Altitudinal Distribution of Bioaerosols and Particulate Matter in Urban and Rural Area

Suthee Janyasuthiwong[a], Thitima Rungratanaubon[*a, b],
Surat Bualert[a, b], Ariya Chindamporn[c, d] and Jutapas Saiohai[a, b]

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Abstract

Microorganisms in the air are considered as bioaerosols which can cause adverse effect to human health especially in the confine area with less air ventilation. In this study, the microorganisms and particulate matter size less than 10 μm were observed their relationship with the meteorological factors. The comparison between the rural and urban area was conducted to evaluate the concentration of the bioaerosols. The samples were collected the Laem Phak Bia Environmental Research and Development Project in Phetchaburi Province (rural) and the Aor Por Ror Building (urban). The results showed that the concentration of microorganisms in the air and the concentration of particulate matters smaller than 10 μm in rural area were higher than urban area. The concentration of microorganisms in the air was highest at 8:00 am., and decreased by altitude and the major size was found ranged from 2.1-3.3 μm. The concentration of microorganisms in the air was significantly related to the meteorological factors, such as temperature, relative humidity and wind speed. The most common found microorganisms were *Aspergillus spp.*, *Penicillum spp.*, *Cladosporium spp.* which can be harmful to health.

Keywords: Altitudinal Distribution; Bioaerosols; Particulate matter; Urban and Rural area

1. Introduction

Bioaerosols are the microbes in the air, or attached to aerosol particles, sizes range from 0.02-100 μm in the form of liquids, solids, or mixture of liquids and solids (Lang, 2011). They also include organism fragments, products of these organisms, bacteria, fungi, viruses, pollen, plant or animal debris and biofilm (Ariyap and Amyot, 2004).They are considered to be related to air pollution and the spread of human, animal and plant disease epidemics. Bioaerosols were found in several site including indoor and outdoor area, residential house, wastewater treatment plants in different species and quantities (Bugajny et al., 2005; Letizia et al., 2006 and Lin et al., 2011). Bioaerosols are divided in three modes by particle sizes such as nuclei mode (diameter<0.1 μm), accumulation mode (diameter 0.1-2.0 μm) and coarse mode (diameter>2.0 μm). Kim et al. (2009) found that environmental factors as temperature, relative humidity and carbon dioxide, related to microbial concentration in the air. Including another factor, ventilated wind effected to the airborne fungal concentration indoor/outdoor (I/O) ratios and bioaerosols were captured and removed from the air by rain (Ki et al., 2014).

Particulate matters are solid or liquid compound, physical and chemical properties, released into the air from natural sources and human activities (Jinsart, 2008). Generally, the particles are classified into three sizes including total suspended particulate matter (TSP, diameter> 100 μm), coarse particulate matter (PM10, diameter> 10 μm) and fine particulate matter (PM2.5, diameter> 2.5μm). Division of Environmental Health (1992) classified sources of particles into two main types: Natural Particle such as sand, dust, drop-

[a] Department of Environmental Science, Faculty of Environment, Kasetsart University, 10900, Thailand.
[b] The Monitoring of Microclimate and Air Pollution in Thailand Project, Kasetsart University, 10900, Thailand
[c] King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand
[d] Department of Microbiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand
*Corresponding author email: thitima.r@ku.th

let, soot, sea salt and Man-made Particle such as black soot, dust from traffic (traffic dust), from construction (construction dust) and from industrial plant by burning fuel (industrial dust. Particle matters are associated with meteorological factors, which are found to be highest in the cold season, especially at night and change according to vertical (Linlin et.al., 2019; Nianliang et.al., 2018). In this study, the aims was to find the relationship between altitudinal distribution of bioaerosols and PM10 (particulates with a diameter <10 μm) with the meteorological factors in both urban and rural areas.

2. Materials and Methods

2.1 Study sites

The 2 study sites used in this study were The Laem Phak Bia Environmental Research and Development Project (LERD) in Phetchaburi Province which represented rural area, while Aor Por Ror Building, Faculty of Medicine, Chulalongkorn University in Bangkok was used as urban area representative (Fig. 1). Both study sites were crowded with visitors with different purposes, one site (Aor Por Ror Building) for medical treatment (visitors mostly stationed at certain area) while LERD for tourism and sightseeing (visitors were mobile).

2.2 Bioaerosols, PM10 sampling and meteorological data collection

The samples of both study sites were collected at 3 altitude level (1, 3 and 7 m for LERD and 1, 18 and 60 m for Aor Por Ror Building) in 3 time intervals (8.00, 13.00 and 17.00) from December to February 2013. The ambient air of both study sites was collected used 6-Stage Viable Andersen Cascade Impactor (Thermo Scientific) to analyze for the quantity and species of the microorganisms in the air. The samples were cultured, identified and characterized morphologically according to Raper and Funnell (1965). For the sizes of the particle which were divided into 6 groups which were >7 μm, 4.7-7.0 μm, 3.3-4.7 μm, 2.1-3.3 μm, 1.1-2.1 μm and 0.65-1.1 μm. The PM10 samples were collected used personal DataRAM (pDR-1500 aerosol monitor) from Thermo Scientific. While the meteorological data such as temperature (T), relative humidity (RH) and wind speed (WS) of both sites was measured using Indoor Air Quallity Meter IAQ-Calc model from TSI.

Figure 1. The 2 study sites a) The Laem Phak Bia Environmental Research and Development Project and b) Aor Por Ror Building, Faculty of Medicine, Chulalongkorn University

3. Results and Discussion

3.1 Microorganism concentration and distribution

3.1.1 Microorganism concentration

The LERD air sample showed that the highest concentration of the microorganisms was found at 8.00 AM during December 2013 at the 1 m height at the concentration of 1,348.41±5.10 colonies/m^3. The distribution of the microorganisms was decreasing according to the level of height above the surface which can be seen in Fig 2a. The air sample from Aor Por Ror building showed the similar trend to the LERD result which the highest concentration was found at 8.00 AM in December 2013 at the height of 1 m at the concentration of 1023.56±10.20 colonies/m^3 which was declined as the it get higher (Fig. 2b).

The distribution trends observed from LERD, which represented rural area, had the higher concentration compare to Aor Por Ror Building (urban area) was different from Zaheer et. al. (2012) which reported the microorganism's density and concentration in various places in Pakistan tend to be higher in the urban area than rural. This might cause by the activity inside the Aor Por Ror Builing which served as medical student practice and study. The disinfection and regularly cleaning including the ventilation infrastructure may have the effect in the microorganism's concentration (Dehghani et. al., 2018) from aforementioned study. Moreover, the results from the microorganism cultured and identification using morphological characteristics according to Raper and Funnell (1965) which used conidial head and colony stained color showed that the most abundance species in the samples were the fungi *Aspergillus fumigatus, Aspergillus flavus, Aspergillus niger*, *Penicillium spp.*, *Cladosporium spp.* and Candida spp. (Fig. 3), while

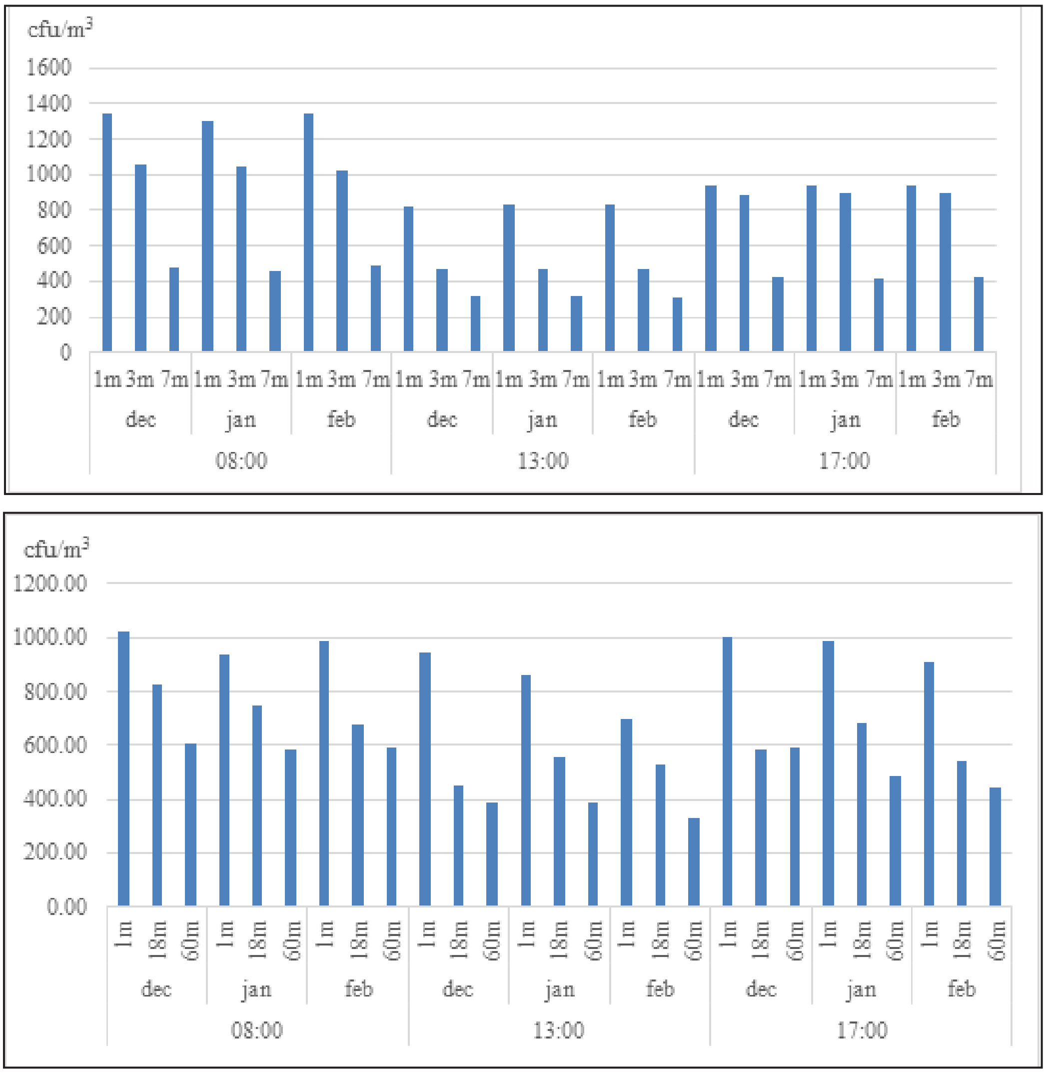


Figure 2. microbial concentration (cfu/m^3) at a) at LERD and b) at Aor Por Ror Building

Bacillus spp. was the most abundance bacteria. At LERD the fungi was contributed to 85% of microorganisms while Aor Por Ror building the fungi contributed up to 80% and Mucor spp. was found only at LERD. It was in accordance with Liao and Luo (2005) study in Taipei, Taiwan which found that the most abundance fungi was *Cladosporium spp., Aspergillus spp., Penicillium spp.* and *Alternaria spp.*. Kim et. al. (2009) had reported that the most common bacteria in the air was *Staphylococcus spp., Micrococcus spp., Corynebacterium spp.* and *Bacillus spp.* while the fungi was *Cladosporium spp., Penicillium spp.* and *Aspergillus spp.*

3.1.2 Microorganism size distribution

The 6-Stage Viable Andersen Cascade Impactor which divided the particle size into 6 groups showed that the highest 3 months averaged size was found in the 4th group (2.1 – 3.3 μm) in both height and time interval categories (Fig. 4).

On the other hands, the Aor Por Ror Building had a different pattern in size distribution according to the height. The 3 months averaged size at 1 and 60 m the most major size was the 5th group (1.1-2.1 μm) while the 4th group (2.1-3.3 μm) was the major at the height of 18 m (Fig 5a). However, the different pattern

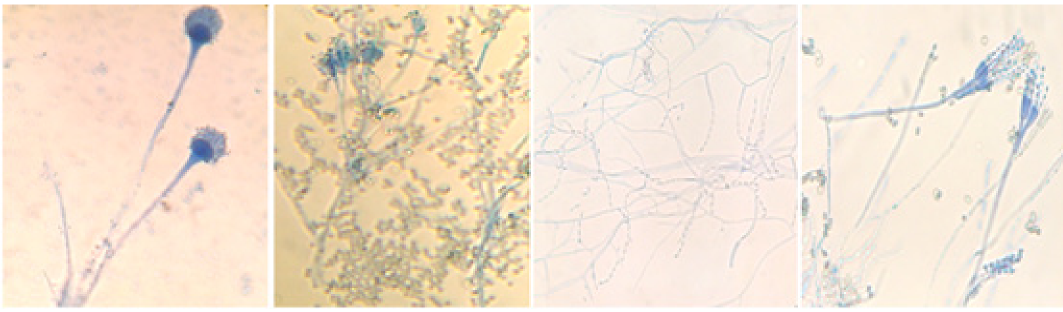
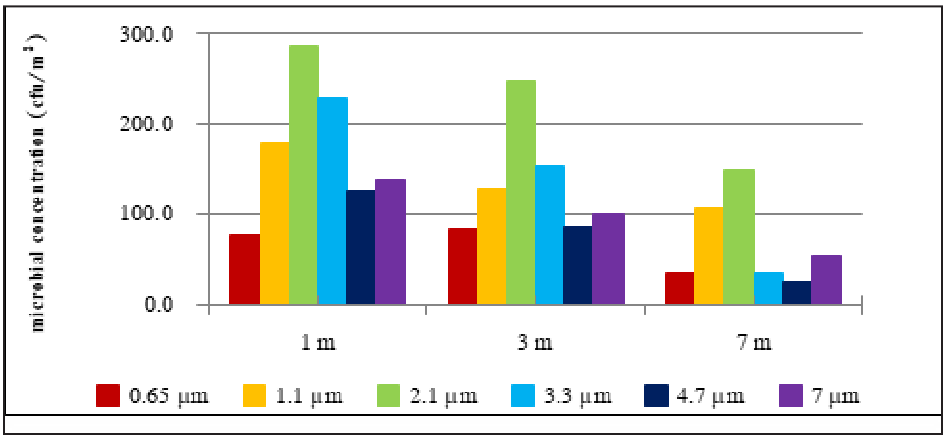


Figure 3. The most available microorganism from the samples a) *Aspergillus spp.* b) *Penicillium spp.* c) *Cladosporium spp.* and d) *Penicillium spp.*



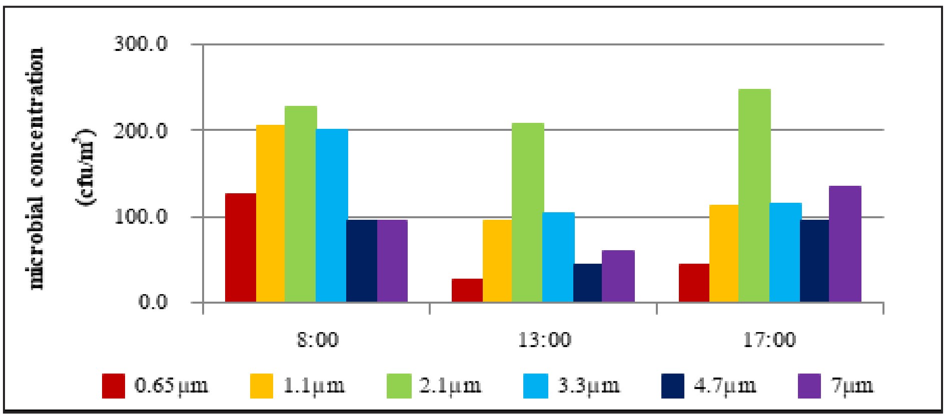


Figure 4. Average particle size at LERD a) by altitude and b) by time interval

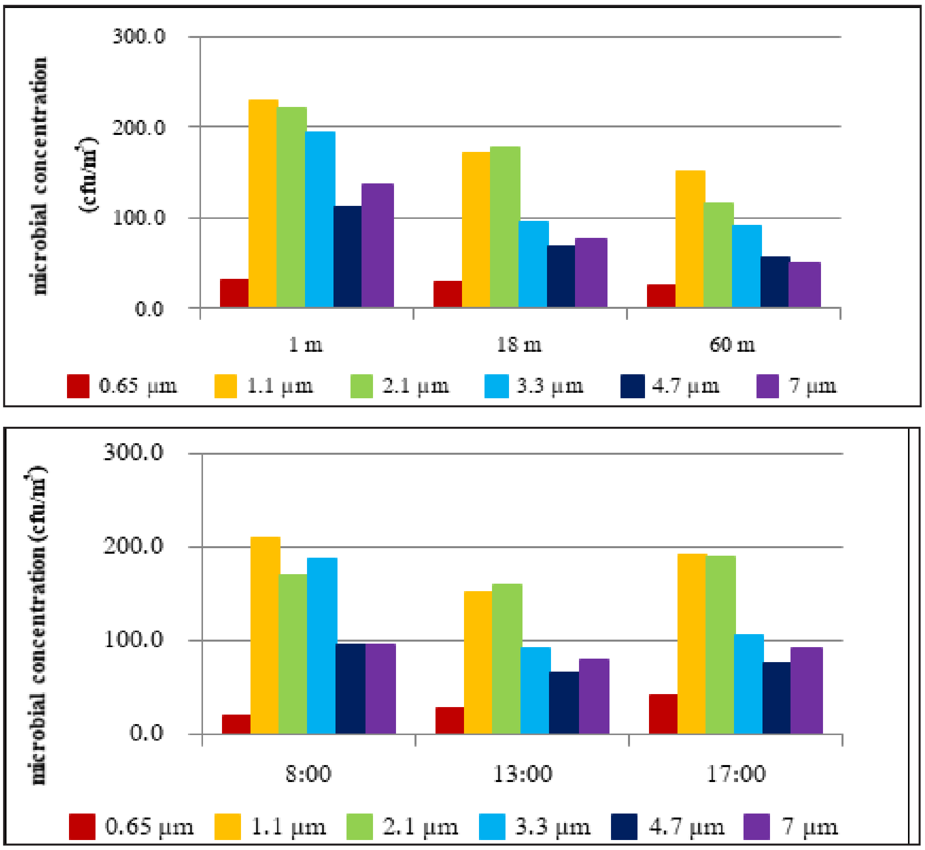


Figure 5. Average particle size at Aor Por Ror Building a) by altitude and b) by time interval

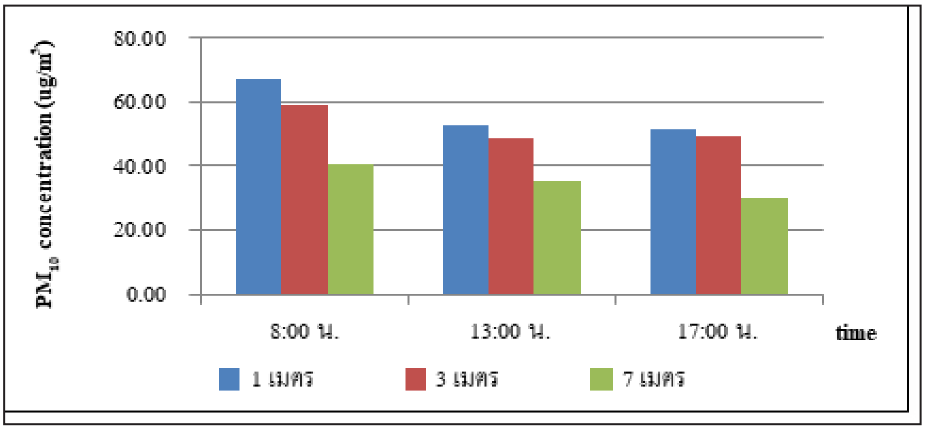


Figure 6. Average 3 months of PM10 concentration at LERD

was obtained from the time interval samples. The overall lowest microbial concentration was found during the 13.00 period with the highest size of 4th group while 5th group was found the highest during 8.00 and 17.00 period (Fig. 5b).

From both study sites, the majority of the particle size found was the 4th and the 5th group which was in accordance with Mengfeiet. al. (2011) study that the major size of the fungi found was 2.1-3.3 µm (the size of the fungi spore). In addition to that, Liao and Luo (2005) observed the fungi and the spore in the air and found that the major size was 2.1-3.3 µm while the spore was 1.96-3.4 µm.

3.2 PM10 concentration in the study sites

The PM10 samples were collected at both study sites from December to February at various time and altitude. The highest PM10 concentration at LERD was found at altitude of 1 m at 8.00 AM in January at 98.04±2.41 µg/m^3. The highest PM10 concentration was start at 8.00 of all altitude and decrease as time passed the concentrations were 56.98 52.25 and 35.39 µg/m^3 at 1, 3 and 7 m respectively (Fig 6).

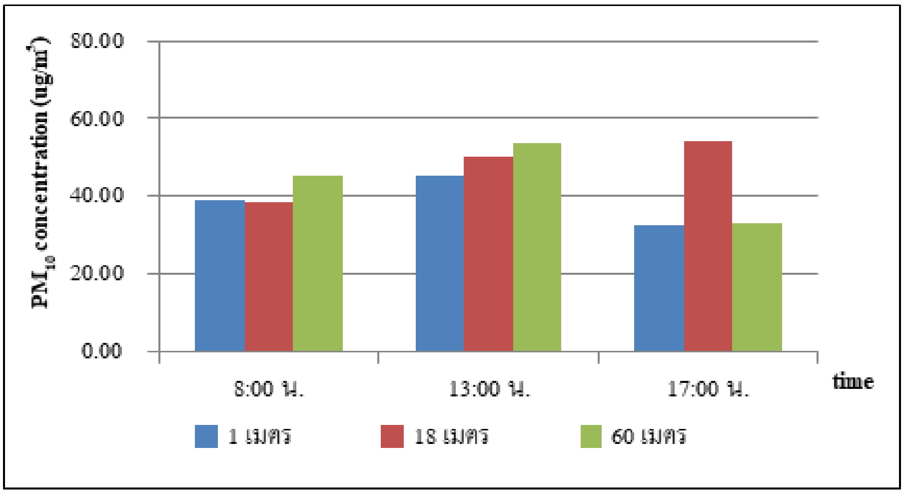


Figure 7. Average 3 months of PM10 concentration at Aor Por Ror Building

However, The Aor Por Ror building was found the highest PM10 concentration at the altitude of 18 m at 17.00 in December at the concentration of 106.75 ± 2.16 μg/m^3 and lowest at 15.60±2.20 μg/m^3 at the altitude of 18 m at 13.00 in January. Fig. 7 showed the result of PM10 concentration at different altitude and time of Aor Por Ror Building.

The average 3 months PM10 concentration by altitude of both study sites showed that the Aor Por Ror Building which was represented urban area had higher PM10 than rural (LERD). This phenomenon was caused by the different activities of both sites which were mangrove and wastewater treatment at LERD while vehicle combustion and human activities occurred at the Aor Por Ror Building. Therefore the PM10 in urban was varied and can be lifted up higher from the wind turbulence.

3.3 Relationship between the bioaerosols concentration, PM10 and meteorological factors

3.3.1 The relationship between bioaerosols, PM10 concentration and altitude

The concentration of the microorganisms and PM10 at the LERD site had the correlation efficient between altitude with microbial concentration and PM10 at 1.00 and 0.98, respectively while the R^2 among microbial and PM10 concentration was 0.97. However at the Aor Por Ror Building, the correlation efficient between microbial concentration and altitude was 0.80 while R^2 of only 0.13 was for PM10 concentration and altitude. The microbial and PM10 concentration R^2 was 0.55 less than at the LERD. The Aor Por Ror Building showed the less R^2 values may come from the dry condition in the ambient of the urban area compare to the LERD which has more humidity in which the increasing in the altitude resulted in decline in microbial concentration with time and particle size (Yunbo et.al., 2018). This similarity pattern had been reported in Rungratanaubon et al. (2018) and Choomanee et al. (2020) studies that different activity in the area resulted in the mass of the air and the distribution in the air pollutants. Moreover, in both studies also report the turbulence of the air in the urban area where high buildings were located which cause the uplift of the pollutants upward unlike the open area (above the mangrove) at the LERD.

3.3.2 The relationship between bioaerosols, PM10 concentration and meteorological factors

The correlation coefficient (R^2) was used to determine the relationship between microbial and PM10 concentration with the meteorological factors such as wind speed, temperature and relative humidity. Table 1 showed the R^2 of the relationship among parameters at LERD. Both microbial concentration and PM10 were decreased when the temperature and wind speed increased while the relative humidity decreased.

The relationship between microbial concentration and PM10 concentration with meteorological factors at Aor Por Ror Building was shown in Table 2. The wind speed was decreasing the concentration of the aerosols due to the dilution of the air from the wind especially the wind moving the air from less con-

Table 1 The Correlation coefficient (R^2) of microbial concentration, PM10 and meteorological factor in LERD

R^2	microbial	PM10	Temp.	Relative Humidity	Wind speed
microbial	1.00				
PM10	0.59	1.00			
Temp.	0.78	0.96	1.00		
Relative Humidity	0.82	0.94	1.00	1.00	
Wind speed	0.76	0.13	0.29	0.33	1.00

Table 2 The correlation coefficient (R^2) of microbial concentration, PM10 and meteorological factors at Aor Por Ror Building

R^2	microbial	PM10	Temp.	Relative Humidity	Wind speed
microbial	1				
PM10	0.73	1.00			
Temp.	0.65	0.15	1.00		
Relative Humidity	0.68	0.17	1.00	1.00	
Wind speed	0.69	0.18	1.00	1.00	1.00

centration of both concerned parameters. Normally the microorganism is attached to the particulate matter in the air, therefore, the dilution of the PM10 at the sampling site resulted in dilution in microbial concentration which was in accordance with the finding from Ewa et. al. (2017) and Wongpun et. al. (2000). The PM10 was decreased as temperature and wind speed decrease but relative humidity increase.

4. Conclusion

The air samples of 2 study sites which were represent rural area (LERD) and urban area (Aor Por Ror Building) were collected in 3 different altitudes and time interval for 3 month (December to February 2013). Both study sites at 1 m height above ground had the highest microorganisms concentration in the aerosols which became lessen as the altitude getting higher. The highest concentration was found at the 8.00. The majority of the particle size found was ranged from 2.1-3.3 μm (both sites) and 1.1-2.1 μm (Aor Por Ror Building) which was the range the can get into the respiratory tracts. Moreover the identification of the microorganisms showed that the most abundance species found were *Aspergillus spp.*, *Penicillum spp.*, *Cladosporium spp.* and *Bacillus spp.* From the analysis of 3 months averaged PM10 concentration according to the altitude level, the LERD PM10 concentration was higher than Aor Por Ror Building which was affected by the differences in activities of both sites and meteorological factors. The PM10 concentration at LERD was decreased when the temperature and wind speed were high while the relative humidity was lower. On the other hands, the Aor Por Ror Building PM10 concentration was decreased when the temperature and wind speed was low while the relative humidity was high.

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