MICROBIAL COUNTS AND PARTICULATE MATTER LEVELS IN ROADSIDE AIR SAMPLES UNDER SKYTRAIN STATIONS, BANGKOK, THAILAND

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Abstract. In conditions with heavy traffic and crowds of people on roadside areas under skytrain stations in Bangkok, the natural air ventilation may be insufficient and air quality may be poor. A study of 350 air samples collected from the roadside, under skytrain stations in Bangkok, was carried out to assess microbial counts (210 air samples) and particulate matter (PM₉₀) levels (140 samples). The results reveal the mean ± standard deviation bacterial counts and fungal counts were 406.8±302.7 cfu/m³ and 128.9±89.7 cfu/m³, respectively. The PM₉₀ level was 186.1±188.1 µg/m³. When compared to recommended levels, 4.8% of air samples (10/210 samples) had bacterial counts more than recommended levels (>1,000 cfu/m³) and 27.1% (38/140 samples) had PM₉₀ levels more than recommended levels (>120 µg/m³). These may affect human health, especially of street vendors who spend most of their working time in these areas.

Key words: air quality, microbial counts, particulate matter levels, roadside air samples

INTRODUCTION

Concern regarding air quality is increasing worldwide. This is an important problem in children, the elderly and immune compromised persons (Graham, 2004). Air quality depends on contaminants in the air. Indoor air quality is based on specific contaminants, including house dust mites, cockroaches, pollen and microbial agents. Human activities provided a major source of bioaerosol for indoor air (Kodama and McGee, 1996), whereas, gasoline vapor emission and motor vehicle exhaust have been recognized as important sources of outdoor air, directly or indirectly affecting health. Motor vehicle exhausts also produce particulate matter (PM₉₀) in outdoor air (Meychting et al, 1998; Raaschou-Nielsen et al, 2001; Lee et al, 2002). A previous study showed concentrations of dust were associated with bioaerosol levels because dust had many organisms attached to it (Jacobs, 1994). Bacteria in the air do not generally present a health hazard, but high counts of bacteria in air samples indicate overcrowding or poor ventilation (Seitz, 1989; Kodama and McGee, 1996). Some biological contaminants trigger allergic reactions, including hypersensitivity pneumonitis, allergic rhinitis and some types of asthma (WHO, 1990; Zweers, 1992; Homer et al,
These contaminants may also irritate the skin of humans and contribute to symptoms, such as, headache, fatigue, eye and/or nose and/or throat irritation (Zweers, 1992).

Bangkok is one of the largest cities in the world which has an airborne particulate matter problem (Pollution Control Department, Thailand, 2002). There are approximately 10 million people living and working in Bangkok each day. Traffic is busy on work days. A recent study in mass transport buses showed 6.1% and 33.3% of air samples collected from studied air-conditioned buses and open-air buses, respectively, had high levels of bacterial counts (>500 cfu/m³) (Luksamijarulkul et al., 2004). The BTS (Bangkok Mass Transit System Public Company, Limited) Skytrain serves a large number of people. In conditions of heavy traffic and crowds of people in Bangkok, the air quality on the roadside, especially areas under skytrain stations, may be poor and affect the street vendors and other people in those areas. This study attempted to assess microbial counts and PM₁₀ levels in roadside air under skytrain stations. It is valuable for improving the environment of the roadside and the quality of working life among street vendors and other people in these study areas.

MATERIALS AND METHODS

Study design and study samples

The BTS Skytrain route contains 17 stations extending from Mohchit station to On Nut station (Fig 1). In these areas, the traffic is normally busy and there are many pedestrians and street vendors selling goods, such as baked food, fried food, fresh fruit, fruit juice, drinking water, salad, clothes and souvenirs. Between January and June 2006, a cross-sectional study was carried out to assess microbial counts and PM₁₀ in outdoor air at the roadside under 7 skytrain stations which were randomly selected. These stations were: station numbers 1, 5, 8, 11, 12, 16 and 17. From each study location, 30 outdoor air samples were collected to investigate bacterial counts and fungal counts (a total of 210 samples), and 20 air samples were collected to quantify PM₁₀ levels (a total of 140 samples). Five indoor air samples were collected from 5 shops along the roadside near the outdoor air sample collection areas to use for comparison.

Air samples and methods of collection

Outdoor air samples were collected from the afternoon to the evening (1:00 to 6:00 PM, Monday to Sunday) when there were many street vendors and pedestrians. The microbial samples were collected using a Millipore Air Tester, and the PM₁₀ samples were collected using a Personal Pump Cyclone in 1-hour collection cycles.

The Millipore Air Tester system is based on the Anderson principle and uses a sieve with about 1,000 micro-perforations, which reduces the potential for overlapping colonies and minimizes the desiccation of the medium. The tester is small enough to be used in confined spaces, but powerful enough to sample up to 1,000 liters in just 7 minutes. This is a lightweight, portable system for testing microbial air quality. In this study, 100 liters of air were filtered. A plate agar count method was used to estimate bacterial and fungal counts. Bacteria were cultured on plate count agar and fungi were cultured on Sabouraud 4% dextrose agar. The bacteria specimens were incubated for 2 days (48 hours) at 37°C and the fungi for 5 days at room temperature with daily observations. After incubation, the bacterial and fungal colonies were counted and calculated by the
Total counts (colony forming units/m³ or cfu/m³) = (Total colonies x 1,000)/100

The personal cyclone pump was used to collect both respirable and total dust samples. The components of the respirable dust sampler are a cyclone, a filter-cassette assembly, and a sampling pump. A cyclone is a size-selective device used to separate respirable and non-respirable sized particles from the air. The filter type was Teflon or Polytetrafluoroethylene (PTFE) determining PM₁₀. For respirable size particles, a cyclone head was used. The cyclone is a particle size selector used in airborne particulate sampling and is named for the rotation of air within its chamber. The cyclone functions on the same principle as a centrifuge: the rapid circulation of air separates particles according to their equivalent aerodynamic diameter. The cyclone/filter assembly is clipped onto the street vendor’s collar or pocket as close to the breathing zone as possible, while the pump is attached to the vendor’s belt. After activating the pump, the vendor wears the apparatus during the entire sampling period. The filter sampler is designed with a reusable filter cassette that holds a 37 mm filter. The chemical hazard method determines the type and pore size of the 37 mm filter. When attached to a personal air sampling pump at 1.7 liter/minute, the weight of the particulate matter (PM₁₀) in a 1 hour period is determined.

**Identification of isolated colonies**

Isolated colonies were identified by their appearance, Gram’s stain and microscopic morphology following Larone (1995).

**Data analysis**

Descriptive statistics, including percentages, means, and standard deviations, were used for describing the microbial counts and PM₁₀ levels in the samples.

**RESULTS**

Totally, 350 air samples (210 for microbial counts and 140 for PM₁₀) were collected and analyzed. The mean ± standard deviation (SD) bacterial count was 406.8±302.7 cfu/m³ (geometric mean ± SD = 392.1±225.8 cfu/m³; range 319.3±194.8 cfu/m³ to 547.7±282.1 cfu/m³) and the mean (±SD) fungal count was 128.9±89.7 cfu/m³ (geometric mean ± SD = 112.9±79.6 cfu/m³; range 89.6±47.2 cfu/m³ to 157.7±84.7 cfu/m³). Air samples collected from the roadside under station No. 5 had the highest mean bacterial count (547.7±282.1 cfu/m³) and highest mean fungal count (157.7±84.7 cfu/m³). The samples under station No. 17 had the lowest mean bacterial and fungal counts (319.3±194.8 cfu/m³ and 89.6±47.2 cfu/m³,

Fig 1–BTS Skytrain route in Bangkok (● studied areas).
Table 1
Mean and standard deviations of bacterial counts from roadside air samples under skytrain stations, Bangkok (n=30 air samples in each studied area).

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean ± SD (cfu/m³)</th>
<th>No. (%) of air samples with high microbial counts (&gt;1,000 cfu/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bacterial counts</td>
<td>Fungal counts</td>
</tr>
<tr>
<td>No. 1: Moh Chit</td>
<td>322.1 ± 262.3</td>
<td>130.8 ± 94.2</td>
</tr>
<tr>
<td>No. 5: Victory Monument</td>
<td>547.7 ± 282.1</td>
<td>157.7 ± 84.7</td>
</tr>
<tr>
<td>No. 8: Siam Center</td>
<td>436.0 ± 369.7</td>
<td>138.7 ± 113.8</td>
</tr>
<tr>
<td>No. 11: Nana</td>
<td>380.0 ± 238.1</td>
<td>111.7 ± 74.5</td>
</tr>
<tr>
<td>No. 12: Asoke</td>
<td>457.0 ± 352.7</td>
<td>127.7 ± 85.0</td>
</tr>
<tr>
<td>No. 16: Phra Khanong</td>
<td>395.3 ± 419.2</td>
<td>146.1 ± 128.4</td>
</tr>
<tr>
<td>No. 17: On Nut</td>
<td>319.3 ± 194.8</td>
<td>89.6 ± 47.2</td>
</tr>
<tr>
<td>Total</td>
<td>406.8 ± 302.7</td>
<td>128.9 ± 89.7</td>
</tr>
<tr>
<td>Indoor air</td>
<td>228.3 ± 162.2</td>
<td>62.0 ± 43.2</td>
</tr>
</tbody>
</table>

*aMost bacterial cultures were Staphylococcus spp.
*bMost fungal cultures were Aspergillus spp, Botrytis spp and Curvularia spp.

respectively) (Table 1). The most common bacteria found was Staphylococcus spp and the most common fungi found were Aspergillus spp, Botrytis spp and Curvularia spp. When the microbial air quality was compared to the guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH, >1,000 cfu/m³) (Seitz, 1989), 4.8% of microbial air samples (10/210 samples) had bacterial counts greater than the recommended level of the ACGIH. None of air samples had fungal counts greater than recommended levels. These highest levels of bacteria were found under station Nos. 17 (105.4±78.2 μg/m³) and 11 (107.7±68.2 μg/m³). When the PM₁₀ levels were compared to the recommended levels of the Pollution Control Department, Ministry of Natural Resources and Environment, Thailand, 2002 (<120 μg/m³), 27.1% (38/140 samples) had PM₁₀ levels greater than recommended levels. The air samples with highest levels of PM₁₀ were collected from under station Nos. 16 (8/20 samples), 12 (7/20 samples) and 5 (7/20 samples) (Table 2).

DISCUSSION

The traffic under the skytrains is normally busy and there were many street venders and pedestrians. Road traffic generally provides the major source of ambient particulate pollution, especially for finer particles (Seitz, 1989; Jacobs, 1994; Lee et al., 2002; Gulliver and Briggs, 2004). A previous study showed particulate levels correlated with bioaerosol levels because
The dust had microbials attached (Jacobs, 1994). The mean (±SD) bacterial counts ranged from 319.3 ± 194.8 cfu/m³ to 547.7 ± 282.1 cfu/m³ and the mean fungal counts ranged from 89.6 ± 47.2 cfu/m³ to 157.7 ± 84.7 cfu/m³. Air samples collected from under station No. 5 had the highest bacterial and fungal counts. The air samples collected from roadside under station Nos. 16 and 12 had the highest levels of PM10 (266.3 ± 214.6 µg/m³ and 245.1 ± 257.4 µg/m³, respectively). These locations have frequent traffic jams and are crowded with street vendors and pedestrians. Several shopping centers and office buildings are at these locations. Samples from under station No. 17 had the lowest bacterial and fungal counts (319.3 ± 194.8 cfu/m³ and 89.6 ± 47.2 cfu/m³, respectively). The lowest levels of PM10 were found under skytrain station Nos. 17 and 11 (105.4 ± 78.2 µg/m³ and 107.7 ± 68.2 µg/m³, respectively). Four point eight percent and 27.1% of air samples had bacterial counts and PM10 levels, respectively, more than recommended levels of the ACGIH (1,000 cfu/m³) (Seitz, 1989) and Ministry of Natural Resources and Environment, Thailand (120 µg/m³) (Pollution Control Department, Thailand, 2002). The detection of bacterial counts and/or PM10 levels are an indication of inadequate air ventilation (Seitz, 1989; Pollution Control Department, Thailand, 2002). A previous study of airborne bacteria in outdoor air samples collected for 80 days at Chulalongkorn Hospital (CU) and Odean Circle (OD), Bangkok, between October 1997 and January 1998 found 23.8% of samples collected from OD and 23.8% collected from CU had 1,000 cfu/m³ or higher (Pratumvong et al., 2001). In a study of outdoor airborne microflora in urban and natural areas in the city of Marseilles and the natural reserve of Porquerolles Island (Di Giorgio et al., 1996), Marseilles had average concentrations of airborne bacteria at 791±598 cfu/m³ (geometric mean 536±103 cfu/m³) a concentration of fungi of 92±92 cfu/m² (geometric mean 63±15 cfu/m³). The microbial counts and types of bacteria and fungi found in outdoor air may depend on temperature, UV light, wind velocity and the number of vehicles in the environment (Di Giorgio et al., 1996; Norris et al. 2002; Yeo and Kim, 2002; Seino et al., 2005).

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean ± Standard deviation PM$_{10}$ (µg/m³)</th>
<th>No. (%) of air samples with high PM$_{10}$ levels (&gt;120 µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1: Moh Chit</td>
<td>154.2 ± 236.1</td>
<td>5 (25.0)</td>
</tr>
<tr>
<td>No. 5: Victory Monument</td>
<td>173.7 ± 215.4</td>
<td>7 (35.0)</td>
</tr>
<tr>
<td>No. 8: Siam Center</td>
<td>230.4 ± 247.0</td>
<td>6 (30.0)</td>
</tr>
<tr>
<td>No. 11: Nana</td>
<td>107.7 ± 68.2</td>
<td>2 (10.0)</td>
</tr>
<tr>
<td>No. 12: Asok</td>
<td>245.1 ± 257.4</td>
<td>7 (35.0)</td>
</tr>
<tr>
<td>No. 16: Phra Khanong</td>
<td>266.3 ± 214.6</td>
<td>8 (40.0)</td>
</tr>
<tr>
<td>No. 17: On Nut</td>
<td>105.4 ± 78.2</td>
<td>3 (15.0)</td>
</tr>
<tr>
<td>Total</td>
<td>186.1 ± 188.1</td>
<td>38 (27.1)</td>
</tr>
<tr>
<td>Indoor air</td>
<td>78 ± 48.6</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 2
Mean and standard deviation of PM$_{10}$ levels from air samples under skytrain stations, Bangkok (n=20 air samples at each studied area).
The present study found most bacterial cultures were gram-positive cocci (Staphylococcus spp) and most fungal cultures were Aspergillus spp, Botrytis spp and Curvularia spp. A study in Korea found four airborne fungi: Fusarium spp, Aspergillus spp, Penicillium spp and Basipetospora spp (Yeo and Kim, 2002). These fungi may cause allergic and asthma-like reactions in some individuals with susceptibility (Homer et al., 1995; McNell and Kreutzer, 1996). These may be different along the roadside, based on the ecology of the environment and the period of time of air sample collection (Norris et al., 2002; Seino et al., 2005). Sources of particulate matter included from cooking, pets and road traffic. Although atmospheric particles may be transported over long distances, peak concentrations tend to occur close to roads. Pedestrians and street venders make up a large proportion of those exposed. PM10 can cause or aggravate a number of health problems and has been linked to illnesses and deaths due to heart or lung disease. It can increase susceptibility to respiratory infections and aggravate existing respiratory diseases, such as asthma and chronic bronchitis (Pope et al., 1991; Ostro et al., 1996; Verhoeff, 1996). Some biological contaminants may trigger allergic reactions, including hypersensitivity pneumonitis, allergic rhinitis and some types of asthma (WHO, 1990; Zweers, 1992). The symptoms may depend on the exposure doses of PM10 and/or bacterial counts and other factors, such as temperature, noise, and the presence of volatile organic compounds (VOCs). These provoke symptoms, such as, headaches, fatigue, eye and/or nose and/or throat irritation and allergic reactions (Meychting et al., 1998; Raaschou-Nielsen et al., 2001; Lee et al., 2002). This study provides only preliminary findings, due to the limitations of the study design (cross-sectional study). A longitudinal study or surveillance should be carried out and other air quality indicators, especially, VOCs and PM2.5, should be included.

In summary, this study found 4.8% and 27.1% of air samples collected from under skytrain stations had bacterial counts and PM10 levels, respectively, higher than recommended levels (>1,000 cfu/m3 for bacterial count, and >120 µg/m3 for PM10). These may affect human health, especially street vendors, who spend most of their working time in these areas. Some interventions, including ventilation improvement and cleaning the roadside environment, should be implemented.

ACKNOWLEDGEMENTS

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