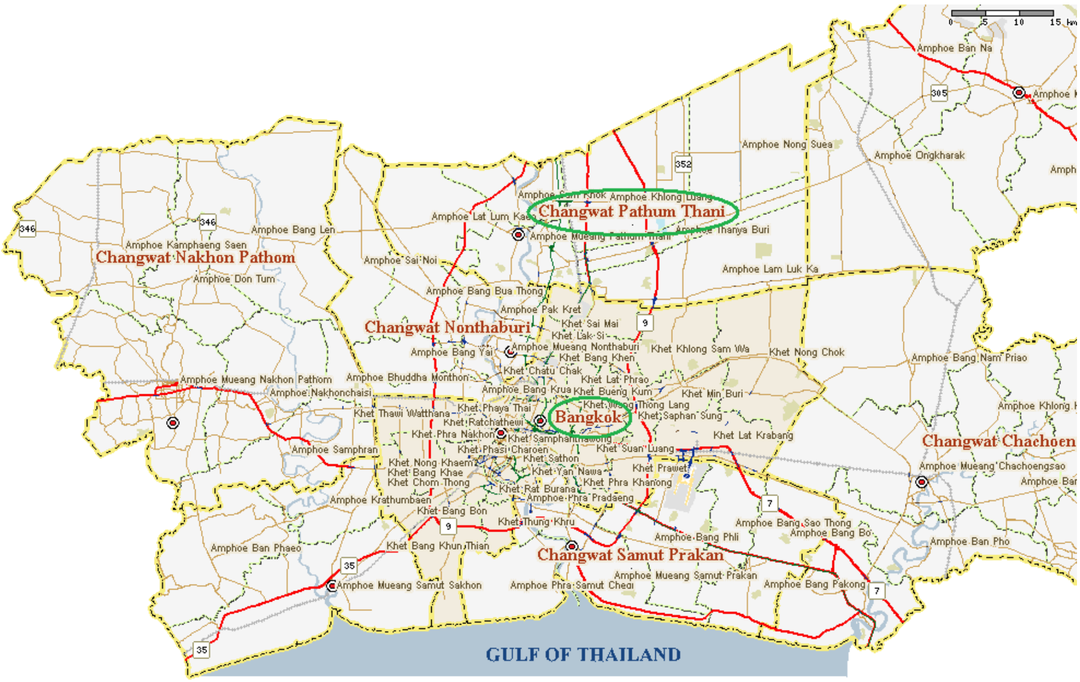


Figure 3.1 Map of Bangkok and Pathumthani Province (scale 1:457,859)

3.1.1 Urban area

Department of General Science, Faculty of Science, Chulalongkorn University, Bangkok was selected for collecting the air samples in urban area.

It is located in the central of Bangkok metropolitan areas and is surrounded by commercial buildings, government and private offices, households, a lot of roads with heavy traffic congestion, the Bangkok Mass Transit System (BTS skytrain), and the Mass Rapid Transit Authority of Thailand (MRTA subway).

Figure 3.2 Chulalongkorn University

3.1.2 Suburban area

The Environmental Research and Training Centre, Pathumthani Province was selected for collecting the air samples in suburban area.

The Environmental Research and Training Centre (ERTC) is a division operating under the Department of Environmental Quality Promotion (DEQP) and under the overall jurisdiction of the Ministry of Natural Resources and Environmental (MONRE). It is located in Rangsit Klong 5 of Pathumthani Province. ERTC is surrounded by commercial buildings, government offices (TISTR and NSM), households, roads, expressways with a few traffic vehicles, and a few industries within 10 km radius of the sampling site.

Figure 3.3 Environmental Research and Training Centre

3.1.3 Roadside area

Silom Road, one of the heaviest traffic congestion areas of Bangkok, was selected for collecting the air samples in roadside area.

Silom road, the intersection between Rama IV road and Ratchadamri road, is located in the central part of Bangkok metropolitan area. It is surrounded by a lot of commercial buildings, government and private offices, hospitals, public park, expressway, the Bangkok Mass Transit System (BTS skytrain), and the Mass Rapid Transit Authority of Thailand (MRTA subway).

Figure 3.4 Silom Road

3.2 Preparation before air sampling

The mixed cellulose ester membrane filters (for fine particle and coarse particle) with the pore size 0.45 μm were used for air sampling. The membrane filters were equilibrated at 25 ^{0}C and relative humidity of 55% for 24 hr and then were weighed by using an electric ultramicrobalance (Mettler UMX2) with a sensitivity of 0.1 μg. At last, the membrane filters were put into the series of cascade impactor.

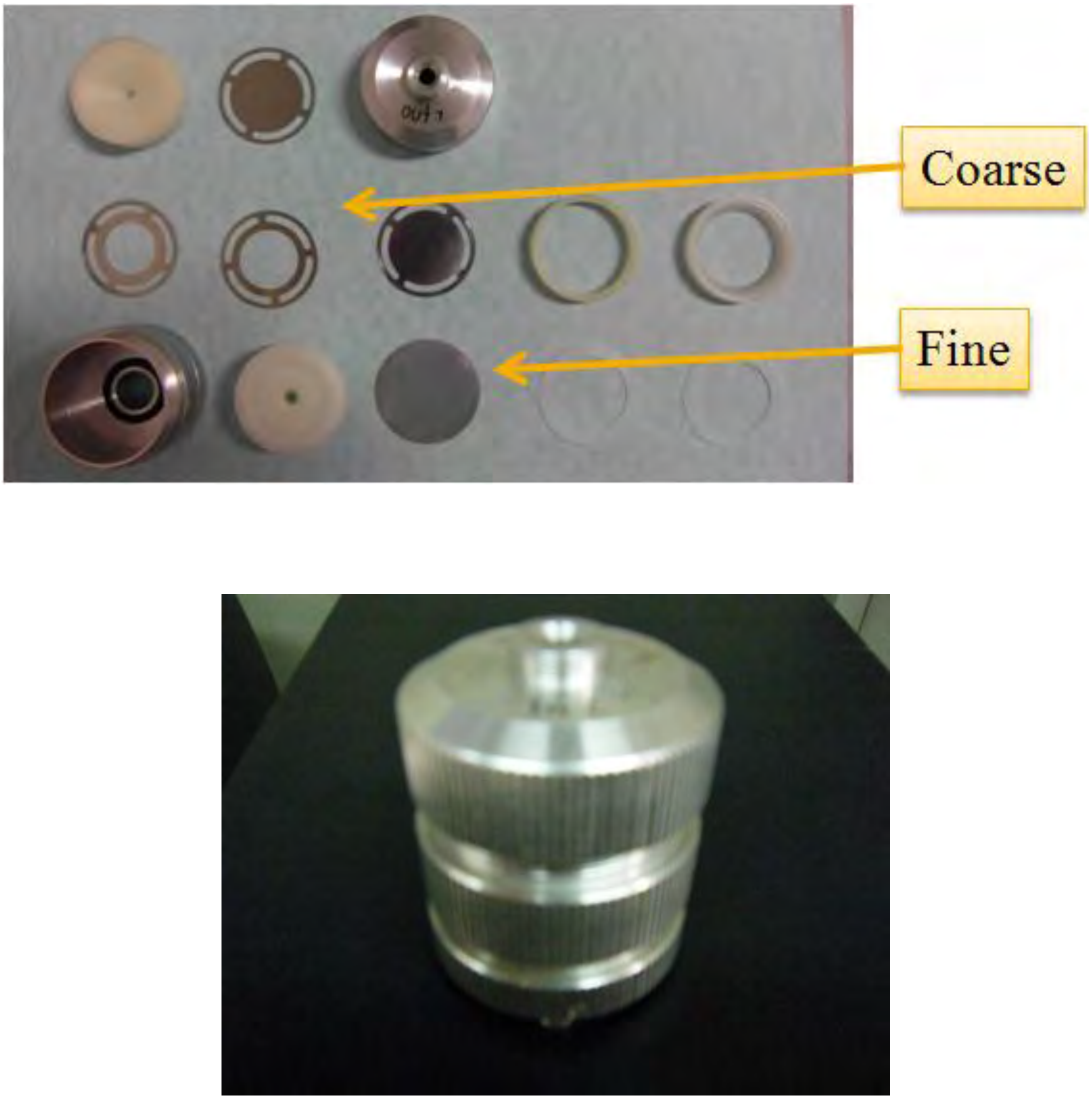


Figure 3.5 Series of cascade impactor

Figure 3.6 An Electric ultramicrobalance (Mettler UMX2) with a sensitivity of 0.1 μg.

3.3 Method for air sampling

For urban and suburban area, air samples were collected at the deck of the building at a height of 25-30 meters above ground level, and air samples at roadside area was collected at a height of 1.5 meters above ground level.

A calibrated Personal air sampler (Sibata Scientific Technology, Ltd.) was equipped with the cascade impactor at a flow rate of 1.70 l/min used for collected fine and coarse particle samplings. In each sampling site, three of completed equipped air samplers were used for air sampling. Two air samplers (two duplicates) were used for particulate matter sampling and the other sampler was used for airborne microorganism sampling. The sampling time period for collecting particulate matters was from 10.00 a.m. to 2.00 p.m. (4 hours). And airborne microorganisms were collected for 10 minutes (three times per day: 10.00-10.10, 12.00-12.10, and 14.00-14.10). In parallel, at Silom road, the data recorded from high-volume air sampler at roadside Chulalongkorn Hospital Pollution Control Department (PCD) station was used to compare with the data recorded from the air simpler in this project. The experiment at each site was duplicated at 7 different dates.

In each sampling sites, fine particle, coarse particle and associated airborne microorganisms were collected at 5 different dates in wet season (from June to Mid-October, 2009) and at 2 different dates in dry season (from Mid-October to November, 2009) at the same condition. The criterion, obtained from the Thai Meteorological Department (TMD), in differentiating between wet and dry season are that wet season begins on the mid of May until the mid of October, while dry season begins on the mid of October until the mid of May (www.tmd.go.th).

(a)

(b)

(c)

Figure 3.7 Air sampling sites

(a) At the deck of Department of General Science's Building, Faculty of Science, Chulalongkorn University

(b) At the deck of Environmental Research Teaching Centre's Building

(c) At the roadside of Silom road

3.4 After air sampling

The total time, total volume of air, and average flow rate were recorded from personal air sampler after air sampling. These data were used to calculate particulate matter concentrations and microbial concentrations.

3.5 Particulate matter concentrations

The membrane filters were equilibrated again under the same conditions and the particulate mass were measured by the gravimetric method with an electric ultramicrobalance (Mettler UMX2) with a sensitivity of 0.1 μg. After recorded, particulate matter concentrations were calculated by using Microsoft excel.

$$\text{Particulate matter concentration} = \frac{\text{Weight after} - \text{Weight before}}{\text{Volume of air sample}} \qquad (1)$$

$$\text{Total particulate matter} = \text{Fine particle} + \text{Coarse particle} \qquad (2)$$

3.6 Determination of microbial count from air sampling

In order to measure the concentration of bacteria and fungi from air sampling, two membrane filters from each air sampler were brought into a beaker containing 50 ml of sterile water. Airborne microorganisms associated with particulate matter on the membrane (fine and coarse particle) were then separately eluted into the water. The microorganisms in the solution were cultivated by using spread plate technique in triplicate (aseptic techniques required). In this techniques, small aliquot (50 μl) of the solution was drawn by micropipette for transferring into an agar plate, then the solution was evenly distributed on the plate by sterile spreading glass, and finally the plates were incubated at specific conditions for growing bacteria and fungi. After incubation, the bacterial and fungal colonies were counted. The numbers of the colonies were used to calculate to obtain the concentration of airborne microorganisms in the term of colony forming units per cubic meters of air (CFU/m^3). The condition for cultivating airborne bacteria and fungi were different as follows. For growing airborne bacteria, Tryptic Soy Agar (TSA: Merck, Germany) was used for cultivation and incubation condition was 37°C and 24-48 hours. In parallel, fungi were cultivated in Sabouraud Dextrose Agar (SDA: Merck. Germany) and incubated at 25°C for 5-14 days.

Tryptic Soy Agar (TSA) is one of the most commonly used culture media for airborne bacteria. Mesophile bacteria (optimum growth at 30 - 37°C) are the the most common bacteria. Saprophytes grow best around 30°C and the parasitic species around 37°C. The main isolation temperature for environmental bacteria should be 30°C but pathogens affecting humans (which are the most heavily studied microbes) tend to have evolved to grow best at the temperature of the human body, 37°C. Therefore, the condition for incubating airborne bacteria in TSA is 37°C for 24-48 hr. The majority of fungi will grow between 0°C and 37°C with an optimum temperature between 25°C and 30°C. Incubation temperature for isolation of environmental fungi is recommended at 25°C. Fungus cultures are incubated at either at 30°C or at room temperature (25°C). Therefore, the condition for incubating airborne bacteria in TSA is 25°C (Brook et al., 2004; Madigan and Martinko, 2006; Maier et al., 1999, 2008).

The following formulas were used for calculating the concentration of airborne microorganisms.

$$\text{Volume of air sample (L)} = \text{Flow rate (L/min)} \times \text{Sampler time (min)} \qquad (3)$$

$$\text{Total colony (CFU/m}^3\text{)} = \frac{\text{Total colony (colony)} \times 1000 \text{ (m}^3\text{)}}{\text{Volume of air sample (L)}} \qquad (4)$$

3.7 Microbial identification

Gram's stain techniques and bacterial morphology study were used for preliminary identification of selected culturable airborne bacteria by using light microscope. To confirm the preliminary identification, the bacteria were then sent to Thailand Institute of Scientific and Technological Research (TISTR). In parallel, for fungal identification, the slide culture technique was used for cultivating airborne fungi in order to isolate into colonies. The culturable fungal genera were identified by using optical microscope, on the basis of fungal classification method (observing the form, shape and color of colony and spore).

3.8 Evaluation of air quality standards

The calculated total particulate matter concentration from air sampling at the urban area and roadside area (every hour from 10.00 a.m. to 2.00 p.m.) were compared the trend with the PM_{10} data recorded by Chulalongkorn Hospital PCD station (This station usually records PM_{10} every hour). However, because of no any nearby air sampling station, total particulate matter concentration at the suburban area were not compared and directly used for air quality assessment.

Recently, there is no standard level of outdoor microbial concentrations in any previous studies. Hence, this project used only the calculated microbial concentration (in term of CFU/m^3) to compare the microbial count in other researches. In addition, other researches provided the information of bacterial type from air pollution by classified them into pathogenic and non-pathogenic level, rather than species level. However, this study provides the first insight into bacterial identification in species level from air sampling at urban area, suburban and roadside areas of Bangkok.

3.9 Resources of meteorological parameters

The meteorological parameters, including wind direction, wind speed, temperature, relative humidity, pressure and solar radiation were obtained from the nearest site of air sampling. The data at urban and roadside area were received from The Thai Meteorological Department (TMD) at Queen Sirikit National Convention Center station and the data at suburban site was received from the observation site at Environmental Research and Training Centre (ERTC).

3.10 Statistical analysis

3.9.1 Mean and standard deviation were used for describing the particulate matter concentrations and microbial concentrations from the air samples.

3.9.2 One-way analysis of variance (ANOVA) was used to compare the temporal, daily, and spatial variation pattern in the group of particulate matter and airborne microbial concentrations.

3.9.3 The association between airborne microorganism level, particulate matter level, and meteorological parameters were statistically analyzed by using the multiple regression analysis via Pearson correlation.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Particulate matter concentrations

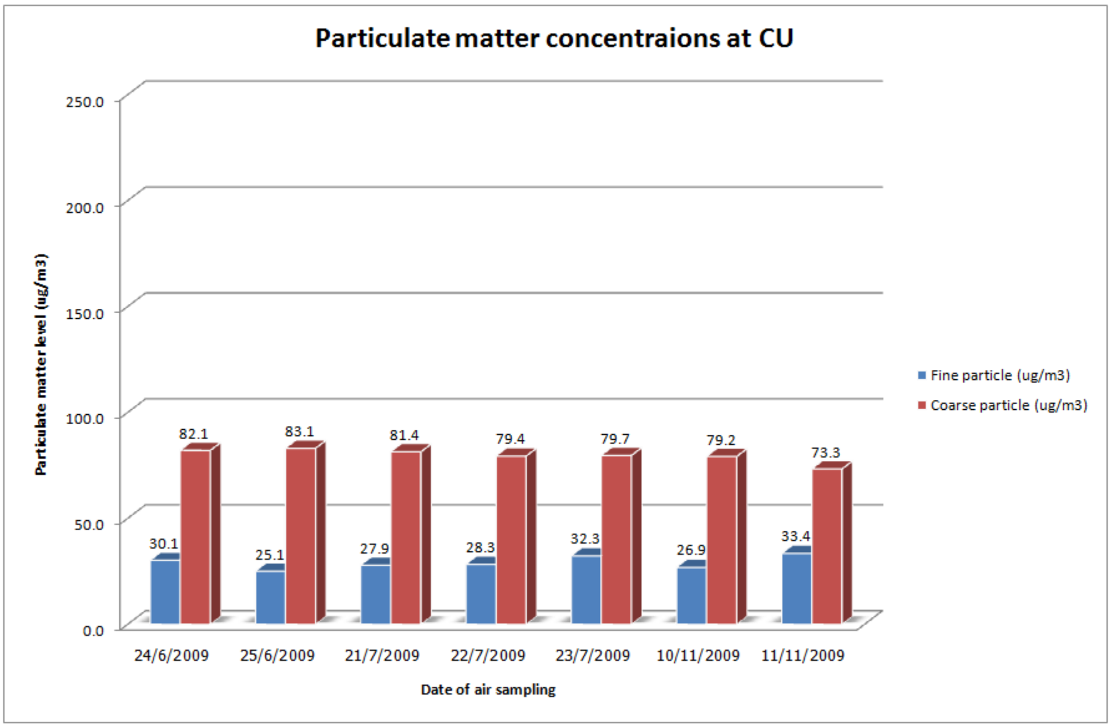
The air samples at CU and ERTC were collected at a height of 25-30 meters above ground level, and the air samples at Silom road were collected at the roadside above ground level approximately 1.5 meters.

4.1.1 Daily and spatial variation pattern comparison of particulate matter profiles

The daily variation of particulate matter concentrations (recorded for 4 hours during 10.00 am - 2.00 pm) at CU, ERTC and Silom road are shown in Table 4.1 and Figure 4.1. The mean concentrations and their standard deviation of fine particle at CU, ERTC, and Silom road were 29.1 ± 3.0, 36.0 ± 15.0, and 117.0 ± 34.5 $\mu g/m^3$, respectively, whereas those of coarse particle at CU, ERTC and Silom road were 79.7 ± 3.2, 47.0 ± 14.6, and 176.4 ± 37.3 $\mu g/m^3$, respectively. Total particulate matter concentrations at CU, ERTC and Silom road were 108.9 ± 2.4, 83.0 ± 17.9, and 293.5 ± 67.2 $\mu g/m^3$, respectively.

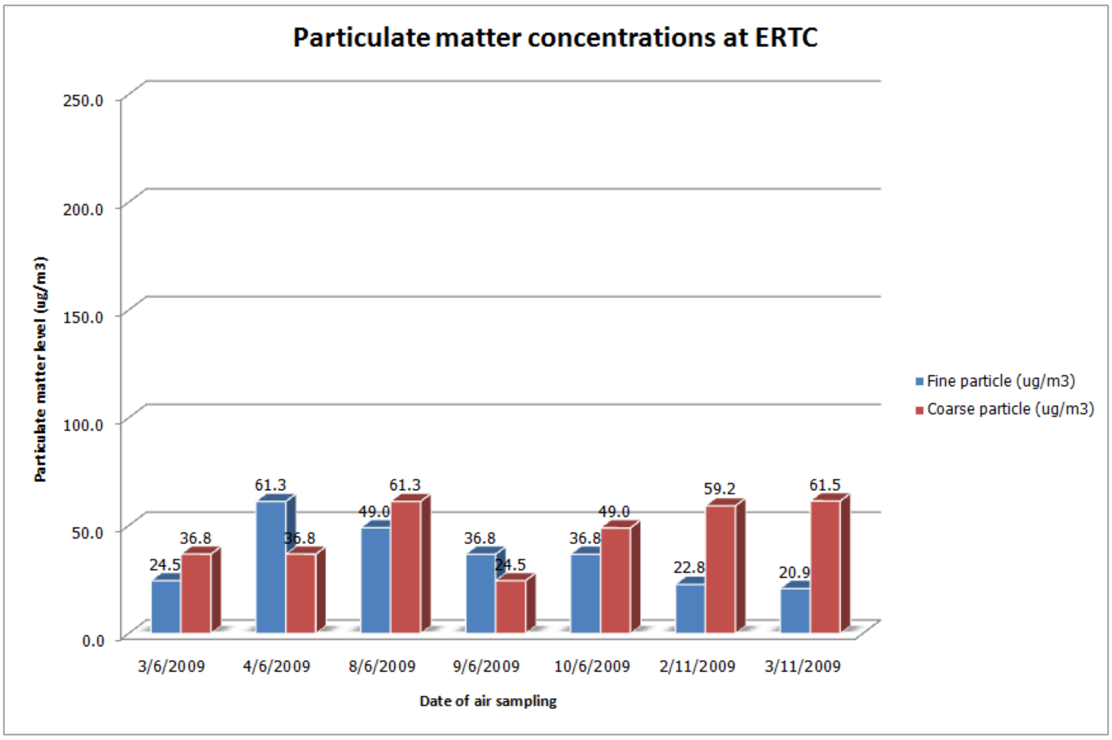
Table 4.1: Particulate matter concentrations (μg/m^3) at each sampling site, measured during 10:00 AM - 2:00 PM

Date	Fine particle (ug/m^3)	Coarse particle (ug/m^3)	Total PM
1. Urban area (CU)			
24/06/2009	30.1	82.1	112.3
25/06/2009	25.1	83.1	108.2
21/07/2009	27.9	81.4	109.3
22/07/2009	28.3	79.4	107.7
23/07/2009	32.3	79.7	112.0
10/11/2009	26.9	79.2	106.1
11/11/2009	33.4	73.3	106.7
Average	29.1 ± 3.0	79.7 ± 3.2	108.9 ± 2.4
2. Suburban area (ERTC)			
03/06/2009	24.5	36.8	61.3
04/06/2009	61.3	36.8	98.0
08/06/2009	49.0	61.3	110.3
09/06/2009	36.8	24.5	61.3
10/06/2009	36.8	49.0	85.8
02/11/2009	22.8	59.2	82.0
03/11/2009	20.9	61.5	82.4
Average	36.0 ± 15.0	47.0 ± 14.6	83.0 ± 17.9
3. Roadside area (Silom road)			
26/8/2009	88.2	140.0	228.3
27/8/2009	98.3	172.7	271.0
28/8/2009	125.2	160.6	285.8
06/10/2009	150.5	207.4	357.9
07/10/2009	173.9	218.7	392.7
26/10/2009	102.4	211.6	314.1
27/10/2009	80.8	123.9	204.7
Average	117.0 ± 34.5	176.4 ± 37.3	293.5 ± 67.2



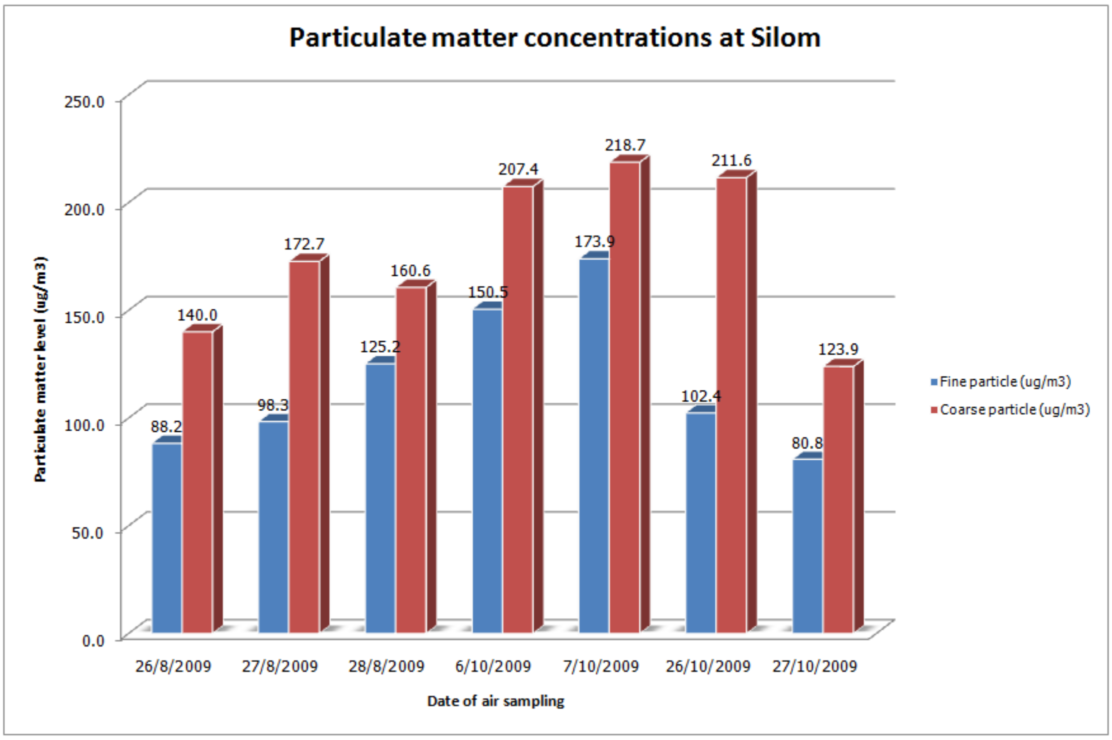
Particulate matter concentraions at CU
Particulate matter level (ug/m3)
250.0
200.0
150.0
100.0
50.0
0.0
82.1
83.1
81.4
79.4
79.7
79.2
73.3
30.1
25.1
27.9
28.3
32.3
26.9
33.4
24/6/2009
25/6/2009
21/7/2009
22/7/2009
23/7/2009
10/11/2009
11/11/2009
Date of air sampling
Fine particle (ug/m3)
Coarse particle (ug/m3)

(a)



Particulate matter concentrations at ERTC
Particulate matter level (ug/m3)
250.0
200.0
150.0
100.0
50.0
0.0
24.5
36.8
61.3
36.8
49.0
61.3
36.8
24.5
36.8
49.0
22.8
59.2
20.9
61.5
3/6/2009
4/6/2009
8/6/2009
9/6/2009
10/6/2009
2/11/2009
3/11/2009
Date of air sampling
Fine particle (ug/m3)
Coarse particle (ug/m3)

(b)



(c)

Figure 4.1 Particulate matter concentrations (fine and coarse particle (μg/m^3)) at different sampling sites ((a) CU, (b) ERTC, and (c) Silom road) and at different dates during 5 days in wet season and 2 days in dry season

Table 4.2: Results of one-way ANOVA analysis used for testing the daily variation of fine and coarse particulate matter concentrations at each air sampling sites: (a) CU (b) ERTC (c) Silom road

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	106.431	6	17.739	3.535	.062
	Within Groups	35.129	7	5.018		
	Total	141.561	13			
Coarse	Between Groups	123.718	6	20.620	2.249	.156
	Within Groups	64.172	7	9.167		
	Total	187.890	13			

(a)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	2686.330	6	447.722	3.417	.066
	Within Groups	917.305	7	131.044		
	Total	3603.634	13			
Coarse	Between Groups	2564.652	6	427.442	3.317	.071
	Within Groups	901.957	7	128.851		
	Total	3466.608	13			

(b)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	14262.019	6	2377.003	457.989	.000
	Within Groups	36.331	7	5.190		
	Total	14298.350	13			
Coarse	Between Groups	16658.061	6	2776.343	154.385	.000
	Within Groups	125.883	7	17.983		
	Total	16783.944	13			

(c)

Table 4.3: Results of one-way ANOVA analysis used for testing the spatial variation of fine and coarse particulate matter concentrations in ambient air among different sampling sites

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	66960.826	2	33480.413	72.366	.000
	Within Groups	18043.545	39	462.655		
	Total	85004.372	41			
Coarse	Between Groups	126788.509	2	63394.254	120.967	.000
	Within Groups	20438.442	39	524.063		
	Total	147226.951	41			

Fine and coarse particulate matter concentration in ambient air at CU site narrowly varied from 25.1 to 33.4 μg/m^3 and from 73.3 to 83.1 μg/m^3, respectively. In contrast, at ERTC site, fine and coarse particulate matter level broadly ranged from 20.9 to 61.3 μg/m^3 and from 24.5 to 61.5 μg/m^3, respectively. At Silom road, alarmingly, the particulate matter concentrations in every date of air sampling were not only measured to be higher than the value recorded from the other sites but also broadly ranged from 80.8 to 173.9 μg/m^3 for the fine particulate matter values and from 123.9 to 218.7 μg/m^3 for coarse particulate matter values.

As shown in Table 4.2, the daily variation patterns of fine particle and total particulate matter concentrations in ambient air recorded from each of air sampling areas can be verified by using the statistical analysis (one-way ANOVA at 95% confidence). As a result, in both urban (CU) and suburban area (ERTC), there was no significant difference in particulate matter (both fine and coarse particulate matter concentrations) mass concentrations among the seven dates of air sampling ($P>0.05$). In contrast, at roadside area (Silom road), the concentrations of particulate matter (both fine and coarse particulate matter concentrations) at different dates were significantly different ($P<0.05$).

In addition, it was previously observed in Table 4.1 that fine particle and total particulate matter concentrations varied greatly among the different sampling sites. These spatial variation patterns of particulate matter concentrations in ambient air among the air sampling sites can also be analyzed by one-way ANOVA at 95% confidence, as shown in Table 4.3. As a result from the statistical analysis, we found that fine and coarse particulate matter concentrations at the roadside area were significantly higher than those at the urban and suburban areas ($P<0.05$). In addition, there was no significant difference of fine particulate matter concentrations between the urban and suburban areas ($P>0.05$) while significant difference of coarse particulate matter concentrations between the urban and suburban areas ($P<0.05$).

4.1.2 Comparison between particulate matter measurement data with PCD

In Thailand, the Pollution Control Department (PCD) does not have the measurement of $PM_{2.5}$ concentration. It has only the hourly PM_{10} concentration. The hourly total particulate matter concentrations at the urban and roadside area were received from roadside Chulalongkorn Hospital PCD station. The hourly total particulate matter concentration from this research compared with the hourly PM_{10} concentration from PCD station is shown in table 4.4. Some of PM_{10} concentrations of PCD data at urban area were missed from the profiles while the PCD data at suburban area were not found the profiles. The trend of particulate matter concentration at roadside area is similarity. The comparison of hourly total particulate matter concentrations between in this study and PCD data at roadside area was found highly significant correlation with r=0.971 at P=0.01.

Particulate matter is emitted into the air from several pollution sources such as vehicle, industrial processes, and miscellaneous (Maier et al., 1999). From the compared data, it showed that the data in urban area was lower than the PCD data because the air samplings were measured from the deck of the building that has a height approximately 25 to 30 meters. There are far from emission sources of particulate matter. Ambient air environment could have particulate matter lower than roadside area. Particulate matter concentrations at roadside area were higher than other sampling sites because it comes from the emission sources of particulate matter such as automobile, and construction site.

Table 4.4: Hourly total particulate matter concentration (μg/m^3) at CU, ERTC and Silom road with hourly PM_{10} concentration of PCD

Date	Total PM (Data)	PM_{10} (PCD)
1. Urban area		
24/06/2009	28.1	57.3
25/06/2009	27.0	No data
21/07/2009	27.3	95.5
22/07/2009	26.9	87.0
23/07/2009	28.0	58.5
10/11/2009	26.5	No data
11/11/2009	26.7	No data
2. Suburban area		
03/06/2009	15.3	No data
04/06/2009	24.5	No data
08/06/2009	27.6	No data
09/06/2009	15.3	No data
10/06/2009	21.4	No data
02/11/2009	20.5	No data
03/11/2009	20.6	No data
3. Roadside area		
26/08/2009	57.1	64.8
27/08/2009	67.8	70.0
28/08/2009	71.5	76.8
06/10/2009	89.5	90.8
07/10/2009	98.2	113.8
26/10/2009	78.5	80.5
27/10/2009	51.2	54.0

4.2 Microbial concentration

Based on the same condition of particulate matter sampling, microbial concentrations (CFU/m^3) at three selected sampling sites were measured for 10 minutes, three times per day (at 10.00 a.m., 12.00 p.m., and 2.00 p.m.), for seven different dates during wet and dry season.

4.2.1 Quantitative analysis

The variations in concentrations of both particle-associated airborne bacteria and airborne fungi at seven dates of air sampling were found at three sampling sites, as shown in Table 4.5 for all sampling sites, Table 4.6 and Figure 4.2 for CU, Table 4.7 and Figure 4.3 for ERTC, and Table 4.8 and Figure 4.4 for Silom road.

Table 4.5: Concentrations of airborne microorganisms associated with particulate matter (CFU/m^3) for all sampling sites

Sites	Airborne bacteria			Airborne fungi		
	Coarse	Fine	Total	Coarse	Fine	Total
Urban	315.6±45.1	344.5±132.2	660.1±98.9	310.0±62.3	377.2±137.6	687.2±114.6
Suburban	232.5±53.7	367.9±157.2	600.4±139.7	268.0±61.3	413.6±177.9	681.6±207.0
Roadside	188.6±41.2	111.1±34.0	299.7±68.0	147.5±22.0	95.2±14.5	242.8±29.3

At urban area (CU), particle-associated airborne bacterial concentrations ranged from 529.4 ± 110.0 to 810.5 ± 313.7 CFU/m^3 with the average concentration of 660.1 ± 98.9 CFU/m^3. Whereas, the concentrations of particle-associated airborne fungi varied from 535.9 ± 85.5 to 849.7 ± 341.9 CFU/m^3 with the average concentration of 687.2 ± 114.6 CFU/m^3. At suburban area (ERTC), the particle-associated bacterial and fungal concentrations ranged from 359.5 ± 126.3 to 732.0 ± 288.3 CFU/m^3 with the mean concentration of 600.4 ± 139.7 CFU/m^3 and from 464.1 ± 74.7 to 954.2 ± 280.2 CFU/m^3 with the mean concentration of 681.6 ± 207.0 CFU/m^3, respectively. Finally, at roadside area (Silom road), the concentrations of particle-associated bacteria ranged from 222.2 ± 64.3 to 437.9 ± 106.5 CFU/m^3 with the mean concentration of 299.7 ± 68.0 CFU/m^3, The particle-associated fungal concentration varied from 183.0 ± 99.5 to 261.4 ± 88.8 CFU/m^3 and the mean concentration was 242.8 ± 29.3 CFU/m^3.

Table 4.6: Concentrations of airborne microorganisms associated with particulate matter (CFU/m^3) at the urban area (CU)

Date	Time	Bacteria			Fungi		
		Coarse	Fine	Total	Coarse	Fine	Total
24/6/2009	10.00 a.m.	274.5	411.8	686.3	215.7	588.2	803.9
	12.00 a.m.	313.7	568.6	882.4	431.4	549.0	980.4
	2.00 p.m.	392.2	235.3	627.5	78.4	568.6	647.1
	Total Daily	326.8	405.2	732.0	241.8	568.6	810.5
25/6/2009	10.00 a.m.	137.3	725.5	862.8	235.3	745.1	980.4
	12.00 a.m.	431.4	705.9	1137.3	549.0	607.8	1156.9
	2.00 p.m.	117.7	313.7	431.4	196.1	215.7	411.8
	Total Daily	228.8	581.7	810.5	326.8	522.9	849.7
21/7/2009	10.00 a.m.	274.5	411.8	686.3	254.9	352.9	607.8
	12.00 a.m.	529.4	588.2	1117.7	549.0	470.6	1019.6
	2.00 p.m.	215.7	58.8	274.5	352.9	117.7	470.6
	Total Daily	339.9	352.9	692.8	385.6	313.7	699.4
22/7/2009	10.00 a.m.	215.7	411.8	627.5	274.5	411.8	686.3
	12.00 a.m.	333.3	431.4	764.7	568.6	431.4	1000.0
	2.00 p.m.	470.6	137.3	607.8	156.9	235.3	392.2
	Total Daily	339.9	326.8	666.7	333.3	359.5	692.8
23/7/2009	10.00 a.m.	372.6	254.9	627.5	235.3	470.6	705.9
	12.00 a.m.	333.3	431.4	764.7	274.5	568.6	843.1
	2.00 p.m.	156.9	372.6	529.4	137.3	254.9	392.2
	Total Daily	287.6	352.9	640.5	215.7	431.4	647.1
10/11/2009	10.00 a.m.	313.7	196.1	509.8	372.6	156.9	529.4
	12.00 a.m.	470.6	196.1	666.7	451.0	254.9	705.9
	2.00 p.m.	313.7	156.9	470.6	274.5	215.7	490.2
	Total Daily	366.0	183.0	549.0	366.0	209.2	575.2
11/11/2009	10.00 a.m.	313.7	215.7	529.4	313.7	235.3	549.0
	12.00 a.m.	352.9	235.3	588.2	294.1	274.5	568.6
	2.00 p.m.	294.1	176.5	470.6	294.1	196.1	490.2
	Total Daily	320.3	209.2	529.4	300.7	235.3	536.0
Total	Mean	315.6	344.5	660.1	310.0	377.2	687.2
	SD	45.1	132.2	98.9	62.3	137.6	114.6

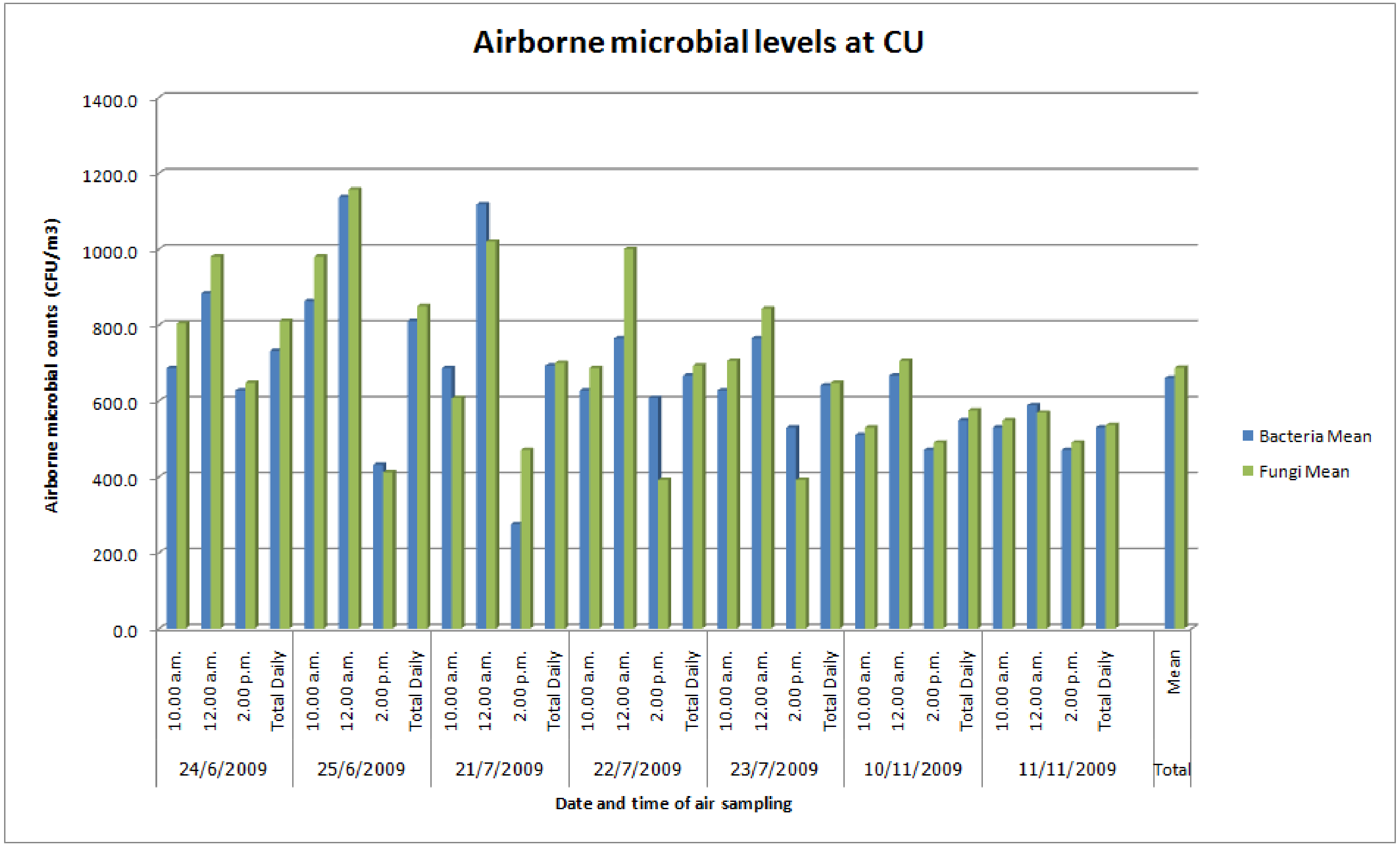


Figure 4.2 Daily variation patterns of particle-associate microbial concentrations (CFU/m^3) at the urban area (CU) during 5 days in wet season and 2 days in dry season

Table 4.7: Concentrations of airborne microorganisms associated with particulate matter (CFU/m^3) at the suburban area (ERTC)

Date	Time	Bacteria			Fungi		
		Coarse	Fine	Total	Coarse	Fine	Total
3/6/2009	10.00 a.m.	215.7	392.2	607.8	215.7	529.4	745.1
	12.00 a.m.	176.5	725.5	902.0	333.3	705.9	1039.2
	2.00 p.m.	137.3	254.9	392.2	156.9	274.5	431.4
	Total	176.5	457.5	634.0	235.3	503.3	738.6
4/6/2009	10.00 a.m.	156.9	411.8	568.6	196.1	451.0	647.1
	12.00 a.m.	313.7	666.7	980.4	294.1	745.1	1039.2
	2.00 p.m.	156.9	274.5	431.4	156.9	333.3	490.2
	Total	209.2	451.0	660.1	215.7	509.8	725.5
8/6/2009	10.00 a.m.	156.9	411.8	568.6	352.9	509.8	862.7
	12.00 a.m.	254.9	725.5	980.4	313.7	902.0	1215.7
	2.00 p.m.	156.9	274.5	431.4	235.3	431.4	666.7
	Total	189.5	470.6	660.1	300.7	614.4	915.0
9/6/2009	10.00 a.m.	235.3	392.2	627.5	294.1	549.0	843.1
	12.00 a.m.	470.6	627.5	1098.0	588.2	725.5	1313.7
	2.00 p.m.	235.3	235.3	470.6	254.9	451.0	705.9
	Total	313.7	418.3	732.0	379.1	575.2	954.2
10/7/2009	10.00 a.m.	176.5	549.0	725.5	137.3	235.3	372.5
	12.00 a.m.	333.3	627.5	960.8	313.7	490.2	803.9
	2.00 p.m.	117.6	313.7	431.4	137.3	156.9	294.1
	Total	209.2	496.7	705.9	196.1	294.1	490.2
2/11/2009	10.00 a.m.	274.5	176.5	451.0	254.9	235.3	490.2
	12.00 a.m.	392.2	176.5	568.6	352.9	235.3	588.2
	2.00 p.m.	235.3	98.0	333.3	235.3	137.3	372.5
	Total	300.7	150.3	451.0	281.0	202.6	483.7
3/11/2009	10.00 a.m.	215.7	98.0	313.7	274.5	176.5	451.0
	12.00 a.m.	294.1	196.1	490.2	254.9	254.9	509.8
	2.00 p.m.	176.5	98.0	274.5	274.5	156.9	431.4
	Total	228.8	130.7	359.5	268.0	196.1	464.1
Total	Mean	232.5	367.9	600.4	268.0	413.6	681.6
	SD	53.7	157.2	139.7	61.3	177.9	207.0

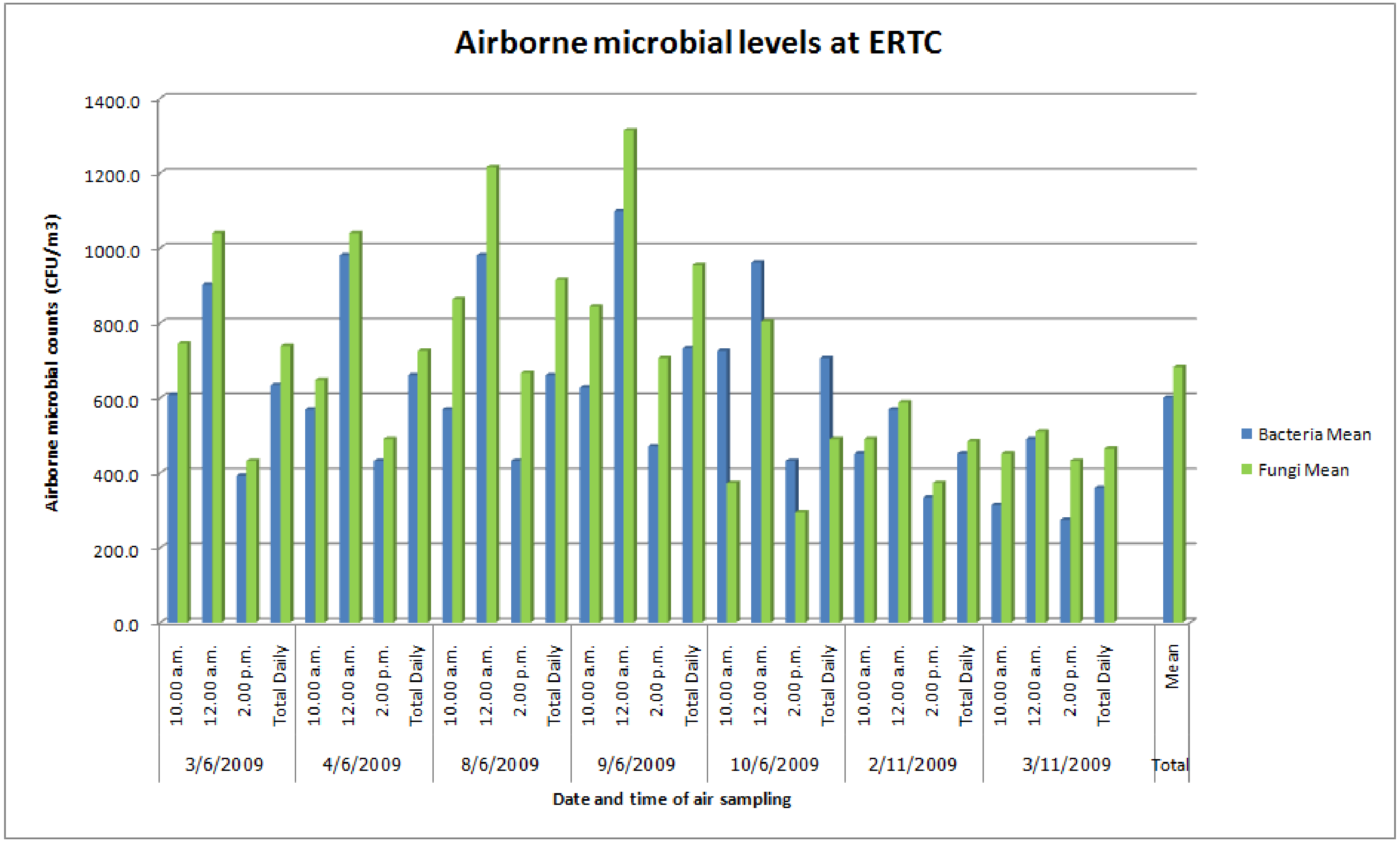


Figure 4.3 Daily variation patterns of particle-associate microbial concentrations (CFU/m^3) at the suburban area (ERTC) during 5 days in wet season and 2 days in dry season

Table 4.8: Concentrations of airborne microorganisms associated with particulate matter (CFU/m^3) at the roadside area (Silom road)

Date	Time	Bacteria			Fungi		
		Coarse	Fine	Total	Coarse	Fine	Total
26/8/2009	10.00 a.m.	313.7	156.9	470.6	176.5	58.8	235.3
	12.00 a.m.	294.1	215.7	509.8	176.5	156.9	333.3
	2.00 p.m.	196.1	137.3	333.3	176.5	39.2	215.7
	Total	268.0	169.9	437.9	176.5	85.0	261.4
27/8/2009	10.00 a.m.	176.5	117.6	294.1	78.4	78.4	156.9
	12.00 a.m.	274.5	117.6	392.2	137.3	117.6	254.9
	2.00 p.m.	176.5	98.0	274.5	117.6	19.6	137.3
	Total	209.2	111.1	320.3	111.1	71.9	183.0
28/8/2009	10.00 a.m.	156.9	117.6	274.5	117.6	137.3	254.9
	12.00 a.m.	235.3	137.3	372.5	196.1	117.6	313.7
	2.00 p.m.	117.6	117.6	235.3	176.5	39.2	215.7
	Total	169.9	124.2	294.1	163.4	98.0	261.4
6/10/2009	10.00 a.m.	137.3	137.3	274.5	137.3	117.6	254.9
	12.00 a.m.	176.5	156.9	333.3	196.1	117.6	313.7
	2.00 p.m.	137.3	98.0	235.3	98.0	117.6	215.7
	Total	150.3	130.7	281.0	143.8	117.6	261.4
7/10/2009	10.00 a.m.	137.3	117.6	254.9	98.0	117.6	215.7
	12.00 a.m.	235.3	137.3	372.5	196.1	117.6	313.7
	2.00 p.m.	215.7	0.0	215.7	117.6	78.4	196.1
	Total	196.1	85.0	281.0	137.3	104.6	241.8
26/10/2009	10.00 a.m.	137.3	98.0	235.3	137.3	117.6	254.9
	12.00 a.m.	215.7	117.6	333.3	196.1	98.0	294.1
	2.00 p.m.	176.5	39.2	215.7	156.9	78.4	235.3
	Total	176.5	85.0	261.4	163.4	98.0	261.4
27/10/2009	10.00 a.m.	117.6	98.0	215.7	156.9	78.4	235.3
	12.00 a.m.	156.9	117.6	274.5	117.6	137.3	254.9
	2.00 p.m.	176.5	0.0	176.5	137.3	58.8	196.1
	Total	150.3	71.9	222.2	137.3	91.5	228.8
Total	Mean	188.6	111.1	299.7	147.5	95.2	242.8
	SD	41.2	34.0	68.0	22.0	14.5	29.3

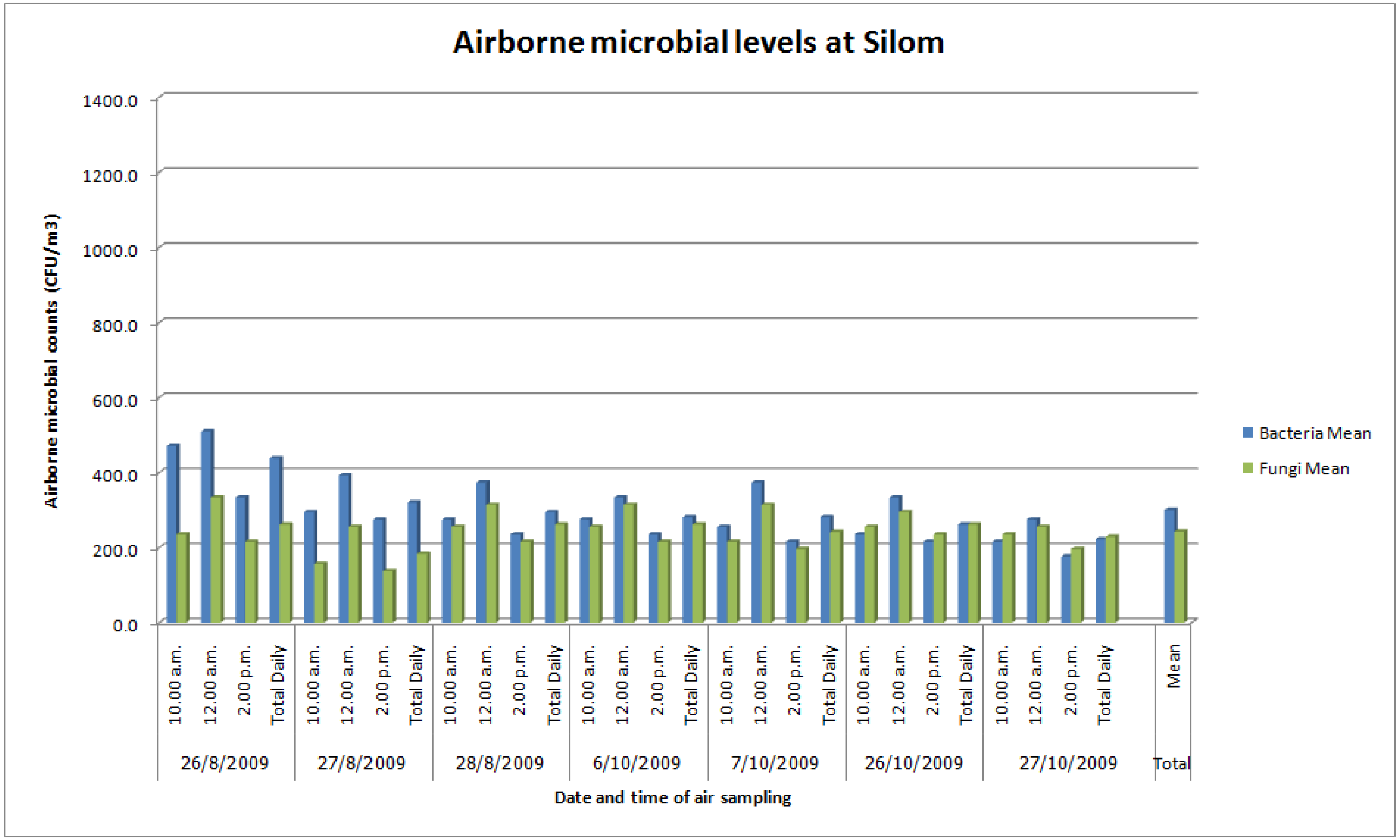


Figure 4.4 Daily variation patterns of particle-associate microbial concentrations (CFU/m^3) at the roadside area (Silom road) during 5 days in wet season and 2 days in dry season

4.2.2 Statistical analysis of temporal, daily and spatial variation pattern of particle-associated microbial concentrations

The temporal variation patterns of the concentrations of particle-associated airborne microorganisms in three sampling sites were examined by using one-way ANOVA, as shown in Table 4.9. At all sampling areas, the bacterial and fungal concentrations recorded at 12.00 p.m. were significantly higher than those at 2.00 p.m. ($P<0.05$), while there was no significant difference of those between the air sampling times at 10.00 a.m. and those at 12.00 p.m., the air sampling times at 10.00 a.m. and those at 2.00 p.m. For the differences of bacterial and fungal concentrations between the air sampling at 10.00 a.m. and 12.00 p.m., there were significant differences within the group of bacterial concentrations recorded at ERTC and the group of fungal concentrations recorded at Silom road.

The daily variation patterns of the concentrations of particle-associated airborne microorganisms at three sampling areas were evaluated by using one-way ANOVA at 95% confidence, as shown in Table 4.10. As a result from the evaluation, for both of the particle-associated bacterial and fungal concentrations in ambient air, there was no significant difference found among the seven dates of air sampling at three sampling sites ($P>0.05$), except the airborne bacterial concentration at roadside area ($P<0.05$).

Table 4.9: Results of one-way ANOVA analysis used for testing the temporal variation of the concentrations of airborne microorganisms associated with particulate matter in ambient air at each sampling sites: (a) CU (b) ERTC (c) Silom road

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	451762.727	2	225881.363	9.244	.002
	Within Groups	439817.966	18	24434.331		
	Total	891580.692	20			
Fungi	Between Groups	634983.326	2	317491.663	12.844	.000
	Within Groups	444931.860	18	24718.437		
	Total	1079915.186	20			

(a)

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	763372.411	2	381686.206	15.150	.000
	Within Groups	453477.053	18	25193.170		
	Total	1216849.465	20			
Fungi	Between Groups	721947.894	2	360973.947	6.989	.006
	Within Groups	929680.697	18	51648.928		
	Total	1651628.590	20			

(b)

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	59405.923	2	29702.961	5.950	.010
	Within Groups	89852.583	18	4991.810		
	Total	149258.506	20			
Fungi	Between Groups	33513.387	2	16756.693	15.793	.000
	Within Groups	19098.240	18	1061.013		
	Total	52611.627	20			

(c)

Table 4.10: Results of one-way ANOVA analysis used for testing the daily variation of the concentrations of airborne microorganisms associated with particulate matter in ambient air at each sampling sites: (a) CU (b) ERTC (c) Silom road

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	176145.259	6	29357.543	.574	.745
	Within Groups	715435.433	14	51102.531		
	Total	891580.692	20			
Fungi	Between Groups	236470.886	6	39411.814	.654	.687
	Within Groups	843444.300	14	60246.021		
	Total	1079915.186	20			

(a)

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	351282.616	6	58547.103	.947	.493
	Within Groups	865566.848	14	61826.203		
	Total	1216849.465	20			
Fungi	Between Groups	771446.802	6	128574.467	2.045	.127
	Within Groups	880181.789	14	62870.128		
	Total	1651628.590	20			

(b)

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	83147.692	6	13857.949	2.935	.045
	Within Groups	66110.813	14	4722.201		
	Total	149258.506	20			
Fungi	Between Groups	15476.160	6	2579.360	.972	.479
	Within Groups	37135.467	14	2652.533		
	Total	52611.627	20			

(c)

Table 4.11: Results of one-way ANOVA analysis used for testing the spatial variation of the concentrations of airborne microorganisms associated with particulate matter in ambient air among different sampling sites

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	1567154.264	2	783577.132	20.824	.000
	Within Groups	2257688.663	60	37628.144		
	Total	3824842.927	62			
Fungi	Between Groups	2731013.963	2	1365506.982	29.427	.000
	Within Groups	2784155.403	60	46402.590		
	Total	5515169.366	62			

The spatial variation patterns of the concentrations of particle-associated airborne microorganisms at three sampling areas were analyzed by using one-way ANOVA at 95% confidence, as shown in Table 4.11. Both the bacterial and fungal concentrations varied greatly at different sampling sites. Significantly higher microbial concentrations were observed at the urban area and the suburban area than at the roadside area ($P<0.05$), and no significant differences of the concentrations were found between the urban area and the suburban area ($P>0.05$).

Both airborne bacteria and airborne fungi were associated with both fine and coarse particle. Data from this study supported that the size of bioaerosol particles varies from below 1 μm to 100 μm in aerodynamic diameter. Totally, airborne fungi were higher than airborne bacteria in urban and suburban area, but airborne bacteria were higher than airborne fungi in roadside area. These differences may have been caused by human activities, background of site location, vehicle traffic, vegetation coverage, and environmental conditions at the three sampling sites. In urban and suburban area, the air samplings were collected at the deck of the building that far away from people, human activities, and vehicle traffic that is the major source of airborne bacteria. In addition, vegetation coverage was found around sampling site that is the source of airborne fungi. It is conversely with roadside area. Airborne microorganisms in cities can be related to several factors such as vehicle traffic, amount of suspended dust, turbulent airflow, and density of the people (Lee et al., 1972; Mancinelli and Shulls, 1977; Madigan and Martinko, 2006; Maier et al., 2008).

High levels of particulate matter are associated with airborne microbial counts in urban and suburban area, while high levels of particulate matter are not associated with airborne microbial counts in roadside area. Both airborne bacteria and airborne fungi at roadside area were lower than those in urban and suburban area. It may be from chemical pollutants from roadside area such as carbon monoxide, total hydrocarbon, pollutants associated with automobile emissions (Lee et al., 1972), nitrogen dioxide (+), and nitric oxide (-) (Mancinelli and Shulls, 1977).

4.2.3 Comparing with other previous studies

Airborne microbial concentration of urban, suburban, and roadside area was not compared with the standard because they do not have outdoor air environment standards in any countries. It is probably due to the fact that, the information about the potential impact of bioaerosol is still developing. Therefore, these results were compared with the other literature reviews.

Generally, the airborne microorganism concentrations in outdoor environments are varied depending on days, times, season, sites, environments, meteorological parameters, and air sampling methods. Therefore, it cannot directly compare but it can compare the roughly quantity.

In Thailand, only roadside area of Bangkok was studied airborne microorganisms, as shown in Table 4.12. Pratumvong (1997) reported that the average total airborne bacteria concentration at Chulalongkorn Hospital was 350 CFU/m^3. It is similar to roadside area, Silom road, in this study. Mopuang et al. (2006) reported that the average outdoor airborne bacteria was 393.9 ± 325.4 CFU/m^3 and outdoor airborne fungi concentrations averaged was 121.0 ± 94.0 CFU/m^3. The averaged airborne bacteria was similar to this study, but the averaged airborne fungi was lower than in this study.

Table 4.12: Other literature reviews at roadside area

Reference	Airborne bacteria (CFU/m^3)	Airborne fungi (CFU/m^3)
Pratumvong (1997)	350 (at CU Hospital)	-
Mopuang et al. (2006)	393.9 ± 325.4 (at BTS)	121.0 ± 94.0 (at BTS)

. For the other countries, only ambient areas of Bangkok were studied airborne microorganisms, as shown in Table 4.13. Giorgio et al. (1996) reported that the airborne bacteria concentrations averaged were 791 ± 598 CFU/m^3 and airborne fungi concentrations averaged was 92 ± 92 CFU/m^3 in France. Airborne microorganisms in urban area were higher than in suburban area and airborne bacteria were higher than airborne fungi (Giorgio et al., 1996). In USA, the highest average number of airborne bacteria during daylight hours was 609 CFU/m^3 at the urban site, 242 CFU/m^3 at the rural site (Shaffer and Lighthart, 1997). The averaged airborne bacteria were similar to this study, but the averaged airborne fungi were lower than in this study. Surprisingly in Beijing, China, the airborne bacteria averaged were 3700 ± 210 CFU/$m^3$and airborne fungi averaged was 1200 ± 73 CFU/m^3 (Fang et al., 2005; Fang et al., 2008). It is higher than this study. Human activities and vegetation coverage are the important factors affected for microbial concentrations (Fang et al., 2005; Fang et al., 2008).

Table 4.13: Other literature reviews at ambient area

Reference	Airborne bacteria (CFU/m^3)	Airborne fungi (CFU/m^3)
Giorgio et al. (1996) : France	791 $\pm$ 598	92 $\pm$ 92
Shaffer and Lighthart (1997) : USA	609	-
Fang et al. (2005, 2008) : China	3700 $\pm$ 210	1200 $\pm$ 73

4.3 Microbial identification (airborne microbial species composition in ambient air)

Most common types of culturable airborne microorganisms associated with particulate matter collected from three sampling sites and cultivated on the plate were chosen for identifying.

4.3.1 Airborne bacterial identification

There was a large diversity of culturable airborne bacteria. Most of the bacteria found at the urban area and the roadside area were gram positive cocci, while those at the suburban area were gram negative cocci.

In this study, gram positive bacteria were found higher than gram negative bacteria because gram negative bacteria are thus mechanically much weaker than gram-positive cells. Beyond the peptidoglycan of the Gram-negative cell wall lies an outer membrane. Moreover, rod-shaped gram positive bacteria have endospore that helps protecting them from the stress environments. Therefore, they can survive in outdoor environment (Madigan and Martinko, 2006; Maier et al., 1999, 2008). In contrast with previous report, most of airborne bacteria in urban area were gram negative bacteria and most of airborne bacteria in natural area were gram positive bacteria (Giorgio et al., 1996). Most of airborne bacteria from urban grain market area of India was found gram negative rod higher than gram positive rod (Verma and Pathak, 2008).

The majority of airborne fungal spores come from vegetation rather than from soil because they can receive nutrients from the leaf surface. Plants can be infected from airborne bacteria and fungi (Fang et al., 2005; Fang et al., 2008).

The three types of selected airborne bacteria were tested for Gram stain reaction and examined the morphology under the light microscope. The result is shown in Table 4.14, Figure 4.5, and Appendix C.

Table 4.14: Preliminary identification by gram stain reaction and morphological study of the selected and culturable airborne bacteria found in ambient air

The bacterial types	Gram stain reaction	Shape	Colony morphology
Unknown bacteria 1	Gram-negative	Rod	Yellow, round, smooth, convex
Unknown bacteria 2	Gram-positive	Cocci	Yellow, round, irregular, drop-like
Unknown bacteria 3	Gram-positive	Rod	White, round, irregular, umbonate

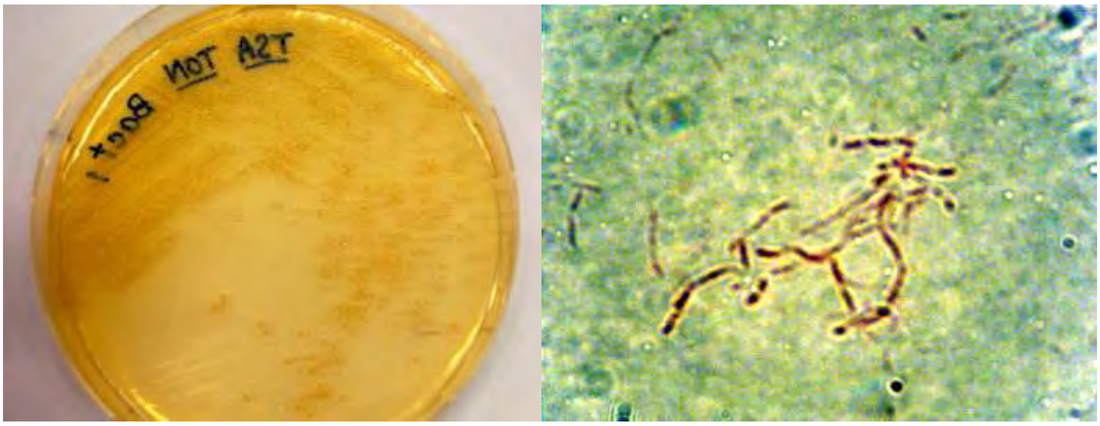
The selected and culturable airborne bacteria were sent to Thailand Institute of Scientific and Technological Research (TISTR) for confirming the preliminary identification and further identifying their genus and species, as shown in Table 4.15, Figure 4.5 and Appendix D.

Table 4.15: Microbial identification of selected bacteria, obtained from TISTR (Confirmation of bacterial types)

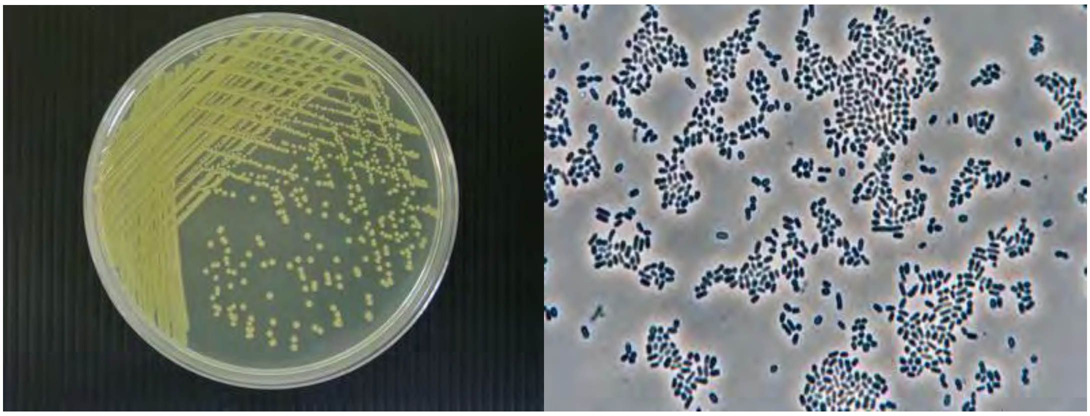
The bacterial types	Scientific name
Unknown bacteria 1	*Pseudomonas fluorescens*
Unknown bacteria 2	*Staphylococcus sciuri*
Unknown bacteria 3	*Bacillus pumilus*

Pseudomonas fluorescens is a common Gram-negative, obligate aerobe, rod-shaped bacterium. It belongs to the *Pseudomonas* genus. It has multiple flagella and an extremely versatile metabolism. It can be found in soil, water, and air. The optimal temperatures for growth are 25-30 degrees Celsius. It can secrete a soluble fluorescent pigment called *fluorescein*. Some *P. fluorescens* strains present biocontrol properties, protecting the roots of some plant species from parasitic fungal infection. Moreover, they can produce antibiotic that can be used in medical treatments. However, *P. fluorescens* is an unusual cause of diseases in human, and usually affects immunocompromised patients (Brook et al., 2004; Madigan and Martinko, 2006; Maier et al., 1999, 2008).

Staphylococcus sciuri is a common Gram-positve, cocci-shaped bacterium. It belongs to the *Staphylococcus* genus. This genus is widespread in nature such as soil, water, and skin of mammals, occasionally humans. This species can be isolated from various food products of animal origin. It is important opportunistic human pathogens, responsible for serious infections, e.g. endocarditis, peritonitis, septic shock, urinary tract infection, pelvic inflammatory disease and wound infections (Brook et al., 2004; Madigan and Martinko, 2006; Maier et al., 2008).



(a)



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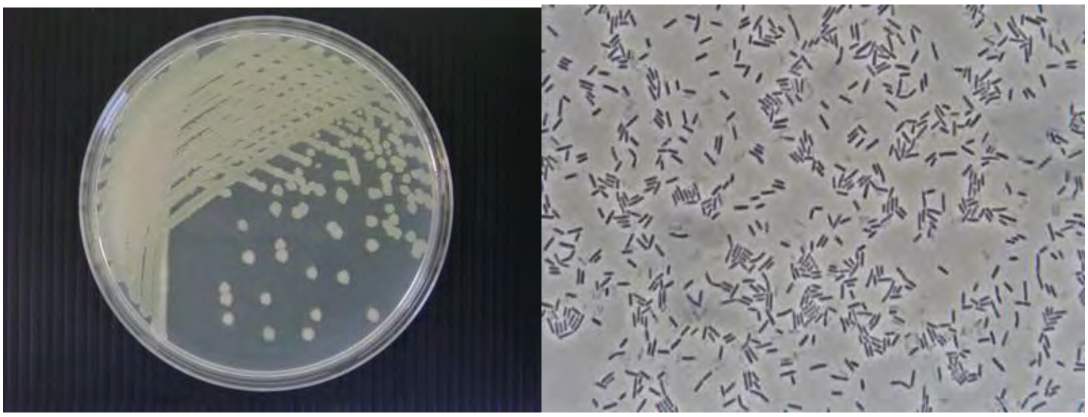


(c)

Figure 4.5 (Left panel) Agar plates streaked with observing bacteria (Right panel) Morphological study of selected bacteria, observed by light microscope at magnification 1000 folds (a) *P. fluorescens* (b) *S. sciuri* (c) *B. pumilus*

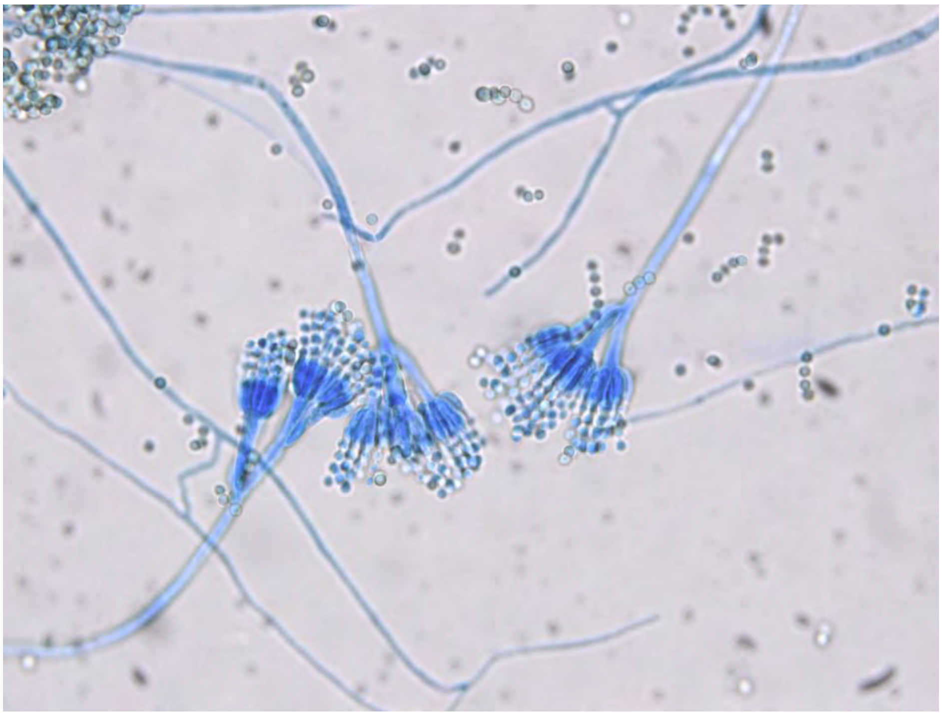
Bacillus pumilus is a common Gram-positive, aerobic, rod-shaped, motility, endospore forming bacterium. It belongs to the *Bacillus* genus. The optimal temperature for growth is 30 degree Celsius. It is widespread in nature such as soil, water, air, and decomposed plant tissue. For industrial implications, it is used for alkaline protease production, environmental dioxin decontamination, and the source of active ingredients in pesticide. However, it can cause food poisoning (Brook et al., 2004; Madigan and Martinko, 2006; Maier et al., 2008).

4.3.2 Airborne fungal identification

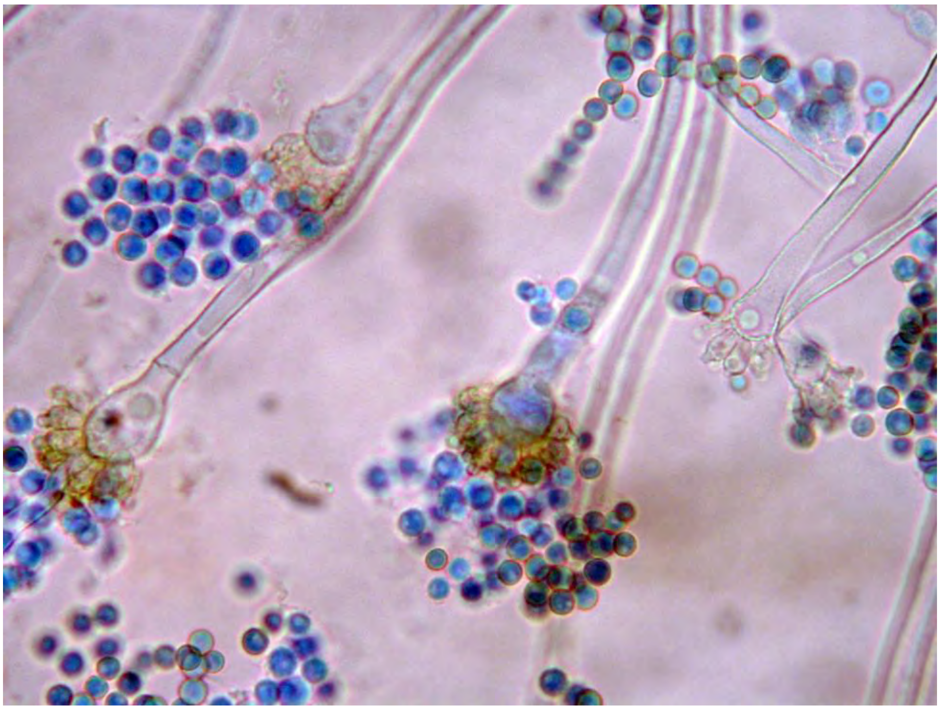
The culturable fungal genera were identified, based on general fungal classification method, which used optical microscope to observe form, shape and color of colony and even spore. Two common types of airborne fungi found in ambient air were identified into genus level. The results of the identification are shown in Table 4.16 and Figure 4.6.

Table 4.16: Identification of the common types of fungi found in ambient air

The fungal types	Scientific name
Unknown airborne fungi 1	*Penicillium spp.*
Unknown airborne fungi 2	*Aspergillus spp.*



(a)



(b)

Figure 4.6 Pictures of two common culturable fungi collected from ambient air sampling, taken by light microscope (1000X): (a) *Penicillium* spp. (b) *Aspergillus* spp.

Penicillium spp. is a genus of ascomycetous fungi which is important for the environment, food, and drug production. It produces penicillin, a molecule used as an antibiotic. Species in genus *Penicillium* are ubiquitous soil fungi. Several species of them play the important roles in the production of cheese and various meat products. They are commonly known as molds that can cause food spoilage and some can produce highly toxic mycotoxins. Moreover, they can be used in the production of antibiotics, enzymes and other macromolecules (Beneke and Rogers, 1981; Brook et al., 2004; Larone, 2002; Madigan and Martinko, 2006; Maier et al., 1999).

Aspergillus spp. is a genus found in several natures worldwide. They can produce asexual spore-forming structure. *Aspergillus* species are highly aerobic and grow on carbon-rich substrates. They are very important for medical treatments. . Some of them cause serious diseases in humans and animals such as allergy and severe symptoms from aflatoxins. Aspergillosis is also an example of diseases caused by *Aspergillus*. The symptoms caused by these pathogens include fever, cough, chest pain or breathlessness, and the symptoms are more severe in immunocompromised persons. Moreover, some species of them are agricultural pathogens, while some are important for commercial microbial fermentations (Beneke and Rogers, 1981; Brook et al., 2004; Larone, 2002; Madigan and Martinko, 2006; Maier et al., 2008).

4.4 Correlation between particulate matter and airborne microorganism

The correlation between particulate matter and airborne microorganisms were statistical analyzed by using SPSS statistical program (Pearson correlation). The statistical analysis is shown in Table 4.17.

As a result from the statistical analysis, at the urban area (CU), there was no significant correlation between particulate matter and airborne microorganisms, while highly positive correlation between airborne bacteria and airborne fungi was observed ($r=0.558$, $P<0.01$), negative correlation between fine particulate matter and coarse particulate matter was found at this sampling site. ($r=-0.631$, $P<0.05$). At the suburban area (ERTC), it was observed that fine particulate matter was significantly correlated with airborne bacteria ($r=0.620$, $P<0.05$) and airborne fungi ($r=0.609$, $P<0.05$). In addition, highly positive correlation between airborne bacteria and airborne fungi ($r=0.844$, $P<0.01$). At the roadside area (Silom road), similar to CU, there was no significant correlation between particulate matter and airborne microorganisms, while the highly positive correlation between airborne bacteria and airborne fungi was found ($r=0.558$, $P<0.01$). In addition, highly positive correlation between fine particle and coarse particulate matter ($r=0.753$, $P<0.01$) were found at the roadside area.

Overall, the correlation between particulate matter and airborne microorganism were found only at suburban area. At this sampling site, fine particle was correlated with airborne bacteria (y=5.725x+394.24, r=0.620, P<0.05) and airborne fungi (y=7.0355x+428.29, r=0.609, P<0.05), as shown in Figure 4.7.

Table 4.17: Results of statistical analysis used for testing the correlation among particulate matter (fine and coarse particulate matter) and airborne microorganism (bacteria and fungi) in three sampling sites (a) CU (b) ERTC (c) Silom road

Correlations

		Fine	Coarse	Bacteria	Fungi
Fine	Pearson Correlation	1	-.631*	-.422	-.388
	Sig. (2-tailed)		.015	.133	.170
	N	14	14	14	14
Coarse	Pearson Correlation	-.631*	1	.413	.448
	Sig. (2-tailed)	.015		.142	.108
	N	14	14	14	14
Bacteria	Pearson Correlation	-.422	.413	1	.894**
	Sig. (2-tailed)	.133	.142		.000
	N	14	14	21	21
Fungi	Pearson Correlation	-.388	.448	.894**	1
	Sig. (2-tailed)	.170	.108	.000	
	N	14	14	21	21

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

(a)

Correlations

		Fine	Coarse	Bacteria	Fungi
Fine	Pearson Correlation	1	-.284	.620*	.609*
	Sig. (2-tailed)		.325	.018	.021
	N	14	14	14	14
Coarse	Pearson Correlation	-.284	1	-.472	-.468
	Sig. (2-tailed)	.325		.088	.092
	N	14	14	14	14
Bacteria	Pearson Correlation	.620*	-.472	1	.844**
	Sig. (2-tailed)	.018	.088		.000
	N	14	14	21	21
Fungi	Pearson Correlation	.609*	-.468	.844**	1
	Sig. (2-tailed)	.021	.092	.000	
	N	14	14	21	21

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

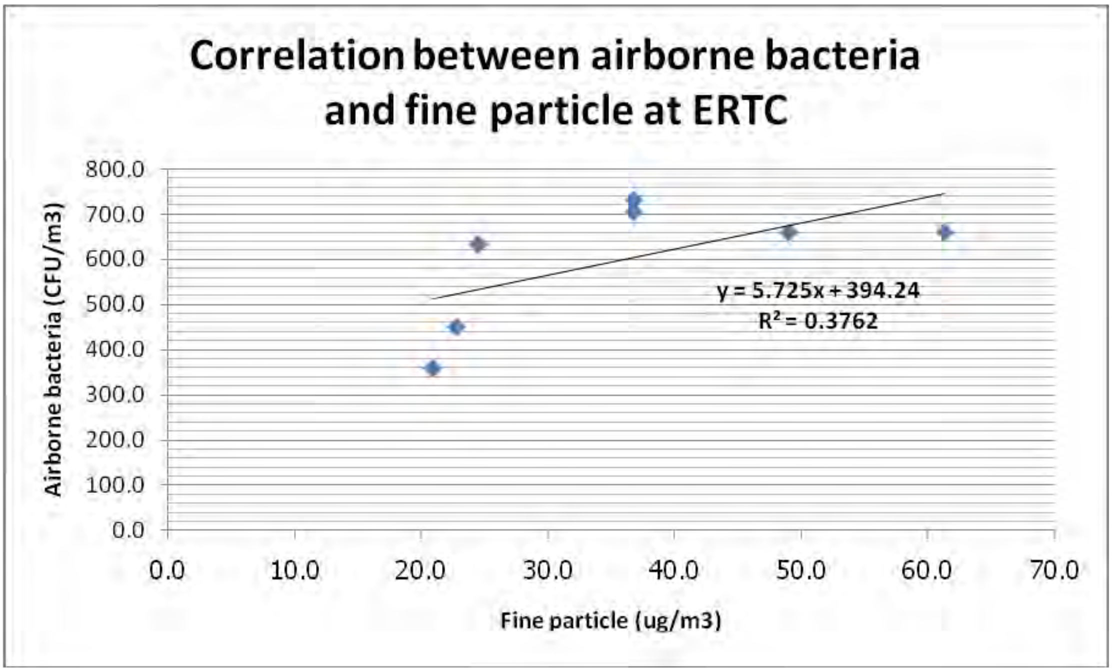
(b)

Correlations

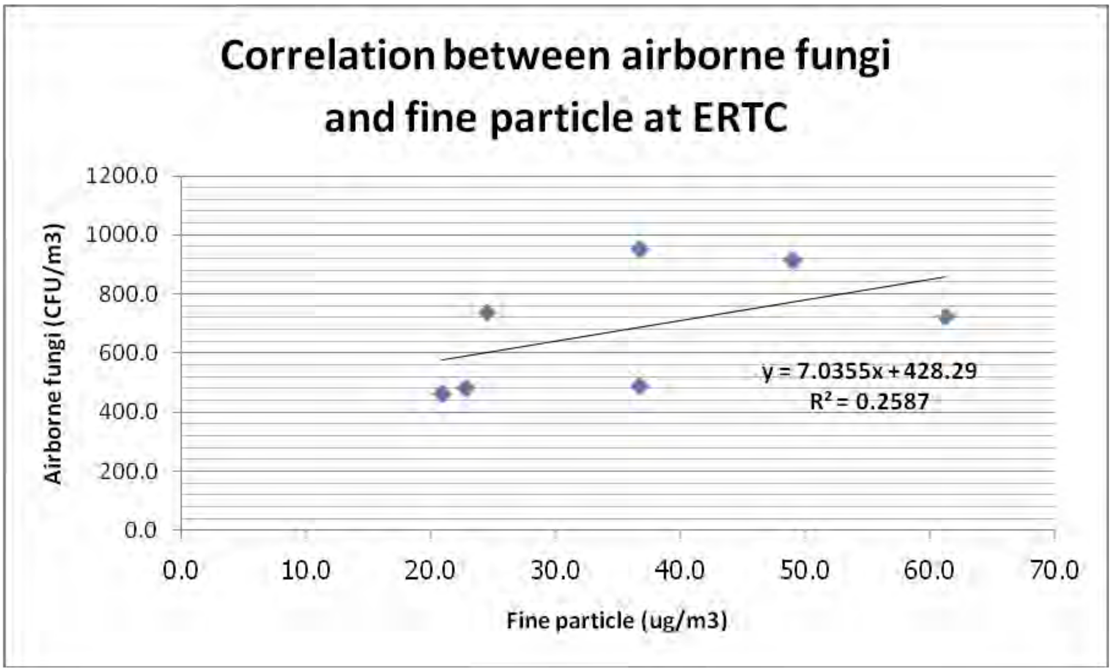
		Fine	Coarse	Bacteria	Fungi
Fine	Pearson Correlation	1	.753**	-.140	.215
	Sig. (2-tailed)		.002	.633	.460
	N	14	14	14	14
Coarse	Pearson Correlation	.753**	1	-.200	.134
	Sig. (2-tailed)	.002		.493	.649
	N	14	14	14	14
Bacteria	Pearson Correlation	-.140	-.200	1	.558**
	Sig. (2-tailed)	.633	.493		.009
	N	14	14	21	21
Fungi	Pearson Correlation	.215	.134	.558**	1
	Sig. (2-tailed)	.460	.649	.009	
	N	14	14	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

(c)



(a)



(b)

Figure 4.7 The correlation between fine particle and airborne bacteria (a) and between fine particle and airborne fungi (b) at the suburban area (ERTC)

To evaluate our results regarding the relationship between airborne microorganisms and the particulate matter, the data from the other relevant studies were used to discuss. Several studies suggested that there was no correlation between those variables. For example, Pratumwong (1997), and Raisi et al. (2010) reported that the bacterial concentrations were high in the ambient environments containing PM_{10}; however, this correlation wasn't significant. Mopuang et al. (2006) found that there was no correlation of PM_{10} level with the bacterial and fungal concentrations in ambient air, while they found the correlation between the concentrations of airborne bacteria and those of fungi instead. In this study, similar to some other studies, we also found that no correlation between particulate matter level and airborne microbial counts in the urban and roadside areas, but the correlation was found only at the suburban area. The differences of the result discussed previously can be explained that both the urban (CU) and roadside (Silom road) areas are in close proximity and located in Bangkok metropolitan, which may have the similar conditions of meteorological parameters, This similar condition between those places may be the reason why both place provided the similar result regarding the correlation, while the suburban area (ERTC) located far from central Bangkok, showed the different result. This difference of our result emphasized that other factors especially meteorological factors may affect direct or indirectly to both particulate matter and airborne microorganisms. Hence, in this study, we also evaluated the relationship of several meteorological factors to particulate matter (both fine and coarse particulate matter) and airborne microorganisms (both bacteria and fungi) for better understanding.

4.5 The effect of meteorological parameters on particulate matter and airborne microorganisms

The meteorological parameters, including wind direction (WD), wind speed (WS), temperature (T), relative humidity (RH), pressure (P), and solar radiation (SR), were obtained from the nearest sites of air sampling. The data at the urban and roadside areas were received from the Thai Meteorological Department (TMD) at Queen Sirikit National Convention Center station, while the data at the suburban area was received from the observation site at Environmental Research and Training Centre (ERTC). Because TMD usually measures the meteorological parameters every three hours, all parameters used for our investigation in the urban and roadside areas could be recorded only at 10.00 a.m. and 1.00 p.m. In addition, the data of all meteorological parameters could be recorded from ERTC at 10.00 a.m., 12.00 p.m. and 2.00 p.m. (the same time used for our air sampling). The meteorological parameters were shown in Table 4.18 for CU, Table 4.19 for ERTC and Table 4.20 for Silom road.

The effect of meteorological parameters on particulate matter and airborne microorganisms were statistically analyzed by using SPSS statistical program (Pearson correlation). The results of statistical analysis are shown in Table 4.21, Table 4.22, and Table 4.23.

Table 4.18: Meteorological parameters provided by the Thai Meteorological Department (TMD), used for the observation at the urban area (CU)

Date	Time (hr)	WD (Degree)	WS (Knots)	T (Celsius)	RH (%)	P (hPa)	RF (mm)	SR (W/m^2)
24/06/2009	10	0	4	31.5	65	1008.21	0.0	166
	13	190	0	33.9	57	1006.61	0.0	325
25/06/2009	10	200	4	32.5	61	1008.11	0.0	233
	13	0	4	32.9	55	1006.49	0.0	350
21/07/2009	10	90	2	28.2	90	1010.22	0.8	102
	13	110	3	26.2	93	1008.28	22.4	25
22/07/2009	10	250	6	29.5	75	1008.89	0.8	162
	13	250	6	31.1	66	1006.92	0.0	145
23/07/2009	10	180	3	29.4	74	1008.17	0.8	215
	13	210	3	30.6	68	1007.20	0.0	172
10/11/2009	10	0	0	31.5	67	1007.94	0.0	506
	13	0	0	34.1	56	1004.64	0.0	735
11/11/2009	10	0	0	31.4	70	1008.18	0.0	385
	13	0	0	33.0	64	1005.87	0.0	724

Table 4.19: Meteorological parameters provided by ERTC, used for the observation at the suburban area (ERTC)

Date	Time (hr)	WD (Degree)	WS (Knots)	T (Celsius)	RH (%)	P (hPa)	SR (w/m^2)
03/06/2009	10	230	7	30.3	66	993.25	74
	12	240	9	31.1	64	992.19	194
	14	250	7	31.6	64	990.72	176
04/06/2009	10	190	7	30.5	67	993.65	110
	12	230	8	30.5	66	992.99	162
	14	230	7	30.6	66	990.85	103
08/06/2009	10	200	4	32.2	63	994.45	82
	12	230	4	33.2	60	994.05	113
	14	280	3	32.6	64	992.85	51
09/06/2009	10	190	4	33.1	63	995.92	169
	12	240	6	33.8	59	994.72	186
	14	270	5	33.7	61	993.39	101
10/06/2009	10	240	4	32.3	64	996.32	181
	12	240	6	33.8	59	995.12	205
	14	250	6	33.5	62	993.65	142
02/11/2009	10	100	4	29.5	78	1000.98	103
	12	240	1	32.9	72	999.25	152
	14	40	3	33.8	69	997.38	127
03/11/2009	10	30	7	26.0	76	1001.25	39
	12	30	7	26.2	75	999.38	104
	14	20	6	25.7	80	998.58	54

Table 4.20: Meteorological parameters provided by the Thai Meteorological Department, used for the observation at roadside area (Silom road)

Date	Time (hr)	WD (Degree)	WS (Knots)	T (Celsius)	RH (%)	P (hPa)	SR (W/m^2)
26/08/2009	10	340	3	31.8	62	1008.90	692
	13	100	2	34.9	51	1006.76	984
27/08/2009	10	330	4	30.8	69	1007.97	518
	13	0	0	33.8	58	1006.59	761
28/08/2009	10	0	0	30.1	72	1008.56	593
	13	160	8	32.8	65	1006.58	300
06/10/2009	10	0	0	30.9	74	1009.99	184
	13	0	0	33.2	56	1007.72	284
07/10/2009	10	200	2	31.0	72	1009.79	159
	13	180	3	30.1	72	1007.55	144
26/10/2009	10	100	3	32.1	68	1012.61	209
	13	60	2	35.0	55	1009.83	242
27/10/2009	10	100	3	32.3	52	1012.06	278
	13	30	2	34.0	53	1010.25	235

According to statistical analysis, we found that meteorological parameters affected to the particulate matter and/or airborne microorganisms at suburban and roadside area. At the urban area (CU), there were no significantly correlation between the airborne microorganisms and particulate matter on meteorological parameters. At the suburban area (ERTC), positive correlations of the bacterial concentration with wind direction ($r=0.490$, $P<0.05$) and solar radiation ($r=0.639$, $P<0.01$), whereas negative correlation of the bacterial concentration with relative humidity ($r=-0.598$, $P<0.01$) were observed. In addition, at this site, there were significantly negative correlation between airborne fungi and relative humidity ($r=-0.528$, $P<0.05$), and between fine particle and pressure ($r=-0.574$, $P<0.05$), coarse particle and solar radiation ($r=-0.593$, $P<0.05$). Lastly, at the roadside area (Silom road), there were significant correlations of the airborne bacteria with pressure negatively ($r=-0.715$, $P<0.01$) and solar radiation positively ($r=0.702$, $P<0.01$) Moreover, relative humidity was positively correlated with both fine particulate matter ($r=0.651$, $P<0.05$) and coarse particulate matter ($r=0.547$, $P<0.05$).

Table 4.21: Result of statistical analysis (Pearson correlation) used for testing the correlation of meteorological parameters with particulate matter and airborne microorganisms at the urban area (CU)

Correlations

		WD	WS	T	RH	P	SR	Bacteria	Fungi	Fine	Coarse
WD	Pearson Correlation	1	.594*	-.279	.169	.248	-.595*	.158	.353	-.113	.290
	Sig. (2-tailed)		.025	.333	.564	.392	.025	.590	.215	.701	.314
	N	14	14	14	14	14	14	14	14	14	14
WS	Pearson Correlation	.594*	1	-.365	.160	.331	-.688**	.335	.506	-.204	.420
	Sig. (2-tailed)	.025		.199	.586	.248	.007	.242	.065	.485	.135
	N	14	14	14	14	14	14	14	14	14	14
T	Pearson Correlation	-.279	-.365	1	-.957**	-.735**	.723**	-.131	.051	.048	-.211
	Sig. (2-tailed)	.333	.199		.000	.003	.003	.655	.863	.870	.470
	N	14	14	14	14	14	14	14	14	14	14
RH	Pearson Correlation	.169	.160	-.957**	1	.737**	-.595*	.019	-.215	.012	.102
	Sig. (2-tailed)	.564	.586	.000		.003	.025	.948	.460	.967	.730
	N	14	14	14	14	14	14	14	14	14	14
P	Pearson Correlation	.248	.331	-.735**	.737**	1	-.727**	-.111	-.204	-.155	.383
	Sig. (2-tailed)	.392	.248	.003	.003		.003	.706	.483	.598	.177
	N	14	14	14	14	14	14	14	14	14	14

SR	Pearson Correlation	-.595*	-.688**	.723**	-.595*	-.727**	1	-.386	-.415	.166	-.566*
	Sig. (2-tailed)	.025	.007	.003	.025	.003		.172	.140	.570	.035
	N	14	14	14	14	14	14	14	14	14	14
Bacteria	Pearson Correlation	.158	.335	-.131	.019	-.111	-.386	1	.894**	-.422	.413
	Sig. (2-tailed)	.590	.242	.655	.948	.706	.172		.000	.133	.142
	N	14	14	14	14	14	14	21	21	14	14
Fungi	Pearson Correlation	.353	.506	.051	-.215	-.204	-.415	.894**	1	-.388	.448
	Sig. (2-tailed)	.215	.065	.863	.460	.483	.140	.000		.170	.108
	N	14	14	14	14	14	14	21	21	14	14
Fine	Pearson Correlation	-.113	-.204	.048	.012	-.155	.166	-.422	-.388	1	-.631*
	Sig. (2-tailed)	.701	.485	.870	.967	.598	.570	.133	.170		.015
	N	14	14	14	14	14	14	14	14	14	14
Coarse	Pearson Correlation	.290	.420	-.211	.102	.383	-.566*	.413	.448	-.631*	1
	Sig. (2-tailed)	.314	.135	.470	.730	.177	.035	.142	.108	.015	
	N	14	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.22: Result of statistical analysis (Pearson correlation) used for testing the correlation of meteorological parameters with particulate matter and airborne microorganisms at the suburban area (ERTC)

Correlations

		WD	WS	T	RH	P	SR	Bacteria	Fungi	Fine	Coarse
WD	Pearson Correlation	1	-.038	.715**	-.811**	-.754**	.446*	.490*	.401	.410	-.422
	Sig. (2-tailed)		.870	.000	.000	.000	.043	.024	.071	.145	.133
	N	21	21	21	21	21	21	21	21	14	14
WS	Pearson Correlation	-.038	1	-.437*	-.023	-.359	.101	.182	.145	.230	-.401
	Sig. (2-tailed)	.870		.048	.920	.110	.664	.431	.531	.428	.156
	N	21	21	21	21	21	21	21	21	14	14
T	Pearson Correlation	.715**	-.437*	1	-.818**	-.472*	.546*	.413	.324	.353	-.319
	Sig. (2-tailed)	.000	.048		.000	.031	.010	.063	.152	.216	.267
	N	21	21	21	21	21	21	21	21	14	14
RH	Pearson Correlation	-.811**	-.023	-.818**	1	.742**	-.522*	-.598**	-.528*	-.522	.434
	Sig. (2-tailed)	.000	.920	.000		.000	.015	.004	.014	.055	.121
	N	21	21	21	21	21	21	21	21	14	14
P	Pearson Correlation	-.754**	-.359	-.472*	.742**	1	-.279	-.296	-.324	-.574*	.530
	Sig. (2-tailed)	.000	.110	.031	.000		.221	.193	.152	.032	.051
	N	21	21	21	21	21	21	21	21	14	14

SR	Pearson Correlation	.446*	.101	.546*	-.522*	-.279	1	.639**	.303	.208	-.593*
	Sig. (2-tailed)	.043	.664	.010	.015	.221		.002	.182	.475	.025
	N	21	21	21	21	21	21	21	21	14	14
Bacteria	Pearson Correlation	.490*	.182	.413	-.598**	-.296	.639**	1	.844**	.620*	-.472
	Sig. (2-tailed)	.024	.431	.063	.004	.193	.002		.000	.018	.088
	N	21	21	21	21	21	21	21	21	14	14
Fungi	Pearson Correlation	.401	.145	.324	-.528*	-.324	.303	.844**	1	.609*	-.468
	Sig. (2-tailed)	.071	.531	.152	.014	.152	.182	.000		.021	.092
	N	21	21	21	21	21	21	21	21	14	14
Fine	Pearson Correlation	.410	.230	.353	-.522	-.574*	.208	.620*	.609*	1	-.284
	Sig. (2-tailed)	.145	.428	.216	.055	.032	.475	.018	.021		.325
	N	14	14	14	14	14	14	14	14	14	14
Coarse	Pearson Correlation	-.422	-.401	-.319	.434	.530	-.593*	-.472	-.468	-.284	1
	Sig. (2-tailed)	.133	.156	.267	.121	.051	.025	.088	.092	.325	
	N	14	14	14	14	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.23: Result of statistical analysis (Pearson correlation) used for testing the correlation of meteorological parameters with particulate matter and airborne microorganisms at the roadside area (Silom road)

Correlations

		WD	WS	T	RH	P	SR	Bacteria	Fungi	Fine	Coarse
WD	Pearson Correlation	1	.588*	-.342	.247	-.082	.107	.248	-.451	-.082	-.081
	Sig. (2-tailed)		.027	.232	.395	.780	.715	.392	.105	.781	.782
	N	14	14	14	14	14	14	14	14	14	14
WS	Pearson Correlation	.588*	1	-.015	.046	-.093	-.148	.105	.019	-.142	-.156
	Sig. (2-tailed)	.027		.961	.875	.752	.614	.721	.948	.629	.595
	N	14	14	14	14	14	14	14	14	14	14
T	Pearson Correlation	-.342	-.015	1	-.865**	-.115	.292	.376	.455	-.523	-.264
	Sig. (2-tailed)	.232	.961		.000	.695	.311	.185	.102	.055	.362
	N	14	14	14	14	14	14	14	14	14	14
RH	Pearson Correlation	.247	.046	-.865**	1	.014	-.330	-.299	-.327	.651*	.547*
	Sig. (2-tailed)	.395	.875	.000		.961	.249	.299	.254	.012	.043
	N	14	14	14	14	14	14	14	14	14	14
P	Pearson Correlation	-.082	-.093	-.115	.014	1	-.525	-.715**	-.362	-.209	.029
	Sig. (2-tailed)	.780	.752	.695	.961		.054	.004	.203	.474	.921
	N	14	14	14	14	14	14	14	14	14	14

SR	Pearson Correlation	.107	-.148	.292	-.330	-.525	1	.702**	.040	-.500	-.530
	Sig. (2-tailed)	.715	.614	.311	.249	.054		.005	.891	.069	.051
	N	14	14	14	14	14	14	14	14	14	14
Bacteria	Pearson Correlation	.248	.105	.376	-.299	-.715**	.702**	1	.558**	-.140	-.200
	Sig. (2-tailed)	.392	.721	.185	.299	.004	.005		.009	.633	.493
	N	14	14	14	14	14	14	21	21	14	14
Fungi	Pearson Correlation	-.451	.019	.455	-.327	-.362	.040	.558**	1	.215	.134
	Sig. (2-tailed)	.105	.948	.102	.254	.203	.891	.009		.460	.649
	N	14	14	14	14	14	14	21	21	14	14
Fine	Pearson Correlation	-.082	-.142	-.523	.651*	-.209	-.500	-.140	.215	1	.753**
	Sig. (2-tailed)	.781	.629	.055	.012	.474	.069	.633	.460		.002
	N	14	14	14	14	14	14	14	14	14	14
Coarse	Pearson Correlation	-.081	-.156	-.264	.547*	.029	-.530	-.200	.134	.753**	1
	Sig. (2-tailed)	.782	.595	.362	.043	.921	.051	.493	.649	.002	
	N	14	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

At the suburban area (ERTC), both bacterial and fungal concentrations were negatively correlated with relative humidity. Microorganisms need humidity to survive and multiply. Bacterial concentrations may increase either with the increase or decrease in relative humidity. The higher relative humidity promotes the viability where as the lower relative humidity promotes the spore release (Mouli et al., 2005). Fungal concentrations are prevented if the surrounding air is kept below 70% relative humidity (Madigan and Martinko, 2006; Maier et al., 2008). For wind direction, bacteria will increase with increasing wind direction because they can spread far away from old environments and survive in the new environments (Giorgio et al., 1996; Mouli et al., 2005; Madigan and Martinko, 2006; Maier et al., 2008). An understanding of the fate of bacterial bioaerosol is necessary for predicting the transport of viable microorganisms to site locations. For solar radiation, at midday with maximum solar intensity would be expected to increase the bacterial concentration in the atmosphere. It is a fact in this study. Lighthart and Shaffer (1997) found that solar radiation has a negatively affecting the ambient bacterial survival. Because high pressure can gather smaller particles to large particles, negative correlation was found between fine particle and pressure (Maier et al., 1999). High solar radiation leads particulate matter to occur photochemical smog, so coarse particulate matter is decreased (Maier et al., 1999; Madigan and Martinko, 2006).

At the roadside area (Silom road), the trend of solar radiation and airborne bacteria is reliable with suburban area. Pressure has an effect for bacterial concentrations. The higher pressure supports the spore release to vegetative cell and the lower pressure has a lethal effect for their cells. High relative humidity can promote the formation of secondary organic aerosols, larger particles of particulate matter.

In this study, we found the correlation of meteorological parameters, including relative humidity, solar radiation, wind direction, and pressure, with airborne microorganisms and/or particulate matter, while other relevant studies provided different record. For example, Mouli et al (2005) showed the correlation of bacterial counts with wind speed, temperature, and relative humidity. Giorgio et al (1996) observed that wind speed, wind direction, temperature affected to bacterial and fungal concentrations, but relative humidity wasn’t significantly correlated with particulate matter level. However, Raisi et al. (2010) didn’t find the correlation between the microbial or the particulate matter data with meteorological parameters.

Although we found the correlations of several meteorological parameters to particulate matter and airborne microorganisms, we cannot exclude the fact that these variables were not influenced by only one meteorological factor in ambient air at the air sampling sites. The complexity of the meteorological parameters at the sampling sites provided some difficulties for evaluating the correlation. Most difficulty is that we cannot separately study the influence of each parameter to the bacterial and fungal counts as well as particulate matter level in ambient air at all sampling sites. Hence, further investigation on the effect of meteorological parameters to those variables is required for better understanding.

CHAPTER V

CONCLUSIONS AND RECOMENDATIONS

In this study, the main objective is to investigate the correlation between particulate matter levels and the levels of airborne microorganisms coming along with the particulate matter which distributed in different areas of Bangkok and nearby region during wet and dry seasons. For primary observations, the concentrations of particulate matter (fine and coarse) and particle-associated airborne bacterial and fungal counts were studied in three representative areas: the urban area of Bangkok (at Chulalongkorn University), suburban area of Bangkok (at the Environment Research and Teaching Centre, Pathumthani Province) and the roadside area (at Silom road). Then, the data from primary study were used to evaluate the correlation between the particulate matter and the airborne microorganisms. In addition, the effects of meteorological parameters, including wind direction, wind speed, temperature, relative humidity, pressure, and solar radiation, to both of those variables were observed in this study.

From the result, we can conclude that (1) regarding the particulate matter levels in ambient air, at the roadside area, both fine and coarse particulate matter levels broadly ranged among different dates of air sampling and were higher than other sampling sites. (2) At all sampling sites, the highest levels of bacterial and fungal counts (CFU/m^3) were found at 12.00 p.m., and the concentrations of bacteria and fungi measured at different dates (during wet and dry seasons) were not significantly different, except the fungal counts at the roadside area. At the urban and suburban areas, the bacterial and fungal counts were higher than those at the roadside areas, and the fungal levels were higher than the bacterial levels; whereas, the bacterial counts at roadside area were higher than the fungal levels. (3) Regarding the microbial identification, some types of bacteria found in ambient air of all sampling sites were *Pseudomonas* spp., *Staphylococcus* spp. and *Bacillus* spp., while the some types of fungi were *Penicillium* spp. and *Aspergillus* spp. (4) the correlations of fine particulate matter levels with airborne bacterial ($r=0.620$, $P<0.05$) and fungal counts ($r=0.609$, $P<0.05$) were found only at the suburban area. (5) Only at suburban and roadside area, some meteorological parameters were positively (+) or negatively (-) correlated to both particulate matter and airborne microorganisms. At the suburban area, the correlation of bacterial counts with wind direction (+), solar radiation (+), relative humidity (-), the correlation of fungal counts with relative humidity (-), the correlation of fine particulate matter with pressure (-), and the correlation of coarse particulate matter with solar radiation (-), were observed in this site. Lastly the correlation of bacterial counts with pressure (-) and solar radiation (+), the correlation of fine and coarse particulate matter with relative humidity (+) were found in the roadside area.

5.1 Limitation of the study

5.1.1 To evaluate the result regarding bacterial and fungal counts in ambient air in this study, we cannot directly compare the results to other relevant studies because the method for collecting the airborne microorganisms in this study was different from others. As discussed previously, conventional method for collecting airborne microorganisms in ambient air from other studies was the direct exposure of cultural medium to air in sampling sites. In contrast, this study used the same conditions of particulate matter sampling for collecting particle-associated airborne microbes, which used membrane filter for collecting particle-associated airborne microorganisms.

5.1.2 Because of the limitation of instruments for this study, the data of meteorological parameters at the urban and roadside areas were received from the Thai Meteorological Department (TMD) at Queen Sirikit National Convention Center (Bangkok). Hence, the real meteorological data at the time of air sampling at both sites might be different from the data provided by TMD, and the result of this study might have some deviation.

5.2 Recommendations for further studies

5.2.1 For better and more reliable statistical analysis regarding the correlation between particulate matter and airborne microorganisms, further studies should observe more sampling sites and also control the conditions of the experiment, including the height of air sampling above ground level, the duration of air sampling, and specific time for air sampling. For example, air sampling at Silom road in this study may be used to compare with the data recorded from other roads in Bangkok.

5.2.2 Further studies may observe the differences of air quality and microbial counts in ambient air at the height of 1.5 meter and 25-30 meter above ground at the same sampling site.

5.2.3 Duration of the studies in the future should be extended to one year, and air sampling in every month may provide better understanding regarding the effect of season to the distribution of air pollutants and airborne microbes.

5.2.4 Meteorological parameters at each sampling site should be recorded at the same place and the same time of air sampling.

5.2.5 The different bacterial and fungal counts among sampling sites may be influenced by different air composition (e.g. levels of CO_2, CH_4, NO_2 etc.) in each area. Hence, it will be useful if the data of air composition at each sampling area can be recorded in addition to meteorological parameters.

5.2.6 The number of patients who suffer from respiratory illnesses in regions near air sampling sites should be used to evaluate its correlation with particle-associated microbial counts as well as microbial types in ambient air in each place of observation.

5.2.7 The standard level of airborne microbial counts in ambient air, using for health risk assessment in Thailand, is still unknown. Hence, more studies are required for better understanding regarding the relationship between airborne microbial counts in ambient air and health profiles of human population in Bangkok and other cities in Thailand.

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APPENDICES

Appendix A

Method of air sampling

Low volume filtration

Size: Portable

Weight: Personal sampling pump

Relative cost: 1

Flow rate: 1-2 l/min

Sample duration: up to 8 hours

Sample media: Polycarbonate filter generally preferred

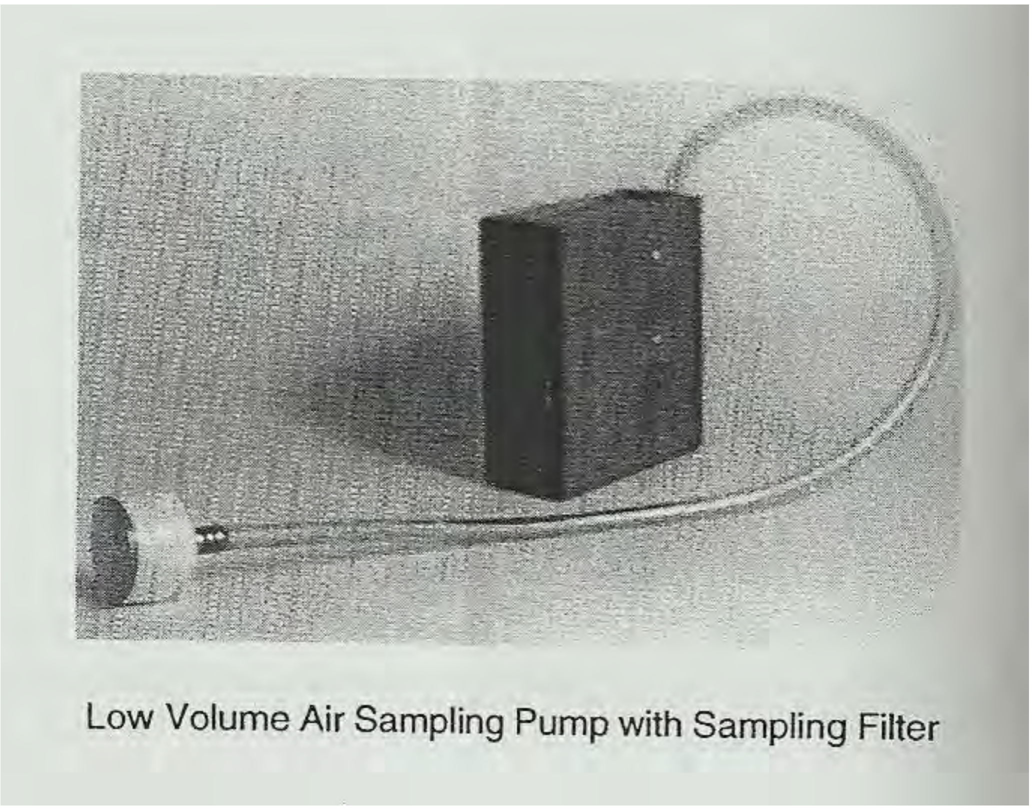

Figure A1 Low volume air sampling pump with sampling filter (Hess, 1996:264)

Comments: Filter collected dust/particles are transferred to a Petri dish through direct transfer o a filter wash solution onto the nutrient agar or retention of the wash solution for multiple plating. Multiple plating capabilities allows for dilutions of otherwise excessive microbial numbers and for the potential plating for the same sample onto several different nutrient agar plates.

Pros: Easy, inexpensive, greater sample duration (more representative of an entire day).

Cons: Probable loss of microbial viability due to drying effect and impaction onto the filter. In a previously mentioned study, filtration of two different types of bacteria had different results. The bacteria *Escherichia coli* was not recovered, but the bacteria *Bacillus subtilis* recovery was equivalent to the recovery by the Andersen impactor. Although bacterial sampling is questionable, filtration sampling is more feasible foe protected spores than the more fragile bacterial types.

References: Hess, 1996:264-265

Principle of cascade impactor

Cascade impactors operate on the principle of inertial impaction i.e. separation is provided on the basis of differences in inertia - a function of particle size and velocity. They consist of a series of stages each made up of a plate, with specific nozzle arrangement, and collection surface. Sample laden air is drawn into the impactor, flowing sequentially through the stages; nozzle size and total nozzle area decrease with stage number.

As particles pass through the nozzles (see figure A2) they either remain entrained in the air stream, which is directed through a right angle at the exit of the nozzle, or break through the lines of flow, impacting on the collection surface. Particles with sufficient inertia are collected, the rest pass onto the next stage. Each stage of the impactor is therefore associated with a cut-off diameter, a figure defining the size of particles that are retained on the collection surface of that stage. Ideally collection efficiency would be a step function – all of the particles above a certain size would be captured and those below it would pass through. In reality there is a curve from which D_{50}, the stage cutoff diameter, is determined (see figure A3).

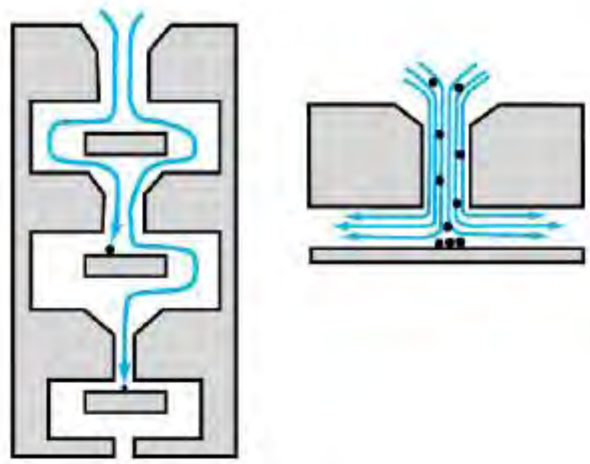

Figure A2: Flow in a cascade impactor

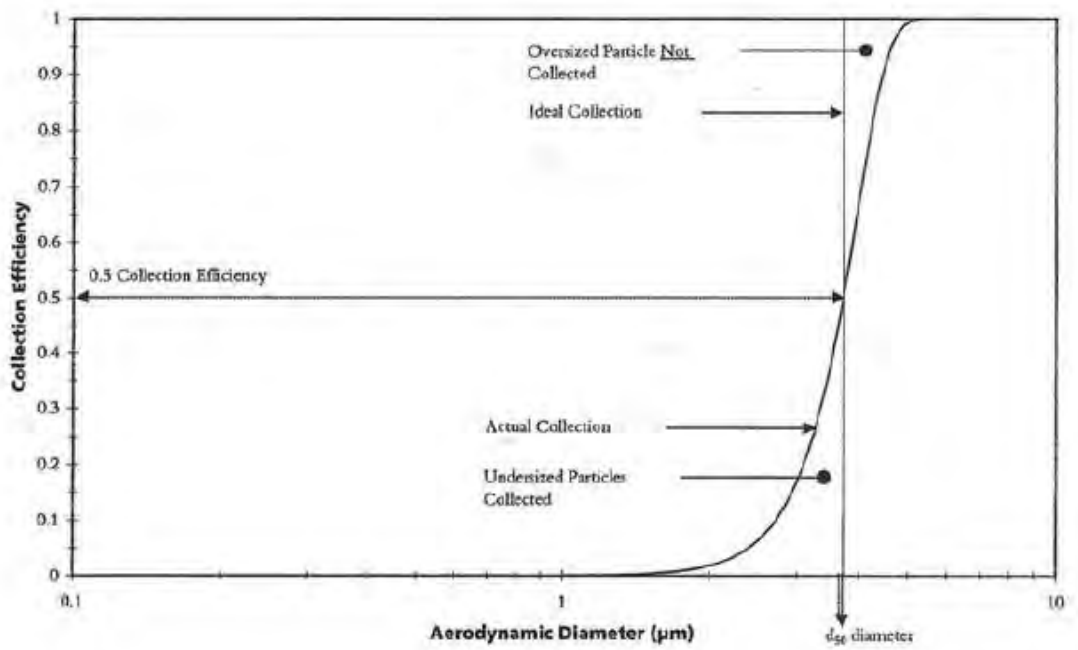

Figure A3: Collection efficiency curve for a cascade impactor stage

As nozzle size decreases, velocity increases, allowing the collection of increasingly small particles, any residual material being captured in a final stage or filter. The sample is thereby separated into a series of size fractions, each of which is individually collected for subsequent analysis, typically by high pressure liquid chromatography (HPLC).

References: www.copleyscientific.co.uk (1 May 2010)

The averaged flow rate used in this study was lower than the 50% collection efficiency (d_{50}). If an impactor is operated at a flow rate that differs from its calibration flow rate, its cut off size can be adjusted by using this equation. This equation can be expressed in terms of the jet flow rate. For a round jet impactor,

$$d_{50}\sqrt{C_c} = \left[\frac{9\text{¶}\eta D_j^3\,(Stk_{50})}{4\text{Þ}_p Q}\right]^{1/2}$$

$$d_{50}\sqrt{C_c} = \left[\frac{9\text{¶}(1.81\times10^{-5})(10^{-3})^3\,(0.24)}{4\times1000\times(2.83\times10^{-5})}\right]^{1/2}$$

$$d_{50}\sqrt{C_c} = 1.042 \quad \mu m$$

However, these equations is accurate within 2% for d_{50} > 0.2 μm an d pressure from 91 to 101 kPa (0.9 to 1.0 atm). For conventional impactor, d_{50} can be estimated from $d_{50}\sqrt{C_c}$ using the following empirical equation.

d_{50}	=	$d_{50}\sqrt{C_c}$ - 0.078	for d_{50} in µm
d_{50}	=	1.042-0.078	
d_{50}	=	0.964	µm

The ratio of the separation distance (the distance between the nozzle and the impaction plate) to the jet diameter or width should be 1 to 5 circular nozzles, with the lower values preferred.

References: (Hinds, 1998: 121-127)

Total samples of air sampling

1. Particulate matter (84 samples)

    a. Fine PM : Duplicate x 7 days x 3 sites

       Total = 2x7x3 = 42 samples

    b. Coarse PM : Duplicate x 7 days x 3 sites

       Total = 2x7x3 = 42 samples

2. Particle associated airborne microorganisms (756 samples)

    a. Bacteria : Triplicate x 2 size-selected x 3 times x 7 days x 3 sites

       Total = 3x2x3x7x3 = 378 samples

    b. Fungi : Triplicate x 2 size-selected x 3 times x 7 days x 3 sites

       Total = 3x2x3x7x3 = 378 samples

Appendix B

Statistical analysis of particulate matter and airborne microorganisms

Table B1: Daily variation of particulate matter concentration at CU

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	106.431	6	17.739	3.535	.062
	Within Groups	35.129	7	5.018		
	Total	141.561	13			
Coarse	Between Groups	123.718	6	20.620	2.249	.156
	Within Groups	64.172	7	9.167		
	Total	187.890	13			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Date	(J) Date	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Fine	2009-06-24T00:00:00.000	2009-06-25T00:00:00.000	5.0885	2.2402	.565	-5.701	15.878
		2009-07-21T00:00:00.000	2.2392	2.2402	.978	-8.550	13.028
		2009-07-22T00:00:00.000	1.8382	2.2402	.992	-8.951	12.627
		2009-07-23T00:00:00.000	-2.1418	2.2402	.982	-12.931	8.647
		2009-11-10T00:00:00.000	3.2817	2.2402	.884	-7.508	14.071
		2009-11-11T00:00:00.000	-3.2644	2.2402	.887	-14.054	7.525

	2009-06-25T00:00:00.000	2009-06-24T00:00:00.000	-5.0885	2.2402	.565	-15.878	5.701
		2009-07-21T00:00:00.000	-2.8494	2.2402	.934	-13.639	7.940
		2009-07-22T00:00:00.000	-3.2503	2.2402	.889	-14.040	7.539
		2009-07-23T00:00:00.000	-7.2304	2.2402	.243	-18.020	3.559
		2009-11-10T00:00:00.000	-1.8068	2.2402	.992	-12.596	8.982
		2009-11-11T00:00:00.000	-8.3529	2.2402	.148	-19.142	2.436
	2009-07-21T00:00:00.000	2009-06-24T00:00:00.000	-2.2392	2.2402	.978	-13.028	8.550
		2009-06-25T00:00:00.000	2.8494	2.2402	.934	-7.940	13.639
		2009-07-22T00:00:00.000	-.4010	2.2402	1.000	-11.190	10.388
		2009-07-23T00:00:00.000	-4.3810	2.2402	.700	-15.170	6.408
		2009-11-10T00:00:00.000	1.0425	2.2402	1.000	-9.747	11.832
		2009-11-11T00:00:00.000	-5.5035	2.2402	.489	-16.293	5.286
	2009-07-22T00:00:00.000	2009-06-24T00:00:00.000	-1.8382	2.2402	.992	-12.627	8.951
		2009-06-25T00:00:00.000	3.2503	2.2402	.889	-7.539	14.040
		2009-07-21T00:00:00.000	.4010	2.2402	1.000	-10.388	11.190
		2009-07-23T00:00:00.000	-3.9800	2.2402	.774	-14.769	6.809
		2009-11-10T00:00:00.000	1.4435	2.2402	.998	-9.346	12.233
		2009-11-11T00:00:00.000	-5.1026	2.2402	.562	-15.892	5.687

	2009-07-23T00:00:00.000	2009-06-24T00:00:00.000	2.1418	2.2402	.982	-8.647	12.931
		2009-06-25T00:00:00.000	7.2304	2.2402	.243	-3.559	18.020
		2009-07-21T00:00:00.000	4.3810	2.2402	.700	-6.408	15.170
		2009-07-22T00:00:00.000	3.9800	2.2402	.774	-6.809	14.769
		2009-11-10T00:00:00.000	5.4235	2.2402	.503	-5.366	16.213
		2009-11-11T00:00:00.000	-1.1225	2.2402	.999	-11.912	9.667
	2009-11-10T00:00:00.000	2009-06-24T00:00:00.000	-3.2817	2.2402	.884	-14.071	7.508
		2009-06-25T00:00:00.000	1.8068	2.2402	.992	-8.982	12.596
		2009-07-21T00:00:00.000	-1.0425	2.2402	1.000	-11.832	9.747
		2009-07-22T00:00:00.000	-1.4435	2.2402	.998	-12.233	9.346
		2009-07-23T00:00:00.000	-5.4235	2.2402	.503	-16.213	5.366
		2009-11-11T00:00:00.000	-6.5461	2.2402	.325	-17.335	4.243
	2009-11-11T00:00:00.000	2009-06-24T00:00:00.000	3.2644	2.2402	.887	-7.525	14.054
		2009-06-25T00:00:00.000	8.3529	2.2402	.148	-2.436	19.142
		2009-07-21T00:00:00.000	5.5035	2.2402	.489	-5.286	16.293
		2009-07-22T00:00:00.000	5.1026	2.2402	.562	-5.687	15.892
		2009-07-23T00:00:00.000	1.1225	2.2402	.999	-9.667	11.912
		2009-11-10T00:00:00.000	6.5461	2.2402	.325	-4.243	17.335

Coarse	2009-06-24T00:00:00.000	2009-06-25T00:00:00.000	-1.0236	3.0278	1.000	-15.606	13.559
		2009-07-21T00:00:00.000	.7154	3.0278	1.000	-13.867	15.298
		2009-07-22T00:00:00.000	2.6961	3.0278	.988	-11.886	17.279
		2009-07-23T00:00:00.000	2.4394	3.0278	.993	-12.143	17.022
		2009-11-10T00:00:00.000	2.8644	3.0278	.983	-11.718	17.447
		2009-11-11T00:00:00.000	8.8224	3.0278	.328	-5.760	23.405
	2009-06-25T00:00:00.000	2009-06-24T00:00:00.000	1.0236	3.0278	1.000	-13.559	15.606
		2009-07-21T00:00:00.000	1.7390	3.0278	.999	-12.843	16.321
		2009-07-22T00:00:00.000	3.7197	3.0278	.943	-10.863	18.302
		2009-07-23T00:00:00.000	3.4630	3.0278	.959	-11.119	18.045
		2009-11-10T00:00:00.000	3.8881	3.0278	.932	-10.694	18.471
		2009-11-11T00:00:00.000	9.8460	3.0278	.238	-4.736	24.428
	2009-07-21T00:00:00.000	2009-06-24T00:00:00.000	-.7154	3.0278	1.000	-15.298	13.867
		2009-06-25T00:00:00.000	-1.7390	3.0278	.999	-16.321	12.843
		2009-07-22T00:00:00.000	1.9807	3.0278	.998	-12.602	16.563
		2009-07-23T00:00:00.000	1.7240	3.0278	.999	-12.858	16.306
		2009-11-10T00:00:00.000	2.1490	3.0278	.996	-12.433	16.731
		2009-11-11T00:00:00.000	8.1069	3.0278	.406	-6.475	22.689

	2009-07-22T00:00:00.000	2009-06-24T00:00:00.000	-2.6961	3.0278	.988	-17.279	11.886
		2009-06-25T00:00:00.000	-3.7197	3.0278	.943	-18.302	10.863
		2009-07-21T00:00:00.000	-1.9807	3.0278	.998	-16.563	12.602
		2009-07-23T00:00:00.000	-.2567	3.0278	1.000	-14.839	14.326
		2009-11-10T00:00:00.000	.1684	3.0278	1.000	-14.414	14.751
		2009-11-11T00:00:00.000	6.1263	3.0278	.671	-8.456	20.709
	2009-07-23T00:00:00.000	2009-06-24T00:00:00.000	-2.4394	3.0278	.993	-17.022	12.143
		2009-06-25T00:00:00.000	-3.4630	3.0278	.959	-18.045	11.119
		2009-07-21T00:00:00.000	-1.7240	3.0278	.999	-16.306	12.858
		2009-07-22T00:00:00.000	.2567	3.0278	1.000	-14.326	14.839
		2009-11-10T00:00:00.000	.4250	3.0278	1.000	-14.157	15.007
		2009-11-11T00:00:00.000	6.3830	3.0278	.635	-8.199	20.965
	2009-11-10T00:00:00.000	2009-06-24T00:00:00.000	-2.8644	3.0278	.983	-17.447	11.718
		2009-06-25T00:00:00.000	-3.8881	3.0278	.932	-18.471	10.694
		2009-07-21T00:00:00.000	-2.1490	3.0278	.996	-16.731	12.433
		2009-07-22T00:00:00.000	-.1684	3.0278	1.000	-14.751	14.414
		2009-07-23T00:00:00.000	-.4250	3.0278	1.000	-15.007	14.157
		2009-11-11T00:00:00.000	5.9579	3.0278	.695	-8.625	20.540

	2009-11-11T00:00:00.000	2009-06-24T00:00:00.000	-8.8224	3.0278	.328	-23.405	5.760
		2009-06-25T00:00:00.000	-9.8460	3.0278	.238	-24.428	4.736
		2009-07-21T00:00:00.000	-8.1069	3.0278	.406	-22.689	6.475
		2009-07-22T00:00:00.000	-6.1263	3.0278	.671	-20.709	8.456
		2009-07-23T00:00:00.000	-6.3830	3.0278	.635	-20.965	8.199
		2009-11-10T00:00:00.000	-5.9579	3.0278	.695	-20.540	8.625

Table B2: Daily variation of particulate matter concentration at ERTC

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	2686.330	6	447.722	3.417	.066
	Within Groups	917.305	7	131.044		
	Total	3603.634	13			
Coarse	Between Groups	2564.652	6	427.442	3.317	.071
	Within Groups	901.957	7	128.851		
	Total	3466.608	13			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Date	(J) Date	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Fine	2009-06-03T00:00:00.000	2009-06-04T00:00:00.000	-36.7647	11.4474	.247	-91.898	18.368
		2009-06-08T00:00:00.000	-24.5098	11.4474	.621	-79.643	30.623
		2009-06-09T00:00:00.000	-12.2549	11.4474	.970	-67.388	42.878
		2009-06-10T00:00:00.000	-12.2549	11.4474	.970	-67.388	42.878
		2009-11-02T00:00:00.000	1.7347	11.4474	1.000	-53.398	56.868
		2009-11-03T00:00:00.000	3.5684	11.4474	1.000	-51.565	58.702

	2009-06-04T00:00:00.000	2009-06-03T00:00:00.000	36.7647	11.4474	.247	-18.368	91.898
		2009-06-08T00:00:00.000	12.2549	11.4474	.970	-42.878	67.388
		2009-06-09T00:00:00.000	24.5098	11.4474	.621	-30.623	79.643
		2009-06-10T00:00:00.000	24.5098	11.4474	.621	-30.623	79.643
		2009-11-02T00:00:00.000	38.4994	11.4474	.213	-16.634	93.633
		2009-11-03T00:00:00.000	40.3331	11.4474	.182	-14.800	95.466
	2009-06-08T00:00:00.000	2009-06-03T00:00:00.000	24.5098	11.4474	.621	-30.623	79.643
		2009-06-04T00:00:00.000	-12.2549	11.4474	.970	-67.388	42.878
		2009-06-09T00:00:00.000	12.2549	11.4474	.970	-42.878	67.388
		2009-06-10T00:00:00.000	12.2549	11.4474	.970	-42.878	67.388
		2009-11-02T00:00:00.000	26.2445	11.4474	.556	-28.889	81.378
		2009-11-03T00:00:00.000	28.0782	11.4474	.490	-27.055	83.211
	2009-06-09T00:00:00.000	2009-06-03T00:00:00.000	12.2549	11.4474	.970	-42.878	67.388
		2009-06-04T00:00:00.000	-24.5098	11.4474	.621	-79.643	30.623
		2009-06-08T00:00:00.000	-12.2549	11.4474	.970	-67.388	42.878
		2009-06-10T00:00:00.000	.0000	11.4474	1.000	-55.133	55.133
		2009-11-02T00:00:00.000	13.9896	11.4474	.945	-41.143	69.123
		2009-11-03T00:00:00.000	15.8233	11.4474	.908	-39.310	70.956

	2009-06-10T00:00:00.000	2009-06-03T00:00:00.000	12.2549	11.4474	.970	-42.878	67.388
		2009-06-04T00:00:00.000	-24.5098	11.4474	.621	-79.643	30.623
		2009-06-08T00:00:00.000	-12.2549	11.4474	.970	-67.388	42.878
		2009-06-09T00:00:00.000	.0000	11.4474	1.000	-55.133	55.133
		2009-11-02T00:00:00.000	13.9896	11.4474	.945	-41.143	69.123
		2009-11-03T00:00:00.000	15.8233	11.4474	.908	-39.310	70.956
	2009-11-02T00:00:00.000	2009-06-03T00:00:00.000	-1.7347	11.4474	1.000	-56.868	53.398
		2009-06-04T00:00:00.000	-38.4994	11.4474	.213	-93.633	16.634
		2009-06-08T00:00:00.000	-26.2445	11.4474	.556	-81.378	28.889
		2009-06-09T00:00:00.000	-13.9896	11.4474	.945	-69.123	41.143
		2009-06-10T00:00:00.000	-13.9896	11.4474	.945	-69.123	41.143
		2009-11-03T00:00:00.000	1.8336	11.4474	1.000	-53.299	56.967
	2009-11-03T00:00:00.000	2009-06-03T00:00:00.000	-3.5684	11.4474	1.000	-58.702	51.565
		2009-06-04T00:00:00.000	-40.3331	11.4474	.182	-95.466	14.800
		2009-06-08T00:00:00.000	-28.0782	11.4474	.490	-83.211	27.055
		2009-06-09T00:00:00.000	-15.8233	11.4474	.908	-70.956	39.310
		2009-06-10T00:00:00.000	-15.8233	11.4474	.908	-70.956	39.310
		2009-11-02T00:00:00.000	-1.8336	11.4474	1.000	-56.967	53.299

Coarse	2009-06-03T00:00:00.000	2009-06-04T00:00:00.000	.0000	11.3513	1.000	-54.670	54.670
		2009-06-08T00:00:00.000	-24.5098	11.3513	.613	-79.180	30.160
		2009-06-09T00:00:00.000	12.2549	11.3513	.968	-42.415	66.925
		2009-06-10T00:00:00.000	-12.2549	11.3513	.968	-66.925	42.415
		2009-11-02T00:00:00.000	-22.4559	11.3513	.691	-77.126	32.214
		2009-11-03T00:00:00.000	-24.7202	11.3513	.605	-79.390	29.950
	2009-06-04T00:00:00.000	2009-06-03T00:00:00.000	.0000	11.3513	1.000	-54.670	54.670
		2009-06-08T00:00:00.000	-24.5098	11.3513	.613	-79.180	30.160
		2009-06-09T00:00:00.000	12.2549	11.3513	.968	-42.415	66.925
		2009-06-10T00:00:00.000	-12.2549	11.3513	.968	-66.925	42.415
		2009-11-02T00:00:00.000	-22.4559	11.3513	.691	-77.126	32.214
		2009-11-03T00:00:00.000	-24.7202	11.3513	.605	-79.390	29.950
	2009-06-08T00:00:00.000	2009-06-03T00:00:00.000	24.5098	11.3513	.613	-30.160	79.180
		2009-06-04T00:00:00.000	24.5098	11.3513	.613	-30.160	79.180
		2009-06-09T00:00:00.000	36.7647	11.3513	.241	-17.905	91.435
		2009-06-10T00:00:00.000	12.2549	11.3513	.968	-42.415	66.925
		2009-11-02T00:00:00.000	2.0539	11.3513	1.000	-52.616	56.724
		2009-11-03T00:00:00.000	-.2104	11.3513	1.000	-54.880	54.460

	2009-06-09T00:00:00.000	2009-06-03T00:00:00.000	-12.2549	11.3513	.968	-66.925	42.415
		2009-06-04T00:00:00.000	-12.2549	11.3513	.968	-66.925	42.415
		2009-06-08T00:00:00.000	-36.7647	11.3513	.241	-91.435	17.905
		2009-06-10T00:00:00.000	-24.5098	11.3513	.613	-79.180	30.160
		2009-11-02T00:00:00.000	-34.7108	11.3513	.286	-89.381	19.959
		2009-11-03T00:00:00.000	-36.9751	11.3513	.236	-91.645	17.695
	2009-06-10T00:00:00.000	2009-06-03T00:00:00.000	12.2549	11.3513	.968	-42.415	66.925
		2009-06-04T00:00:00.000	12.2549	11.3513	.968	-42.415	66.925
		2009-06-08T00:00:00.000	-12.2549	11.3513	.968	-66.925	42.415
		2009-06-09T00:00:00.000	24.5098	11.3513	.613	-30.160	79.180
		2009-11-02T00:00:00.000	-10.2010	11.3513	.987	-64.871	44.469
		2009-11-03T00:00:00.000	-12.4653	11.3513	.966	-67.135	42.205
	2009-11-02T00:00:00.000	2009-06-03T00:00:00.000	22.4559	11.3513	.691	-32.214	77.126
		2009-06-04T00:00:00.000	22.4559	11.3513	.691	-32.214	77.126
		2009-06-08T00:00:00.000	-2.0539	11.3513	1.000	-56.724	52.616
		2009-06-09T00:00:00.000	34.7108	11.3513	.286	-19.959	89.381
		2009-06-10T00:00:00.000	10.2010	11.3513	.987	-44.469	64.871
		2009-11-03T00:00:00.000	-2.2643	11.3513	1.000	-56.934	52.406

	2009-11-03T00:00:00.000	2009-06-03T00:00:00.000	24.7202	11.3513	.605	-29.950	79.390
		2009-06-04T00:00:00.000	24.7202	11.3513	.605	-29.950	79.390
		2009-06-08T00:00:00.000	.2104	11.3513	1.000	-54.460	54.880
		2009-06-09T00:00:00.000	36.9751	11.3513	.236	-17.695	91.645
		2009-06-10T00:00:00.000	12.4653	11.3513	.966	-42.205	67.135
		2009-11-02T00:00:00.000	2.2643	11.3513	1.000	-52.406	56.934

Table B3: Daily variation of particulate matter concentration at Silom road

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	14262.019	6	2377.003	457.989	.000
	Within Groups	36.331	7	5.190		
	Total	14298.350	13			
Coarse	Between Groups	16658.061	6	2776.343	154.385	.000
	Within Groups	125.883	7	17.983		
	Total	16783.944	13			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Date	(J) Date	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Fine	2009-08-26T00:00:00.000	2009-08-27T00:00:00.000	-10.0862	2.2782	.073	-21.058	.886
		2009-08-28T00:00:00.000	-36.9500*	2.2782	.000	-47.922	-25.978
		2009-10-06T00:00:00.000	-62.2722*	2.2782	.000	-73.244	-51.300
		2009-10-07T00:00:00.000	-85.6926*	2.2782	.000	-96.665	-74.720
		2009-10-26T00:00:00.000	-14.1935*	2.2782	.013	-25.166	-3.221
		2009-10-27T00:00:00.000	7.4550	2.2782	.233	-3.517	18.427

	2009-08-27T00:00:00.000	2009-08-26T00:00:00.000	10.0862	2.2782	.073	-.886	21.058
		2009-08-28T00:00:00.000	-26.8638*	2.2782	.000	-37.836	-15.892
		2009-10-06T00:00:00.000	-52.1860*	2.2782	.000	-63.158	-41.214
		2009-10-07T00:00:00.000	-75.6064*	2.2782	.000	-86.579	-64.634
		2009-10-26T00:00:00.000	-4.1073	2.2782	.764	-15.079	6.865
		2009-10-27T00:00:00.000	17.5412*	2.2782	.004	6.569	28.513
	2009-08-28T00:00:00.000	2009-08-26T00:00:00.000	36.9500*	2.2782	.000	25.978	47.922
		2009-08-27T00:00:00.000	26.8638*	2.2782	.000	15.892	37.836
		2009-10-06T00:00:00.000	-25.3222*	2.2782	.000	-36.294	-14.350
		2009-10-07T00:00:00.000	-48.7426*	2.2782	.000	-59.715	-37.770
		2009-10-26T00:00:00.000	22.7565*	2.2782	.001	11.784	33.729
		2009-10-27T00:00:00.000	44.4050*	2.2782	.000	33.433	55.377
	2009-10-06T00:00:00.000	2009-08-26T00:00:00.000	62.2722*	2.2782	.000	51.300	73.244
		2009-08-27T00:00:00.000	52.1860*	2.2782	.000	41.214	63.158
		2009-08-28T00:00:00.000	25.3222*	2.2782	.000	14.350	36.294
		2009-10-07T00:00:00.000	-23.4204*	2.2782	.001	-34.393	-12.448
		2009-10-26T00:00:00.000	48.0787*	2.2782	.000	37.107	59.051
		2009-10-27T00:00:00.000	69.7273*	2.2782	.000	58.755	80.699

	2009-10-07T00:00:00.000	2009-08-26T00:00:00.000	85.6926*	2.2782	.000	74.720	96.665
		2009-08-27T00:00:00.000	75.6064*	2.2782	.000	64.634	86.579
		2009-08-28T00:00:00.000	48.7426*	2.2782	.000	37.770	59.715
		2009-10-06T00:00:00.000	23.4204*	2.2782	.001	12.448	34.393
		2009-10-26T00:00:00.000	71.4991*	2.2782	.000	60.527	82.471
		2009-10-27T00:00:00.000	93.1477*	2.2782	.000	82.176	104.120
	2009-10-26T00:00:00.000	2009-08-26T00:00:00.000	14.1935*	2.2782	.013	3.221	25.166
		2009-08-27T00:00:00.000	4.1073	2.2782	.764	-6.865	15.079
		2009-08-28T00:00:00.000	-22.7565*	2.2782	.001	-33.729	-11.784
		2009-10-06T00:00:00.000	-48.0787*	2.2782	.000	-59.051	-37.107
		2009-10-07T00:00:00.000	-71.4991*	2.2782	.000	-82.471	-60.527
		2009-10-27T00:00:00.000	21.6486*	2.2782	.001	10.676	32.621
	2009-10-27T00:00:00.000	2009-08-26T00:00:00.000	-7.4550	2.2782	.233	-18.427	3.517
		2009-08-27T00:00:00.000	-17.5412*	2.2782	.004	-28.513	-6.569
		2009-08-28T00:00:00.000	-44.4050*	2.2782	.000	-55.377	-33.433
		2009-10-06T00:00:00.000	-69.7273*	2.2782	.000	-80.699	-58.755
		2009-10-07T00:00:00.000	-93.1477*	2.2782	.000	-104.120	-82.176
		2009-10-26T00:00:00.000	-21.6486*	2.2782	.001	-32.621	-10.676

Coarse	2009-08-26T00:00:00.000	2009-08-27T00:00:00.000	-32.6456*	4.2407	.004	-53.070	-12.222
		2009-08-28T00:00:00.000	-20.6085*	4.2407	.048	-41.032	-.185
		2009-10-06T00:00:00.000	-67.3552*	4.2407	.000	-87.779	-46.931
		2009-10-07T00:00:00.000	-78.6994*	4.2407	.000	-99.123	-58.276
		2009-10-26T00:00:00.000	-71.6036*	4.2407	.000	-92.027	-51.180
		2009-10-27T00:00:00.000	16.0771	4.2407	.139	-4.347	36.501
	2009-08-27T00:00:00.000	2009-08-26T00:00:00.000	32.6456*	4.2407	.004	12.222	53.070
		2009-08-28T00:00:00.000	12.0371	4.2407	.351	-8.387	32.461
		2009-10-06T00:00:00.000	-34.7096*	4.2407	.003	-55.133	-14.286
		2009-10-07T00:00:00.000	-46.0538*	4.2407	.000	-66.478	-25.630
		2009-10-26T00:00:00.000	-38.9579*	4.2407	.001	-59.382	-18.534
		2009-10-27T00:00:00.000	48.7227*	4.2407	.000	28.299	69.147
	2009-08-28T00:00:00.000	2009-08-26T00:00:00.000	20.6085*	4.2407	.048	.185	41.032
		2009-08-27T00:00:00.000	-12.0371	4.2407	.351	-32.461	8.387
		2009-10-06T00:00:00.000	-46.7467*	4.2407	.000	-67.171	-26.323
		2009-10-07T00:00:00.000	-58.0909*	4.2407	.000	-78.515	-37.667
		2009-10-26T00:00:00.000	-50.9951*	4.2407	.000	-71.419	-30.571
		2009-10-27T00:00:00.000	36.6856*	4.2407	.002	16.262	57.110

	2009-10-06T00:00:00.000	2009-08-26T00:00:00.000	67.3552*	4.2407	.000	46.931	87.779
		2009-08-27T00:00:00.000	34.7096*	4.2407	.003	14.286	55.133
		2009-08-28T00:00:00.000	46.7467*	4.2407	.000	26.323	67.171
		2009-10-07T00:00:00.000	-11.3442	4.2407	.407	-31.768	9.080
		2009-10-26T00:00:00.000	-4.2484	4.2407	.978	-24.672	16.176
		2009-10-27T00:00:00.000	83.4323*	4.2407	.000	63.008	103.856
	2009-10-07T00:00:00.000	2009-08-26T00:00:00.000	78.6994*	4.2407	.000	58.276	99.123
		2009-08-27T00:00:00.000	46.0538*	4.2407	.000	25.630	66.478
		2009-08-28T00:00:00.000	58.0909*	4.2407	.000	37.667	78.515
		2009-10-06T00:00:00.000	11.3442	4.2407	.407	-9.080	31.768
		2009-10-26T00:00:00.000	7.0959	4.2407	.814	-13.328	27.520
		2009-10-27T00:00:00.000	94.7765*	4.2407	.000	74.353	115.200
	2009-10-26T00:00:00.000	2009-08-26T00:00:00.000	71.6036*	4.2407	.000	51.180	92.027
		2009-08-27T00:00:00.000	38.9579*	4.2407	.001	18.534	59.382
		2009-08-28T00:00:00.000	50.9951*	4.2407	.000	30.571	71.419
		2009-10-06T00:00:00.000	4.2484	4.2407	.978	-16.176	24.672
		2009-10-07T00:00:00.000	-7.0959	4.2407	.814	-27.520	13.328
		2009-10-27T00:00:00.000	87.6807*	4.2407	.000	67.257	108.105

	2009-10-27T00:00:00.000	2009-08-26T00:00:00.000	-16.0771	4.2407	.139	-36.501	4.347
		2009-08-27T00:00:00.000	-48.7227*	4.2407	.000	-69.147	-28.299
		2009-08-28T00:00:00.000	-36.6856*	4.2407	.002	-57.110	-16.262
		2009-10-06T00:00:00.000	-83.4323*	4.2407	.000	-103.856	-63.008
		2009-10-07T00:00:00.000	-94.7765*	4.2407	.000	-115.200	-74.353
		2009-10-26T00:00:00.000	-87.6807*	4.2407	.000	-108.105	-67.257

*. The mean difference is significant at the 0.05 level.

Table B4: Spatial variation of particulate matter concentration

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fine	Between Groups	66960.826	2	33480.413	72.366	.000
	Within Groups	18043.545	39	462.655		
	Total	85004.372	41			
Coarse	Between Groups	126788.509	2	63394.254	120.967	.000
	Within Groups	20438.442	39	524.063		
	Total	147226.951	41			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Fine	1	2	-6.86596	8.12980	.702	-27.5550	13.8230
		3	-87.92569*	8.12980	.000	-108.6147	-67.2367
	2	1	6.86596	8.12980	.702	-13.8230	27.5550
		3	-81.05973*	8.12980	.000	-101.7487	-60.3707
	3	1	87.92569*	8.12980	.000	67.2367	108.6147
		2	81.05973*	8.12980	.000	60.3707	101.7487
Coarse	1	2	32.74316*	8.65252	.002	10.7239	54.7624
		3	-96.67884*	8.65252	.000	-118.6981	-74.6596
	2	1	-32.74316*	8.65252	.002	-54.7624	-10.7239
		3	-129.42200*	8.65252	.000	-151.4412	-107.4028
	3	1	96.67884*	8.65252	.000	74.6596	118.6981
		2	129.42200*	8.65252	.000	107.4028	151.4412

*. The mean difference is significant at the 0.05 level.

Table B5: Temporal variation of microbial concentration at CU

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	451762.727	2	225881.363	9.244	.002
	Within Groups	439817.966	18	24434.331		
	Total	891580.692	20			
Fungi	Between Groups	634983.326	2	317491.663	12.844	.000
	Within Groups	444931.860	18	24718.437		
	Total	1079915.186	20			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bacteria	10	12	-198.8714	83.5538	.085	-421.650	23.907
		14	159.6857	83.5538	.190	-63.093	382.465
	12	10	198.8714	83.5538	.085	-23.907	421.650
		14	358.5571*	83.5538	.002	135.778	581.336
	14	10	-159.6857	83.5538	.190	-382.465	63.093
		12	-358.5571*	83.5538	.002	-581.336	-135.778
Fungi	10	12	-201.6857	84.0381	.082	-425.756	22.385
		14	224.0571	84.0381	.050	-.013	448.127
	12	10	201.6857	84.0381	.082	-22.385	425.756
		14	425.7429*	84.0381	.000	201.673	649.813
	14	10	-224.0571	84.0381	.050	-448.127	.013
		12	-425.7429*	84.0381	.000	-649.813	-201.673

*. The mean difference is significant at the 0.05 level.

Table B6: Temporal variation of microbial concentration at ERTC

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	763372.411	2	381686.206	15.150	.000
	Within Groups	453477.053	18	25193.170		
	Total	1216849.465	20			
Fungi	Between Groups	721947.894	2	360973.947	6.989	.006
	Within Groups	929680.697	18	51648.928		
	Total	1651628.590	20			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bacteria	10	12	-302.5171*	84.8413	.008	-528.729	-76.305
		14	156.8686	84.8413	.209	-69.343	383.080
	12	10	302.5171*	84.8413	.008	76.305	528.729
		14	459.3857*	84.8413	.000	233.174	685.597
	14	10	-156.8686	84.8413	.209	-383.080	69.343
		12	-459.3857*	84.8413	.000	-685.597	-233.174
Fungi	10	12	-299.7114	121.4777	.073	-623.607	24.184
		14	145.6657	121.4777	.501	-178.229	469.561
	12	10	299.7114	121.4777	.073	-24.184	623.607
		14	445.3771*	121.4777	.007	121.482	769.272
	14	10	-145.6657	121.4777	.501	-469.561	178.229
		12	-445.3771*	121.4777	.007	-769.272	-121.482

*. The mean difference is significant at the 0.05 level.

Table B7: Temporal variation of microbial concentration at Silom road

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	763372.411	2	381686.206	15.150	.000
	Within Groups	453477.053	18	25193.170		
	Total	1216849.465	20			
Fungi	Between Groups	721947.894	2	360973.947	6.989	.006
	Within Groups	929680.697	18	51648.928		
	Total	1651628.590	20			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bacteria	10	12	-81.2143	37.7655	.128	-181.908	19.480
		14	47.6143	37.7655	.467	-53.080	148.308
	12	10	81.2143	37.7655	.128	-19.480	181.908
		14	128.8286*	37.7655	.011	28.135	229.522
	14	10	-47.6143	37.7655	.467	-148.308	53.080
		12	-128.8286*	37.7655	.011	-229.522	-28.135
Fungi	10	12	-67.2000*	17.4111	.004	-113.623	-20.777
		14	28.0000	17.4111	.299	-18.423	74.423
	12	10	67.2000*	17.4111	.004	20.777	113.623
		14	95.2000*	17.4111	.000	48.777	141.623
	14	10	-28.0000	17.4111	.299	-74.423	18.423
		12	-95.2000*	17.4111	.000	-141.623	-48.777

*. The mean difference is significant at the 0.05 level.

Table B8: Daily variation of microbial concentration at CU

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	176145.259	6	29357.543	.574	.745
	Within Groups	715435.433	14	51102.531		
	Total	891580.692	20			
Fungi	Between Groups	236470.886	6	39411.814	.654	.687
	Within Groups	843444.300	14	60246.021		
	Total	1079915.186	20			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Date	(J) Date	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bacteria	2009-06-24T00:00:00.000	2009-06-25T00:00:00.000	-78.4333	184.5761	1.000	-841.391	684.524
		2009-07-21T00:00:00.000	39.2333	184.5761	1.000	-723.724	802.191
		2009-07-22T00:00:00.000	65.4000	184.5761	1.000	-697.557	828.357
		2009-07-23T00:00:00.000	91.5333	184.5761	1.000	-671.424	854.491
		2009-11-10T00:00:00.000	183.0333	184.5761	.982	-579.924	945.991
		2009-11-11T00:00:00.000	202.6667	184.5761	.971	-560.291	965.624

	2009-06-25T00:00:00.000	2009-06-24T00:00:00.000	78.4333	184.5761	1.000	-684.524	841.391
		2009-07-21T00:00:00.000	117.6667	184.5761	.998	-645.291	880.624
		2009-07-22T00:00:00.000	143.8333	184.5761	.995	-619.124	906.791
		2009-07-23T00:00:00.000	169.9667	184.5761	.988	-592.991	932.924
		2009-11-10T00:00:00.000	261.4667	184.5761	.907	-501.491	1024.424
		2009-11-11T00:00:00.000	281.1000	184.5761	.876	-481.857	1044.057
	2009-07-21T00:00:00.000	2009-06-24T00:00:00.000	-39.2333	184.5761	1.000	-802.191	723.724
		2009-06-25T00:00:00.000	-117.6667	184.5761	.998	-880.624	645.291
		2009-07-22T00:00:00.000	26.1667	184.5761	1.000	-736.791	789.124
		2009-07-23T00:00:00.000	52.3000	184.5761	1.000	-710.657	815.257
		2009-11-10T00:00:00.000	143.8000	184.5761	.995	-619.157	906.757
		2009-11-11T00:00:00.000	163.4333	184.5761	.990	-599.524	926.391
	2009-07-22T00:00:00.000	2009-06-24T00:00:00.000	-65.4000	184.5761	1.000	-828.357	697.557
		2009-06-25T00:00:00.000	-143.8333	184.5761	.995	-906.791	619.124
		2009-07-21T00:00:00.000	-26.1667	184.5761	1.000	-789.124	736.791
		2009-07-23T00:00:00.000	26.1333	184.5761	1.000	-736.824	789.091
		2009-11-10T00:00:00.000	117.6333	184.5761	.998	-645.324	880.591
		2009-11-11T00:00:00.000	137.2667	184.5761	.996	-625.691	900.224

	2009-07-23T00:00:00.000	2009-06-24T00:00:00.000	-91.5333	184.5761	1.000	-854.491	671.424
		2009-06-25T00:00:00.000	-169.9667	184.5761	.988	-932.924	592.991
		2009-07-21T00:00:00.000	-52.3000	184.5761	1.000	-815.257	710.657
		2009-07-22T00:00:00.000	-26.1333	184.5761	1.000	-789.091	736.824
		2009-11-10T00:00:00.000	91.5000	184.5761	1.000	-671.457	854.457
		2009-11-11T00:00:00.000	111.1333	184.5761	.999	-651.824	874.091
	2009-11-10T00:00:00.000	2009-06-24T00:00:00.000	-183.0333	184.5761	.982	-945.991	579.924
		2009-06-25T00:00:00.000	-261.4667	184.5761	.907	-1024.424	501.491
		2009-07-21T00:00:00.000	-143.8000	184.5761	.995	-906.757	619.157
		2009-07-22T00:00:00.000	-117.6333	184.5761	.998	-880.591	645.324
		2009-07-23T00:00:00.000	-91.5000	184.5761	1.000	-854.457	671.457
		2009-11-11T00:00:00.000	19.6333	184.5761	1.000	-743.324	782.591
	2009-11-11T00:00:00.000	2009-06-24T00:00:00.000	-202.6667	184.5761	.971	-965.624	560.291
		2009-06-25T00:00:00.000	-281.1000	184.5761	.876	-1044.057	481.857
		2009-07-21T00:00:00.000	-163.4333	184.5761	.990	-926.391	599.524
		2009-07-22T00:00:00.000	-137.2667	184.5761	.996	-900.224	625.691
		2009-07-23T00:00:00.000	-111.1333	184.5761	.999	-874.091	651.824
		2009-11-10T00:00:00.000	-19.6333	184.5761	1.000	-782.591	743.324

Fungi	2009-06-24T00:00:00.000	2009-06-25T00:00:00.000	-39.2333	200.4096	1.000	-867.639	789.173
		2009-07-21T00:00:00.000	111.1333	200.4096	.999	-717.273	939.539
		2009-07-22T00:00:00.000	117.6333	200.4096	.999	-710.773	946.039
		2009-07-23T00:00:00.000	163.4000	200.4096	.994	-665.006	991.806
		2009-11-10T00:00:00.000	235.3000	200.4096	.960	-593.106	1063.706
		2009-11-11T00:00:00.000	274.5333	200.4096	.920	-553.873	1102.939
	2009-06-25T00:00:00.000	2009-06-24T00:00:00.000	39.2333	200.4096	1.000	-789.173	867.639
		2009-07-21T00:00:00.000	150.3667	200.4096	.996	-678.039	978.773
		2009-07-22T00:00:00.000	156.8667	200.4096	.995	-671.539	985.273
		2009-07-23T00:00:00.000	202.6333	200.4096	.981	-625.773	1031.039
		2009-11-10T00:00:00.000	274.5333	200.4096	.920	-553.873	1102.939
		2009-11-11T00:00:00.000	313.7667	200.4096	.861	-514.639	1142.173
	2009-07-21T00:00:00.000	2009-06-24T00:00:00.000	-111.1333	200.4096	.999	-939.539	717.273
		2009-06-25T00:00:00.000	-150.3667	200.4096	.996	-978.773	678.039
		2009-07-22T00:00:00.000	6.5000	200.4096	1.000	-821.906	834.906
		2009-07-23T00:00:00.000	52.2667	200.4096	1.000	-776.139	880.673
		2009-11-10T00:00:00.000	124.1667	200.4096	.999	-704.239	952.573
		2009-11-11T00:00:00.000	163.4000	200.4096	.994	-665.006	991.806

	2009-07-22T00:00:00.000	2009-06-24T00:00:00.000	-117.6333	200.4096	.999	-946.039	710.773
		2009-06-25T00:00:00.000	-156.8667	200.4096	.995	-985.273	671.539
		2009-07-21T00:00:00.000	-6.5000	200.4096	1.000	-834.906	821.906
		2009-07-23T00:00:00.000	45.7667	200.4096	1.000	-782.639	874.173
		2009-11-10T00:00:00.000	117.6667	200.4096	.999	-710.739	946.073
		2009-11-11T00:00:00.000	156.9000	200.4096	.995	-671.506	985.306
	2009-07-23T00:00:00.000	2009-06-24T00:00:00.000	-163.4000	200.4096	.994	-991.806	665.006
		2009-06-25T00:00:00.000	-202.6333	200.4096	.981	-1031.039	625.773
		2009-07-21T00:00:00.000	-52.2667	200.4096	1.000	-880.673	776.139
		2009-07-22T00:00:00.000	-45.7667	200.4096	1.000	-874.173	782.639
		2009-11-10T00:00:00.000	71.9000	200.4096	1.000	-756.506	900.306
		2009-11-11T00:00:00.000	111.1333	200.4096	.999	-717.273	939.539
	2009-11-10T00:00:00.000	2009-06-24T00:00:00.000	-235.3000	200.4096	.960	-1063.706	593.106
		2009-06-25T00:00:00.000	-274.5333	200.4096	.920	-1102.939	553.873
		2009-07-21T00:00:00.000	-124.1667	200.4096	.999	-952.573	704.239
		2009-07-22T00:00:00.000	-117.6667	200.4096	.999	-946.073	710.739
		2009-07-23T00:00:00.000	-71.9000	200.4096	1.000	-900.306	756.506
		2009-11-11T00:00:00.000	39.2333	200.4096	1.000	-789.173	867.639

	2009-11-11T00:00:00.000	2009-06-24T00:00:00.000	-274.5333	200.4096	.920	-1102.939	553.873
		2009-06-25T00:00:00.000	-313.7667	200.4096	.861	-1142.173	514.639
		2009-07-21T00:00:00.000	-163.4000	200.4096	.994	-991.806	665.006
		2009-07-22T00:00:00.000	-156.9000	200.4096	.995	-985.306	671.506
		2009-07-23T00:00:00.000	-111.1333	200.4096	.999	-939.539	717.273
		2009-11-10T00:00:00.000	-39.2333	200.4096	1.000	-867.639	789.173

Table B9: Daily variation of microbial concentration at ERTC

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	351282.616	6	58547.103	.947	.493
	Within Groups	865566.848	14	61826.203		
	Total	1216849.465	20			
Fungi	Between Groups	771446.802	6	128574.467	2.045	.127
	Within Groups	880181.789	14	62870.128		
	Total	1651628.590	20			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Date	(J) Date	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bacteria	2009-06-03T00:00:00.000	2009-06-04T00:00:00.000	-26.1433	203.0209	1.000	-865.343	813.056
		2009-06-08T00:00:00.000	-26.1433	203.0209	1.000	-865.343	813.056
		2009-06-09T00:00:00.000	-98.0400	203.0209	1.000	-937.240	741.160
		2009-06-10T00:00:00.000	-71.8933	203.0209	1.000	-911.093	767.306
		2009-11-02T00:00:00.000	183.0200	203.0209	.989	-656.180	1022.220
		2009-11-03T00:00:00.000	274.5200	203.0209	.924	-564.680	1113.720

	2009-06-04T00:00:00.000	2009-06-03T00:00:00.000	26.1433	203.0209	1.000	-813.056	865.343
		2009-06-08T00:00:00.000	.0000	203.0209	1.000	-839.200	839.200
		2009-06-09T00:00:00.000	-71.8967	203.0209	1.000	-911.096	767.303
		2009-06-10T00:00:00.000	-45.7500	203.0209	1.000	-884.950	793.450
		2009-11-02T00:00:00.000	209.1633	203.0209	.979	-630.036	1048.363
		2009-11-03T00:00:00.000	300.6633	203.0209	.889	-538.536	1139.863
	2009-06-08T00:00:00.000	2009-06-03T00:00:00.000	26.1433	203.0209	1.000	-813.056	865.343
		2009-06-04T00:00:00.000	.0000	203.0209	1.000	-839.200	839.200
		2009-06-09T00:00:00.000	-71.8967	203.0209	1.000	-911.096	767.303
		2009-06-10T00:00:00.000	-45.7500	203.0209	1.000	-884.950	793.450
		2009-11-02T00:00:00.000	209.1633	203.0209	.979	-630.036	1048.363
		2009-11-03T00:00:00.000	300.6633	203.0209	.889	-538.536	1139.863
	2009-06-09T00:00:00.000	2009-06-03T00:00:00.000	98.0400	203.0209	1.000	-741.160	937.240
		2009-06-04T00:00:00.000	71.8967	203.0209	1.000	-767.303	911.096
		2009-06-08T00:00:00.000	71.8967	203.0209	1.000	-767.303	911.096
		2009-06-10T00:00:00.000	26.1467	203.0209	1.000	-813.053	865.346
		2009-11-02T00:00:00.000	281.0600	203.0209	.916	-558.140	1120.260
		2009-11-03T00:00:00.000	372.5600	203.0209	.754	-466.640	1211.760

	2009-06-10T00:00:00.000	2009-06-03T00:00:00.000	71.8933	203.0209	1.000	-767.306	911.093
		2009-06-04T00:00:00.000	45.7500	203.0209	1.000	-793.450	884.950
		2009-06-08T00:00:00.000	45.7500	203.0209	1.000	-793.450	884.950
		2009-06-09T00:00:00.000	-26.1467	203.0209	1.000	-865.346	813.053
		2009-11-02T00:00:00.000	254.9133	203.0209	.945	-584.286	1094.113
		2009-11-03T00:00:00.000	346.4133	203.0209	.809	-492.786	1185.613
	2009-11-02T00:00:00.000	2009-06-03T00:00:00.000	-183.0200	203.0209	.989	-1022.220	656.180
		2009-06-04T00:00:00.000	-209.1633	203.0209	.979	-1048.363	630.036
		2009-06-08T00:00:00.000	-209.1633	203.0209	.979	-1048.363	630.036
		2009-06-09T00:00:00.000	-281.0600	203.0209	.916	-1120.260	558.140
		2009-06-10T00:00:00.000	-254.9133	203.0209	.945	-1094.113	584.286
		2009-11-03T00:00:00.000	91.5000	203.0209	1.000	-747.700	930.700
	2009-11-03T00:00:00.000	2009-06-03T00:00:00.000	-274.5200	203.0209	.924	-1113.720	564.680
		2009-06-04T00:00:00.000	-300.6633	203.0209	.889	-1139.863	538.536
		2009-06-08T00:00:00.000	-300.6633	203.0209	.889	-1139.863	538.536
		2009-06-09T00:00:00.000	-372.5600	203.0209	.754	-1211.760	466.640
		2009-06-10T00:00:00.000	-346.4133	203.0209	.809	-1185.613	492.786
		2009-11-02T00:00:00.000	-91.5000	203.0209	1.000	-930.700	747.700

Fungi	2009-06-03T00:00:00.000	2009-06-04T00:00:00.000	13.0700	204.7277	1.000	-833.185	859.325
		2009-06-08T00:00:00.000	-176.4733	204.7277	.991	-1022.728	669.782
		2009-06-09T00:00:00.000	-215.6867	204.7277	.976	-1061.942	630.568
		2009-06-10T00:00:00.000	248.3667	204.7277	.953	-597.888	1094.622
		2009-11-02T00:00:00.000	254.9300	204.7277	.947	-591.325	1101.185
		2009-11-03T00:00:00.000	274.4967	204.7277	.927	-571.758	1120.752
	2009-06-04T00:00:00.000	2009-06-03T00:00:00.000	-13.0700	204.7277	1.000	-859.325	833.185
		2009-06-08T00:00:00.000	-189.5433	204.7277	.988	-1035.798	656.712
		2009-06-09T00:00:00.000	-228.7567	204.7277	.968	-1075.012	617.498
		2009-06-10T00:00:00.000	235.2967	204.7277	.964	-610.958	1081.552
		2009-11-02T00:00:00.000	241.8600	204.7277	.959	-604.395	1088.115
		2009-11-03T00:00:00.000	261.4267	204.7277	.941	-584.828	1107.682
	2009-06-08T00:00:00.000	2009-06-03T00:00:00.000	176.4733	204.7277	.991	-669.782	1022.728
		2009-06-04T00:00:00.000	189.5433	204.7277	.988	-656.712	1035.798
		2009-06-09T00:00:00.000	-39.2133	204.7277	1.000	-885.468	807.042
		2009-06-10T00:00:00.000	424.8400	204.7277	.642	-421.415	1271.095
		2009-11-02T00:00:00.000	431.4033	204.7277	.626	-414.852	1277.658
		2009-11-03T00:00:00.000	450.9700	204.7277	.580	-395.285	1297.225

	2009-06-09T00:00:00.000	2009-06-03T00:00:00.000	215.6867	204.7277	.976	-630.568	1061.942
		2009-06-04T00:00:00.000	228.7567	204.7277	.968	-617.498	1075.012
		2009-06-08T00:00:00.000	39.2133	204.7277	1.000	-807.042	885.468
		2009-06-10T00:00:00.000	464.0533	204.7277	.549	-382.202	1310.308
		2009-11-02T00:00:00.000	470.6167	204.7277	.534	-375.638	1316.872
		2009-11-03T00:00:00.000	490.1833	204.7277	.488	-356.072	1336.438
	2009-06-10T00:00:00.000	2009-06-03T00:00:00.000	-248.3667	204.7277	.953	-1094.622	597.888
		2009-06-04T00:00:00.000	-235.2967	204.7277	.964	-1081.552	610.958
		2009-06-08T00:00:00.000	-424.8400	204.7277	.642	-1271.095	421.415
		2009-06-09T00:00:00.000	-464.0533	204.7277	.549	-1310.308	382.202
		2009-11-02T00:00:00.000	6.5633	204.7277	1.000	-839.692	852.818
		2009-11-03T00:00:00.000	26.1300	204.7277	1.000	-820.125	872.385
	2009-11-02T00:00:00.000	2009-06-03T00:00:00.000	-254.9300	204.7277	.947	-1101.185	591.325
		2009-06-04T00:00:00.000	-241.8600	204.7277	.959	-1088.115	604.395
		2009-06-08T00:00:00.000	-431.4033	204.7277	.626	-1277.658	414.852
		2009-06-09T00:00:00.000	-470.6167	204.7277	.534	-1316.872	375.638
		2009-06-10T00:00:00.000	-6.5633	204.7277	1.000	-852.818	839.692
		2009-11-03T00:00:00.000	19.5667	204.7277	1.000	-826.688	865.822

	2009-11-03T00:00:00.000	2009-06-03T00:00:00.000	-274.4967	204.7277	.927	-1120.752	571.758
		2009-06-04T00:00:00.000	-261.4267	204.7277	.941	-1107.682	584.828
		2009-06-08T00:00:00.000	-450.9700	204.7277	.580	-1297.225	395.285
		2009-06-09T00:00:00.000	-490.1833	204.7277	.488	-1336.438	356.072
		2009-06-10T00:00:00.000	-26.1300	204.7277	1.000	-872.385	820.125
		2009-11-02T00:00:00.000	-19.5667	204.7277	1.000	-865.822	826.688

Table B10: Daily variation of microbial concentration at Silom road

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	83147.692	6	13857.949	2.935	.045
	Within Groups	66110.813	14	4722.201		
	Total	149258.506	20			
Fungi	Between Groups	15476.160	6	2579.360	.972	.479
	Within Groups	37135.467	14	2652.533		
	Total	52611.627	20			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Date	(J) Date	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bacteria	2009-08-26T00:00:00.000	2009-08-27T00:00:00.000	117.6333	56.1082	.632	-114.294	349.560
		2009-08-28T00:00:00.000	143.8000	56.1082	.412	-88.127	375.727
		2009-10-06T00:00:00.000	156.8667	56.1082	.318	-75.060	388.794
		2009-10-07T00:00:00.000	156.8667	56.1082	.318	-75.060	388.794
		2009-10-26T00:00:00.000	176.4667	56.1082	.206	-55.460	408.394
		2009-10-27T00:00:00.000	215.6667	56.1082	.077	-16.260	447.594

	2009-08-27T00:00:00.000	2009-08-26T00:00:00.000	-117.6333	56.1082	.632	-349.560	114.294
		2009-08-28T00:00:00.000	26.1667	56.1082	1.000	-205.760	258.094
		2009-10-06T00:00:00.000	39.2333	56.1082	.997	-192.694	271.160
		2009-10-07T00:00:00.000	39.2333	56.1082	.997	-192.694	271.160
		2009-10-26T00:00:00.000	58.8333	56.1082	.977	-173.094	290.760
		2009-10-27T00:00:00.000	98.0333	56.1082	.792	-133.894	329.960
	2009-08-28T00:00:00.000	2009-08-26T00:00:00.000	-143.8000	56.1082	.412	-375.727	88.127
		2009-08-27T00:00:00.000	-26.1667	56.1082	1.000	-258.094	205.760
		2009-10-06T00:00:00.000	13.0667	56.1082	1.000	-218.860	244.994
		2009-10-07T00:00:00.000	13.0667	56.1082	1.000	-218.860	244.994
		2009-10-26T00:00:00.000	32.6667	56.1082	.999	-199.260	264.594
		2009-10-27T00:00:00.000	71.8667	56.1082	.940	-160.060	303.794
	2009-10-06T00:00:00.000	2009-08-26T00:00:00.000	-156.8667	56.1082	.318	-388.794	75.060
		2009-08-27T00:00:00.000	-39.2333	56.1082	.997	-271.160	192.694
		2009-08-28T00:00:00.000	-13.0667	56.1082	1.000	-244.994	218.860
		2009-10-07T00:00:00.000	.0000	56.1082	1.000	-231.927	231.927
		2009-10-26T00:00:00.000	19.6000	56.1082	1.000	-212.327	251.527
		2009-10-27T00:00:00.000	58.8000	56.1082	.977	-173.127	290.727

	2009-10-07T00:00:00.000	2009-08-26T00:00:00.000	-156.8667	56.1082	.318	-388.794	75.060
		2009-08-27T00:00:00.000	-39.2333	56.1082	.997	-271.160	192.694
		2009-08-28T00:00:00.000	-13.0667	56.1082	1.000	-244.994	218.860
		2009-10-06T00:00:00.000	.0000	56.1082	1.000	-231.927	231.927
		2009-10-26T00:00:00.000	19.6000	56.1082	1.000	-212.327	251.527
		2009-10-27T00:00:00.000	58.8000	56.1082	.977	-173.127	290.727
	2009-10-26T00:00:00.000	2009-08-26T00:00:00.000	-176.4667	56.1082	.206	-408.394	55.460
		2009-08-27T00:00:00.000	-58.8333	56.1082	.977	-290.760	173.094
		2009-08-28T00:00:00.000	-32.6667	56.1082	.999	-264.594	199.260
		2009-10-06T00:00:00.000	-19.6000	56.1082	1.000	-251.527	212.327
		2009-10-07T00:00:00.000	-19.6000	56.1082	1.000	-251.527	212.327
		2009-10-27T00:00:00.000	39.2000	56.1082	.997	-192.727	271.127
	2009-10-27T00:00:00.000	2009-08-26T00:00:00.000	-215.6667	56.1082	.077	-447.594	16.260
		2009-08-27T00:00:00.000	-98.0333	56.1082	.792	-329.960	133.894
		2009-08-28T00:00:00.000	-71.8667	56.1082	.940	-303.794	160.060
		2009-10-06T00:00:00.000	-58.8000	56.1082	.977	-290.727	173.127
		2009-10-07T00:00:00.000	-58.8000	56.1082	.977	-290.727	173.127
		2009-10-26T00:00:00.000	-39.2000	56.1082	.997	-271.127	192.727

Fungi	2009-08-26T00:00:00.000	2009-08-27T00:00:00.000	78.4000	42.0518	.741	-95.424	252.224
		2009-08-28T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-06T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-07T00:00:00.000	19.6000	42.0518	1.000	-154.224	193.424
		2009-10-26T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-27T00:00:00.000	32.6667	42.0518	.995	-141.157	206.491
	2009-08-27T00:00:00.000	2009-08-26T00:00:00.000	-78.4000	42.0518	.741	-252.224	95.424
		2009-08-28T00:00:00.000	-78.4000	42.0518	.741	-252.224	95.424
		2009-10-06T00:00:00.000	-78.4000	42.0518	.741	-252.224	95.424
		2009-10-07T00:00:00.000	-58.8000	42.0518	.912	-232.624	115.024
		2009-10-26T00:00:00.000	-78.4000	42.0518	.741	-252.224	95.424
		2009-10-27T00:00:00.000	-45.7333	42.0518	.972	-219.557	128.091
	2009-08-28T00:00:00.000	2009-08-26T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-08-27T00:00:00.000	78.4000	42.0518	.741	-95.424	252.224
		2009-10-06T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-07T00:00:00.000	19.6000	42.0518	1.000	-154.224	193.424
		2009-10-26T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-27T00:00:00.000	32.6667	42.0518	.995	-141.157	206.491

	2009-10-06T00:00:00.000	2009-08-26T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-08-27T00:00:00.000	78.4000	42.0518	.741	-95.424	252.224
		2009-08-28T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-07T00:00:00.000	19.6000	42.0518	1.000	-154.224	193.424
		2009-10-26T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-27T00:00:00.000	32.6667	42.0518	.995	-141.157	206.491
	2009-10-07T00:00:00.000	2009-08-26T00:00:00.000	-19.6000	42.0518	1.000	-193.424	154.224
		2009-08-27T00:00:00.000	58.8000	42.0518	.912	-115.024	232.624
		2009-08-28T00:00:00.000	-19.6000	42.0518	1.000	-193.424	154.224
		2009-10-06T00:00:00.000	-19.6000	42.0518	1.000	-193.424	154.224
		2009-10-26T00:00:00.000	-19.6000	42.0518	1.000	-193.424	154.224
		2009-10-27T00:00:00.000	13.0667	42.0518	1.000	-160.757	186.891
	2009-10-26T00:00:00.000	2009-08-26T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-08-27T00:00:00.000	78.4000	42.0518	.741	-95.424	252.224
		2009-08-28T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-06T00:00:00.000	.0000	42.0518	1.000	-173.824	173.824
		2009-10-07T00:00:00.000	19.6000	42.0518	1.000	-154.224	193.424
		2009-10-27T00:00:00.000	32.6667	42.0518	.995	-141.157	206.491

	2009-10-27T00:00:00.000	2009-08-26T00:00:00.000	-32.6667	42.0518	.995	-206.491	141.157
		2009-08-27T00:00:00.000	45.7333	42.0518	.972	-128.091	219.557
		2009-08-28T00:00:00.000	-32.6667	42.0518	.995	-206.491	141.157
		2009-10-06T00:00:00.000	-32.6667	42.0518	.995	-206.491	141.157
		2009-10-07T00:00:00.000	-13.0667	42.0518	1.000	-186.891	160.757
		2009-10-26T00:00:00.000	-32.6667	42.0518	.995	-206.491	141.157

Table B11: Spatial variation of microbial concentration

One way ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Bacteria	Between Groups	1567154.264	2	783577.132	20.824	.000
	Within Groups	2257688.663	60	37628.144		
	Total	3824842.927	62			
Fungi	Between Groups	2731013.963	2	1365506.982	29.427	.000
	Within Groups	2784155.403	60	46402.590		
	Total	5515169.366	62			

Post Hoc tests

Multiple Comparisons

Scheffe

Dependent Variable	(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bacteria	1	2	59.77810	59.86345	.610	-90.4878	210.0440
		3	360.43333*	59.86345	.000	210.1675	510.6992
	2	1	-59.77810	59.86345	.610	-210.0440	90.4878
		3	300.65524*	59.86345	.000	150.3894	450.9211
	3	1	-360.43333*	59.86345	.000	-510.6992	-210.1675
		2	-300.65524*	59.86345	.000	-450.9211	-150.3894
Fungi	1	2	5.60857	66.47777	.996	-161.2602	172.4774
		3	444.44762*	66.47777	.000	277.5788	611.3164
	2	1	-5.60857	66.47777	.996	-172.4774	161.2602
		3	438.83905*	66.47777	.000	271.9703	605.7078
	3	1	-444.44762*	66.47777	.000	-611.3164	-277.5788
		2	-438.83905*	66.47777	.000	-605.7078	-271.9703

*. The mean difference is significant at the 0.05 level.

Appendix C

Total culturable bacteria, fungi at three sites

Table C1: Total culturable bacteria at CU

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
1	Yellow	Round	Smooth	Convex	Negative	Rod	114
2	Yellow	Round	Irregular	Drop-like	Positive	Coccus	197
3	White	Round	Irregular	Umbonate	Positive	Rod	97
4	White	Round	Irregular	Convex	Negative	Coccus	13
5	Yellow	Irregular	Irregular	Raised	Negative	Rod	8
6	Cream	Filamentous	Irregular	Convex	Positive	Coccus	2
7	White	Round	Smooth	Convex	Positive	Coccus	8
8	White	-	Smooth	Umbonate	Positive	Coccus	7
9	Purple	Irregular	Irregular	-	Positive	Coccus	4
10	Yellow	Filamentous	Wavy	Raised	Positive	Coccus	2
11	Cream	Round	Irregular	Convex	Negative	Rod	8
12	White	-	Irregular	Raised	Negative	Coccus	9
13	Yellow	Round	Irregular	Convex	Negative	Rod	5
14	Cream	Filiform	Smooth	Convex	Positive	Coccus	7
15	White	Round	Wavy	Convex	Positive	Coccus	3
16	White	Irregular	-	Convex	Positive	Coccus	8
17	Cream	Filamentous	Irregular	Raised	Negative	Coccus	2

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
18	White	Filiform	Irregular	Convex	Positive	Rod	3
19	Yellow	Round	-	Raised	Positive	Rod	4
20	Red	Irregular	-	Convex	Positive	Coccus	2
21	White	Irregular	Irregular	Convex	Positive	Coccus	5
22	Purple	Filamentous	Irregular	Raised	Positive	Coccus	7
23	Yellow	Irregular	Wavy	Convex	Negative	Coccus	3
24	Cream	Round	Smooth	Convex	Positive	Coccus	12
25	White	Irregular	Irregular	Umbonate	Positive	Coccus	4
26	Yellow	Filamentous	Irregular	Convex	Positive	Coccus	2
27	White	Filiform	Irregular	-	Positive	Coccus	7
28	Yellow	Round	Irregular	Convex	Negative	Rod	5
29	White	Irregular	Smooth	Umbonate	Positive	Rod	4
30	Cream	Round	Smooth	-	Positive	Coccus	4
31	Yellow	Irregular	Smooth	Raised	Positive	Rod	4
32	White	Filamentous	Irregular	Convex	Positive	Coccus	3
33	Purple	Round	Irregular	Convex	Positive	Coccus	14
34	White	Round	-	Convex	Positive	Rod	4

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
18	White	Filiform	Irregular	Convex	Positive	Rod	3
35	Yellow	Irregular	Smooth	Convex	Negative	Rod	7
36	White	Filamentous	Irregular	Convex	Positive	Coccus	9
37	Red	-	Irregular	Raised	Positive	Rod	3
38	Yellow	Irregular	Irregular	Umbonate	Negative	Rod	3
39	Cream	Round	Irregular	Umbonate	Positive	Rod	4
40	Red	-	Wavy	Raised	Negative	Rod	3
41	Yellow	Round	Smooth	Convex	Negative	Rod	4
42	Cream	Round	Smooth	Convex	Negative	Rod	13
43	Yellow	Irregular	Smooth	Convex	Positive	Coccus	9
44	Yellow	Round	Smooth	-	Positive	Coccus	3
45	Yellow	Round	Irregular	-	Positive	Rod	5
46	Purple	Round	Wavy	Convex	Positive	Rod	16
47	Cream	Irregular	Irregular	Convex	Positive	Coccus	6
48	Yellow	Round	Irregular	Umbonate	Negative	Rod	3
49	-	-	-	-	-	-	38

Table C2: Total culturable bacteria at ERTC

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
1	Yellow	Round	Smooth	Convex	Negative	Rod	143
2	Yellow	Round	Irregular	Drop-like	Positive	Coccus	109
3	White	Round	Irregular	Umbonate	Positive	Rod	117
4	White	Irregular	Smooth	Convex	Negative	Coccus	23
5	White	Round	Smooth	Convex	Negative	Coccus	12
6	Yellow	Round	Wavy	Raised	Negative	Coccus	7
7	White	Irregular	Smooth	Convex	Positive	Rod	3
8	Cream	-	Irregular	Raised	Negative	Rod	6
9	White	Round	Irregular	Convex	Negative	Coccus	3
10	White	Round	Smooth	Convex	Negative	Coccus	5
11	White	Round	Wavy	-	Negative	Coccus	8
12	Cream	Round	Smooth	Raised	Negative	Coccus	3
13	White	-	Irregular	Raised	Negative	Rod	13
14	White	Filamentous	Irregular	Convex	Negative	Rod	2
15	White	Round	Smooth	Convex	Positive	Coccus	4
16	White	Irregular	Smooth	Convex	Positive	Coccus	8
17	White	Irregular	Smooth	Convex	Positive	Coccus	3

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
18	Cream	Round	-	Umbonate	Negative	Coccus	4
19	White	Filamentous	Irregular	Umbonate	Negative	Rod	2
20	White	Round	Irregular	Convex	Positive	Coccus	4
21	Cream	Filamentous	Irregular	-	Negative	Coccus	4
22	Yellow	Irregular	Smooth	Convex	Positive	Coccus	1
23	White	Irregular	-	Convex	Positive	Rod	1
24	Cream	Round	Smooth	Convex	Negative	Coccus	4
25	Yellow	Irregular	-	Raised	Positive	Rod	1
26	White	Round	Smooth	Convex	Positive	Rod	3
27	Yellow	Round	Smooth	Raised	Negative	Coccus	5
28	Cream	Round	Irregular	Convex	Negative	Rod	7
29	Cream	-	Irregular	Convex	Negative	Coccus	11
30	Cream	Irregular	Smooth	-	Negative	Rod	1
31	White	Round	Smooth	Convex	Positive	Coccus	5
32	White	Round	Smooth	Convex	Positive	Rod	2
33	Cream	Round	Smooth	-	Negative	Rod	12
34	White	Round	-	Umbonate	Negative	Coccus	9

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
35	Yellow	Round	Smooth	Convex	Positive	Rod	3
36	White	Irregular	-	Convex	Positive	Rod	5
37	White	Irregular	Smooth	Raised	Positive	Rod	22
38	Cream	Irregular	-	-	Negative	Rod	2
39	White	-	Irregular	-	Negative	Rod	4
40	Cream	-	Smooth	Convex	Negative	Coccus	3
41	White	Filamentous	Smooth	Convex	Negative	Coccus	3
42	White	-	-	Convex	Negative	Coccus	7
43	-	-	-	-	-	-	49

Table C3: Total culturable bacteria at Silom road

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
1	Yellow	Round	Smooth	Convex	Negative	Rod	39
2	Yellow	Round	Irregular	Drop-like	Positive	Coccus	57
3	White	Round	Irregular	Umbonate	Positive	Rod	43
4	Cream	Round	Wavy	Convex	Positive	Coccus	5
5	White	Irregular	Smooth	-	Positive	Rod	4
6	White	Round	Irregular	Umbonate	Positive	Coccus	4
7	White	Round	Irregular	Raised	Positive	Coccus	13
8	Yellow	Round	Irregular	-	Positive	Rod	3
9	Yellow	Irregular	Smooth	Raised	Negative	Coccus	6
10	Cream	Round	Wavy	Convex	Negative	Coccus	1
11	Cream	Round	-	Convex	Negative	Rod	1
12	Yellow	Round	Smooth	Convex	Positive	Rod	3
13	Yellow	Irregular	-	Convex	Positive	Coccus	13
14	White	-	-	Convex	Negative	Rod	6
15	White	Round	Irregular	Convex	Negative	Coccus	3
16	White	Irregular	Wavy	Convex	Negative	Rod	2
17	White	Round	Smooth	-	Positive	Rod	5

Samples	Macroscopic features				Microscopic features		Total colonies
	Color	Configurations	Margins	Elevations	Gram	Shape	
18	White	Filamentous	Smooth	-	Negative	Coccus	3
19	Yellow	Round	Irregular	-	Positive	Coccus	2
20	White	-	Wavy	-	Negative	Rod	3
21	Pink	Irregular	-	Convex	Negative	Coccus	2
22	Cream	Filamentous	Smooth	Raised	Positive	Coccus	2
23	Red	Irregular	Irregular	Convex	Positive	Coccus	4
24	White	Round	Irregular	Raised	Positive	Rod	3
25	Yellow	Round	-	Raised	Negative	Coccus	12
26	Yellow	Round	Smooth	Convex	Positive	Coccus	2
27	White	-	-	Umbonate	Negative	Rod	5
28	Cream	Irregular	-	Convex	Negative	Rod	2
29	Cream	Irregular	Smooth	-	Positive	Coccus	4
30	Yellow	Round	-	Convex	Negative	Coccus	2
31	Yellow	Round	Irregular	-	Positive	Rod	1
32	Cream	-	Smooth	Raised	Positive	Rod	2
33	-	-	-	-	-	-	64

Figure C1 Examples culture plate of culturable fungi at three sites

Appendix D

Report on bacterial identification from TISTR

TISTR

Request No. 2553 / 047 (E: 2010 / 047) At Bangkok MIRCEN

REPORT ON TESTING AND ANALYSIS

FOR

Chulalongkorn University

Testing / Analysis of Identification of microorganisms

Method of testing / analysis Standard method of API Identification

Condition of testing / analysis: Temperature 30 and 37°C

Date of testing / analysis 6 - 14 January 2009

Result of testing / analysis

Identification result as show below:

Bact. 1*: *Pseudomonas fluorescens*

Bact. 2*: *Staphylococcus sciuri*

Bact. 3*: *Bacillus pumilus*

(Please see attached documents)

Remark: *Test sample was the fresh culture

Tested / analyzed by

Ms. Pirawan Srisin

Examined by

(Ms. Susakul Palakawong Na Ayudthaya)

Approved by

(Mr. Suparp Artjariyasripong)

Director of Bioscience Department

Date 29 January 2010

The above results are valid exclusively for tests or analyzed samples as mentioned in this report. Changed data in this report is illegal.

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Thailand Institute of Scientific and Technological Research
35 Moo 3, Technopolis Tambon Khlong 5 Amphoe Khlong Luang Pathum Thani 12120 Thailand
Tel. (66) 0 2577 9000 Fax 0 2577 9009
E-mail : tistr@tistr.or.th Website : www.tistr.or.th

Request No. 2553 / 047 (E: 2010 / 047)

TISTR

Analytical Results

Table 1. Characteristics of the bacterial strain Bact. 1: *Pseudomonas fluorescens*

Characteristics	Reaction
Gram reaction	-ve
Reduction of nitrate	-
Indole production of tryptophane	-
Fermentative of acid from glucose	-
Arginine dihydrolase	-
Urease production	-
Hydrolysis of esculin	-
Hydrolysis of gelatin	-
β-galactosidase production	-
(p-nitro phenyl-β-galactopyranoside)	
Assimilation of:	
Glucose	+
Arabinose	+
Mannose	-
Mannital	+
N-acetyl-glucosamine	+
Maltose	-
Gluconate	+
Caprate	+
Adipate	-
Malate	+
Citrate	+
Phenyl-acetate	-
Cytochrome oxidase	+
Growth 4% NaCl	-

Remark : - ve = Gram negative bacteria

\+ = Positive reaction

\- = Negative reaction

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Request No. 2553 / 047 (E: 2010 / 047)

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Analytical Results

Table 2. Characteristics of the bacterial strain Bact. 2: *Staphylococcus sciuri*

Characteristics	Reaction
Gram reaction	+ve
Fermentative production of acid from:	
D-Glucose	+
D-Fructose	+
D-Mannose	+
Maltose	+
Lactose	-
D-Trehalose	+
D-Mannitol	+
Xylitol	-
D-Melibiose	-
Raffinose	-
Xylose	-
Sucrose	+
α-methyl-D-glucdside	-
N-acetyl-glucosamine	+
Reduction of nitrate	-
Alkaline phosphatase	+
Acetyl-methyl-carbinol production	+
Arginine dihydrolase	-
Urease production	-
Catalase test	+

Remark : + ve = Gram positive bacteria
+ = Positive reaction
\- = Negative reaction

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Request No. 2553 / 047 (E: 2010 / 047)

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Analytical Results

Table 3. Characteristics of the bacterial strain Bact. 3: *Bacillus pumilus*

Characteristics	Reaction
Gram reaction	+ve
Fermentative production of acid from:	
Glycerol	-
Erythritol	-
D-arabinose	-
L-arabinose	+
D-ribose	+
D-xylose	-
L-xylose	-
D-adonitol	-
Methyl-βD-xylopyranoside	-
D-galactose	-
D-glucose	+
D-fructose	+
D-mannose	+
L-sorbose	-
L-rhamnose	-
Dulcitol	-
Inositol	-
D-mannitol	+
D-sorbitol	-
Methyl-αD-mannopyranoside	-
Methyl-αD-glucopyranoside	-
N-acetylglucosamine	-
Amygdaline	+
Arbutine	+

Remark : + ve = Gram positive bacteria
\+ = Positive reaction
\- = Negative reaction

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Analytical Results

Table 3. (continued) Characteristics of the bacterial strain Bact. 3: *Bacillus pumilus*

Characteristics	Reaction
Fermentative production of acid from: (continued)	
Esculine ferric citrate	+
Salicine	+
D-cellobiose	+
D-maltose	-
D-lactose (bovine orgin)	-
D-melibiose	-
D-saccharose (sucrose)	+
D-trehalose	+
Inuline	-
D-melezitose	-
D-raffinose	-
Amidon (starch)	-
Glycogen	-
Xylitol	-
Gentiobiose	+
D-turanose	-
D-lyxose	-
D-tagatose	+
D-fucose	-
L-fucose	-
D-arabitol	-
L-arabitol	-
Potassium gluconate	-
Potassium 2-ketogluconate	-
Potassium 5-ketogluconate	-

Remark : + ve = Gram positive bacteria
\+ = Positive reaction
\- = Negative reaction

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BIOGRAPHY

Mr. Phunchaya Pattanasuk was born in 1985 at Bangkok. I got Bachelor of Science in Microbiology (Second class honor) from Chulalongkorn University in 2007. The title of “Investigation of airborne microorganisms and fine particulate level in Bangkok” has been published in the 6^{th} Asian Aerosol Conference (6^{th} AAC).