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

Pipat Luksamijarulkul[1] and Pornpimol Kongtip[2]

[1]Department of Microbiology, [2]Department of Occupational Health and Safety, Faculty of Public Health, Mahidol University, Bangkok, Thailand

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 (PM_{10}) levels (140 samples). The results reveal the mean ± standard deviation bacterial counts and fungal counts were 406.8±302.7 cfu/m^3 and 128.9±89.7 cfu/m^3, respectively. The PM_{10} level was 186.1±188.1 μg/m^3. When compared to recommended levels, 4.8% of air samples (10/210 samples) had bacterial counts more than recommended levels (>1,000 cfu/m^3) and 27.1% (38/140 samples) had PM_{10} levels more than recommended levels (>120 μg/m^3). These may affect human health, especially of street venders 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 (PM_{10}) 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*,

Correspondence: Pipat Luksamijarulkul, Department of Microbiology, Faculty of Public Health, Mahidol University, 420/1 Ratchawithi Road, Bangkok 10400, Thailand.
Tel : +66 (0) 2354 8525; Fax: +66 (0) 2640 9835
E-mail: luksamijarulkul@hotmail.com, phpls@mahidol.ac.th

1995). 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/m^3) (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 venders and other people in those areas. This study attempted to assess microbial counts and PM_{10} 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 venders 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 pedestrains and street venders 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 PM_{10} 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 PM_{10} 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 venders and pedestrains. The microbial samples were collected using a Millipore Air Tester, and the PM_{10} 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 37ºC 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

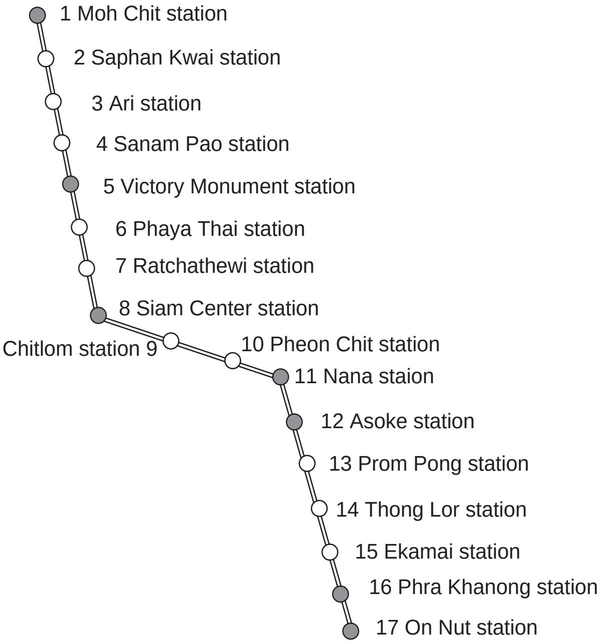

Fig 1–BTS Skytrain route in Bangkok (● studied areas).

following:

Total counts (colony forming units/m^3 or cfu/m^3) = (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 PM_{10}. 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 vender's collar or pocket as close to the breathing zone as possible, while the pump is attached to the vender's belt. After activating the pump, the vender 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 (PM_{10}) 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 PM_{10} levels in the samples.

RESULTS

Totally, 350 air samples (210 for microbial counts and 140 for PM_{10}) were collected and analyzed. The mean ± standard deviation (SD) bacterial count was 406.8±302.7 cfu/m^3 (geometric mean ± SD = 392.1±225.8 cfu/m^3; range 319.3±194.8 cfu/m^3 to 547.7±282.1 cfu/m^3) and the mean (±SD) fungal count was 128.9±89.7 cfu/m^3 (geometric mean ± SD = 112.9±79.6 cfu/m^3; range 89.6±47.2 cfu/m^3 to 157.7±84.7 cfu/m^3). Air samples collected from the roadside under station No. 5 had the highest mean bacterial count (547.7±282.1 cfu/m^3) and highest mean fungal count (157.7±84.7 cfu/m^3). The samples under station No. 17 had the lowest mean bacterial and fungal counts (319.3±194.8 cfu/m^3 and 89.6±47.2 cfu/m^3,

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).

Location	Mean ± SD (cfu/m^3) for		No. (%) of air samples with high microbial counts (>1,000 cfu/m^3)	
	Bacterial counts	Fungal counts	Bacteria	Fungi
No. 1: Moh Chit	322.1 ± 262.3	130.8 ± 94.2	0 (0.0)	0 (0.0)
No. 5: Victory Monument	547.7 ± 282.1	157.7 ± 84.7	3 (10.0)	0 (0.0)
No. 8: Siam Center	436.0 ± 369.7	138.7 ± 113.8	2 (6.7)	0 (0.0)
No. 11: Nana	380.0 ± 238.1	111.7 ± 74.5	0 (0.0)	0 (0.0)
No. 12: Asoke	457.0 ± 352.7	127.7 ± 85.0	3 (10.0)	0 (0.0)
No. 16: Phra Khanong	395.3 ± 419.2	146.1 ± 128.4	2 (6.7)	0 (0.0)
No. 17: On Nut	319.3 ± 194.8	89.6 ± 47.2	0 (0.0)	0 (0.0)
Total	406.8 ± 302.7[a]	128.9 ± 89.7[b]	10 (4.8)	0 (0.0)
Indoor air	228.3 ± 162.2	62.0 ± 43.2	0 (0.0)	0 (0.0)

[a]Most bacterial cultures were *Staphylococcus* spp.
[b]Most 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 *Curvalaria* spp. When the microbial air quality was compared to the guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH, >1,000 cfu/m^3) (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. 5 (3/30 samples), 12 (3/30 samples), 8 (2/30 samples) and 16 (2/30 samples). The details are shown in Table 1.

The mean (± SD) PM_{10} level was 186.1±188.1 $\mu g/m^3$ (geometric mean ± SD = 162.9±114.8 $\mu g/m^3$). The highest levels of PM_{10} were found under station Nos. 16 and 12 (266.3±214.6 $\mu g/m^3$ and 245.1±257.4 $\mu g/m^3$, respectively), and the lowest levels were found at station Nos. 17 (105.4±78.2 $\mu g/m^3$) and 11 (107.7±68.2 $\mu g/m^3$). When the PM_{10} levels were compared to the recommended levels of the Pollution Control Department, Ministry of Natural Resources and Environment, Thailand, 2002 (<120 $\mu g/m^3$), 27.1% (38/140 samples) had PM_{10} levels greater than recommended levels. The air samples with highest levels of PM_{10} 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 pedestrains. 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

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).

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

the dust had microbials attached (Jacobs, 1994). The mean (± SD) bacterial counts ranged from 319.3±194.8 cfu/m^3 to 547.7±282.1 cfu/m^3 and the mean fungal counts ranged from 89.6±47.2 cfu/m^3 to 157.7±84.7 cfu/m^3. 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 PM_{10} (266.3±214.6 µg/m^3 and 245.1±257.4 µg/m^3, respectively). These locations have frequent traffic jams and are crowded with street venders and pedestrains. 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/m^3 and 89.6±47.2 cfu/m^3, respectively). The lowest levels of PM_{10} were found under skytrain station Nos. 17 and 11 (105.4±78.2 µg/m^3 and 107.7±68.2 µg/m^3, respectively). Four point eight percent and 27.1% of air samples had bacterial counts and PM_{10} levels, respectively, more than recommended levels of the ACGIH (1,000 cfu/m^3) (Seitz, 1989) and Ministry of Natural Resources and Environment, Thailand (120 µg/m^3) (Pollution Control Department, Thailand, 2002). The detection of bacterial counts and/or PM_{10} 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/m^3 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/m^3 (geometric mean 536±103 cfu/m^3) a concentration of fungi of 92±92 cfu/m^2 (geometric mean 63±15 cfu/m^3). 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).

The present study found most bacterial cultures were gram-positive cocci (*Staphylococcus* spp) and most fungal cultures were *Aspergillus* spp, *Botrytis* spp and *Curvalarium* 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. Pedestrains and street venders make up a large proportion of those exposed. PM_{10} 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 PM_{10} 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 $PM_{2.5}$, 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 PM_{10} levels, respectively, higher than recommended levels (>1,000 cfu/m^3 for bacterial count, and >120 μg/m^3 for PM_{10}). These may affect human health, especially street venders, who spend most of their working time in these areas. Some interventions, including ventilation improvement and cleaning the roadside environment, should be implemented.

ACKNOWLEDGEMENTS

The authors would like to thank the Pollution Control Department, Ministry of Resources and Environments, Thailand, for the data. The study was partially supported by the China Medical Board (CMB), Faculty of Public Health, Mahidol University, Bangkok, Thailand.

REFERENCES

Di Giorgio C, Krempff A, Guiraud H, Binder P, Tiret C, Dumenil G. Atmospheric pollution by airborne microorganisms in the city of Marseilles. *Atmos Environ* 1996; 30: 155-60.

Graham LM. All I need is the air that I breath: outdoor air quality an asthma. *Pediatr Resp Rev* 2004; 5 (suppl a): S59-64.

Gulliver J, Briggs DJ. Personal exposure to particulate air pollution in transport microenvironments. *Atmos Environ* 2004; 38: 1-8.

Homer WE, Helbling A, Salvaggio JE, Lehrer SB. Fungal allergens. *Clin Microbiol Rev* 1995; 8: 161-79.

Jacobs RR. Risk environments. In: Rylander R, Jacobs RR, eds. Organic dusts: exposure, effects and prevention. USA: Lewis, 1994: 3-15.

Kodama AM, McGee RII. Airborne microbial contaminants in indoor environments naturally ventilated and air-conditioned homes. *Archives Environ Health* 1996; 144: 302-11.

Larone DH. Medically important fungi: A guide to identification. 3rd ed. Washington, DC: American Society of Microbiology Press, 1995: 1-274.

Lee CC, Chen MR, Shih TS, Tgai PJ, Lai CH, Liou SH. Exposure assessment on volatile organic compounds (VOCs) for Tollway station workers via direct and indirect approaches. *J Occup Health* 2002; 44: 294-300.

Luksamijarulkul P, Sundhiyodhin V, Luksamijarulkul S, Kaewboonchoo O. Microbial air quality in mass transport buses and work-related illness among bus drivers of Bangkok Mass Transit Authority. *J Med Assoc Thai* 2004; 87: 697-703.

McNell SV, Kreutzer RA. Fungi and indoor air quality. *Health Environ Digest* 1996; 10: 9-12.

Meychting M, Svensson D, Ahlbom A. Exposure to motor vehicle exhaust and childhood cancer. *Scand J Work Environ Health* 1998; 24: 8-11.

Norris TB, McDermott TR, Castenholz RW. The long-term effects of UV exclusion on the microbial composition and photosynthetic competence of bacteria in hot-spring microbial mats. *FEMS Micro Ecol* 2002; 39: 193-209.

Ostro BD, Sanchez JM, Aranda C, Eskeland GS. Air pollution and mortality: results from a study of Santiago, Chile. *J Expos Anal Environ Epidemiol* 1996; 6: 97-114.

Pollution Control Department, Thailand. Particulate matter. 2002. [Cited 2009 Nov 10]. Available from: URL: http://www.aqnis.pcd.go.th/basic/pollution_pm.htm

Pope III CA, Dockery DW, Spengler JD, Raizenne ME. Respiratory health and PM_{10} pollution: a daily time series analysis. *Am Rev Resp Dis* 1991; 144: 668-74.

Pratumvong K, Suthienkun O, Panich N, Nivatapan U. Airborne bacteria at traffic congested areas in Bangkok metropolis. *J Public Health* 2001; 31: 205-16.

Raaschou-Nielsen O, Hertel O, Thomsen BL, Olsen JH. Air pollution from traffic at the residence of children with cancer. *Am J Epidemiol* 2001; 153: 433-43.

Seino K, Takano T, Nakamura K, Watanabe M. An evidential example of airborne bacteria in a crowded, underground public concourse in Tokyo. *Atmos Environ* 2005; 39: 337-41.

Seitz TA. NIOSH indoor air quality investigations 1971-1988. In: Weekes DM, Gammage RB, eds. Proceedings of the indoor air quality, international symposium: The practitioner's approach to indoor air quality investigations. Ohio: American Industrial Hygiene Association, 1989: 163-71.

Verhoeff AP, Hoek G, Schwartz J, Van Wijnen JH. Air pollution and daily mortality in Amsterdam. *Epidemiology* 1996; 7: 225-30.

World Health Organization (WHO). Indoor air quality: Biological contaminants. *European Ser* 1990; 30: 374-85.

Yeo HG, Kim JH. SPM and fungal spores in the ambient air of West Korea during the Asian dust (Yellow sand) period. *Atmos Environ* 2002; 36: 5437-42.

Zweers T. Health and indoor climates complaints of 7,043 office workers in 61 building in the Natherlands. *Indoor Air*1992; 2: 127-36.