Microbial Counts and Particulate Matter Levels in Indoor Air Samples Collected from a Child Home-Care Center in Bangkok, Thailand

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Objective: *To assess the microbial count (bacteria and fungi) and particulate matter with sizes less than 10 µm (PM_{10}) level in indoor air of a child home-care center in Bangkok.*
Material and Method: *A total of 287 air samples were collected from the indoor air of twenty households which were part of a child home-care center to assess bacterial and fungal counts (212 samples) and PM_{10} levels (66 samples). Additionally, fifty-two and twenty-six outdoor air samples were collected to compare microbial count and PM_{10} levels.*
Results: *It was found that means $\pm$ standard deviation (SD) for bacterial and fungal counts in the child home-care center were 527.8 ± 230.9 cfu/m^3 and 514.6 ± 256.7 cfu/m^3, respectively (those in outdoor air samples were 264.6 ± 179.7 cfu/m^3 and 308.7 ± 217.3 cfu/m^3, respectively). The mean $\pm$ SD of PM_{10} level was 125.1 ± 48.0 µg/m^3 (that in outdoor air samples was 120.1 ± 66.9 µg/m^3). When compared with the level for the indoor air quality guideline, 47.2% and 47.6% of total air samples had bacterial and fungal counts higher than the recommended levels and 47.0% of total air samples had PM_{10} levels higher than the recommended level.*
Conclusion: *The present study found that about 47% of total air samples collected from the child home-care center had bacterial and fungal counts and PM_{10} levels higher than the recommended levels. These results may affect the health of a child who spends most of his/her time in this center. Some intervention or preventive endeavors should be undertaken, including periodic cleaning and maintenance of the ventilation systems and adoption of a regular schedule for room cleaning should be implemented.*

Keywords: *Indoor air quality, Microbial count, PM_{10}, Child home-care center*

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Changes in our lifestyle amongst 21st Century urbanites has been an ongoing process over the past few decades. More time is increasingly spent indoors in all latitudes around the world and thus the quality of air inside homes and offices has become an important issue(1). Clinicians today face the important yet common health issue regarding indoor environments(2). Recent reports show an increase in the incidence of symptoms related to interior air measuring between 30 and 200 percent in those buildings with air-conditioning systems, regardless of humidification factors, when compared with those buildings with natural ventilation systems(3). In the United States, the National Ambient Air Quality Standard (NAAQS) offers a specific standard for air quality that is used for health risk assessment for persons who have had long-term exposure to poor air quality(4). The indoor environment in developing countries is more greatly subjected to pollutants from numerous sources(5). Indoor air quality is important for the health of children who increasingly spend more time indoors and especially for those suffering from asthma and respiratory symptoms(6,7). Dampness and the subsequent growth of molds in home environments has been associated with adverse respiratory effects, particularly among children(8,9). The present study by Fernandez-Caldas and referred to here as the Annals reported high levels of indoor allergens in daycare settings in warm and humid environments(10). Dust mite levels ranging from 10 to 1,200 mites/gram of dust were found in 75% of the daycare centers tested, and 40% of the studied daycare centers had mite

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allergen levels > 2 μg/g. In addition, settled dust was recognized as a risk for sensitization and concentrations > 10 μg/g of dust have been associated with asthma exacerbations in sensitized individuals[11]. Children in childcare are known to have an increased risk of respiratory illnesses[12-15]. The previous study of Mommers et al investigated the relationship between indoor environment risk factors and respiratory symptoms in 7- to 8-year-old children living in the Dutch-German borderland and showed an increased risk of respiratory symptoms in children exposed to several indoor environmental risk factors[16].

A home-care center provides welfare services and aids in the development of needy children. Services provided are the basic necessities, including formal and vocational education, in accordance with each individual's ability. Around the studied child-care center, there are 3 hospitals and a busy traffic junction that tested high for outdoor microbial counts[17]. Additionally, there are new construction sites, including a part of the express-way. The present study of microbial counts and PM_{10} levels in indoor air collected from this child-care center may help to identify proper and suitable methods to develop healthy programs for a better quality of life among children and care providers in this welfare service center.

Material and Method

Study design and study samples

A cross-sectional study was conducted between October 2006 and March 2007 to assess bacterial counts, fungal counts and PM_{10} levels in the indoor air of a child home-care center in Bangkok that includes 19 care providers and 424 children living in 20 households consisting of 20 bedrooms, 20 living rooms, 20 care provider's rooms and 6 classrooms. Indoor air samples were collected from every room in each household to determine test results. After counting the bacteria and fungi, the identification of isolated colonies was carried out according to their colony appearance, Gram's stain and microscopic morphology following Larone (1995)[18].

Duplicated indoor air samples were collected at one or two points in the central area of each room to count bacteria and fungi (212 air samples) using the Millipore air tester. The air sample was collected from one point in each room to quantify PM_{10} levels (66 air samples) by Personal pump cyclone. Additionally, fifty-two outdoor air samples for bacterial and fungal counts and twenty-six outdoor air samples for PM_{10} quantification, were collected from each household and classroom for comparison, Table 1.

Methods of air sample collection

Indoor and outdoor air samples were collected during the hours from 9 am to 12 pm, Monday to Saturday, using the Millipore air tester for bacterial and fungal counts and Personal pump cyclone for PM_{10} quantification. The Millipore air tester system is based on the Anderson principle and uses a sieve with about 1,000 microperforations, 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 seven minutes. In the present study, 250 liters of air was collected. The plate count method was used to estimate bacterial or fungal counts. General bacteria were cultured in plate count agar at 37°C for 48 hrs and general fungi were cultured in a Sabouraud 4% dextrose agar, at room temperature, for 5 days with daily observation. After incubation, the bacterial and fungal colonies were counted and calculated to express as colony forming unit/m^3 (cfu/m^3) by the following formula:

Total counts (colony forming unit/m^3 or cfu/m^3) = [Total colonies X 1,000]/250

Personal pump cyclone: a 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 care provider's collar or pocket as close to the breathing zone as possible, while the pump is attached onto a care provider's belt. After activating the pump, the care provider 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 and method determines the type and pore size of the 37 mm filter. When attached to a personal air sampling pump at 1.7 L/min, the weight of particulate matter (PM_{10}) in a 1 hr period was determined.

Data analysis

Data were analyzed by computer program. Descriptive statistics including percentage, mean and standard deviation were used for describing the bacterial count, fungal count and PM_{10} level.

Results

A total of 212 indoor air samples were collected

Table 1. The sampling points and number of air samples of a studied child home-care center

Sampling points	No. of rooms	No. of air samples for microbial count (Bacteria and Fungi)	No. of air samples for PM_{10} level
Living room	20	80	20
Bedroom	20	80	20
Care provider's room	20	40	20
Classroom	6	12	6
Outdoor (Out-side the building)	-	52	26

Table 2. Mean and standard deviation of bacterial count, fungal count and PM_{10} level in indoor air samples collected from a child home-care center and outdoor

Rooms or area	Mean $\pm$ SD		
	Bacterial count (cfu/m^3) (Min-Max)	Fungal count (cfu/m^3) (Min-Max)	PM_{10} level ($\mu g/m^3$) (Min-Max)
Living room	569.4 ± 247.3 (136-1,152)	530.5 ± 234.0 (136-1,088)	128.7 ± 45.3 (69-229)
Bedroom	573.1 ± 220.0 (136-1,120)	579.7 ± 288.4 (40-1,088)	114.4 ± 33.4 (44-180)
Careprovider's room	401.8 ± 175.7 (96-928)	369.4 ± 201.1 (64-800)	134.4 ± 66.3 (68-335)
Classroom	367.3 ± 115.9 (192-512)	453.3 ± 127.9 (224-640)	118.2 ± 18.4 (94-140)
Total	527.8 ± 230.9 (96-1,152)	514.6 ± 256.7 (40-1,088)	125.1 ± 48.0 (44-335)
Outdoor	264.6 ± 179.7 (40-930)	308.7 ± 217.3 (11-1,056)	120.1 ± 66.9 (68-335)

to investigate bacterial and fungal counts and 66 samples were collected to assess PM_{10} levels. It was found that means $\pm$ standard deviation (SD) of bacterial counts and fungal counts in the child home-care center were 527.8 ± 230.9 cfu/m^3 and 514.6 ± 256.7 cfu/m^3, (Geometric means = 509.8 ± 241.6 cfu/m^3 and 501.4 ± 262.5 cfu/m^3, respectively), whereas, those in outdoor air samples were 264.6 ± 179.7 cfu/m^3 and 308.7 ± 217.3 cfu/m^3. The highest mean level was found in bedrooms (573.1 ± 220.0 cfu/m^3 and 579.7 ± 288.4 cfu/m^3). The lowest level was found in the classroom (367.3 ± 115.9 cfu/m^3 and 369.4 ± 201.1 cfu/m^3). The mean $\pm$ SD of PM_{10} level was 125.1 ± 48.0 $\mu g/m^3$ (that in outdoor air samples was 120.1 ± 66.9 $\mu g/m^3$). The highest level was found in the care provider's room (134.4 ± 66.3 $\mu g/m^3$) and the lowest level was found in bedrooms (114.4 ± 33.4 $\mu g/m^3$), Table 2.

The indoor air levels were compared with the guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH) and the Pollution Control Department, Ministry of Natural Resources and Environment of Thailand. It was found that 47.2% and 47.6 % of total air samples had bacterial and fungal counts higher than the recommended indoor air level of the ACGIH (> 500 cfu/m^3) and 47.0% of total air samples had PM_{10} levels higher than the recommended level from the Pollution Control Department, Ministry of Natural Resources and Environment of Thailand (> 120 $\mu g/m^3$). Details are shown in Table 3.

The isolated colonies of bacteria and fungi were identified by group or genus when gram stained and with lacto-phenol cotton blue dye. It was found that the most common bacteria was *Staphylococcus* spp. (71%) and *Streptococcus* spp. (19.2%), whereas, the most common fungi was septate hypha fungi (59.7%) and *Aspergillus* spp. (37.2%). Details are shown in Table 4.

Table 3. Number and percentage of air samples with bacterial count, fungal count, and PM_{10} level of studied air samples compared with the recommended level

Room or area	No.(%) of bacterial count, fungal count and PM_{10} level					
	Bacterial count (cfu/m^3)		Fungal count (cfu/m^3)		PM_{10} level (µg/m^3)	
	$\leq$ 500	> 500	$\leq$ 500	> 500	$\leq$120	> 120
Living room	(n = 80)		(n = 80)		(n = 20)	
	35 (43.8)	45 (56.2)	39 (48.8)	41 (51.2)	11 (55.0)	9 (45.0)
Bedroom	(n = 80)		(n = 80)		(n = 20)	
	35 (43.8)	45 (56.2)	36 (45.0)	44 (55.0)	10 (50.0)	10 (50.0)
Careprovider's room	(n = 40)		(n = 40)		(n = 20)	
	31 (77.5)	9 (22.5)	30 (75.0)	10 (25.0)	11 (55.0)	9 (45.0)
Classroom	(n = 12)		(n = 12)		(n = 6)	
	11 (91.7)	1 (8.3)	6 (50.0)	6 (50.0)	3 (50.0)	3 (50.0)
Total	(n = 212)		(n = 212)		(n = 66)	
	112 (52.8)	100 (47.2)	111 (52.4)	101 (47.6)	35 (53.0)	31 (47.0)
Outdoor	(n = 52)		(n = 52)		(n = 26)	
	46 (88.5)	6 (11.5)	41 (78.8)	11 (21.2)	15 (75.0)	5 (25.0)

Table 4. Number and percentage of bacterial and fungal groups isolated from indoor air samples of the child home-care center (n = 390 colonies)

Isolates	No. (%) of Isolates by room				
	Living rooms (n = 145)	Bedrooms (n = 155)	Care provider's room (n = 50)	Classrooms (n = 40)	Total (n = 390)
Bacterial Isolates					
Staphylococcus spp.	95 (65.5)	114 (73.5)	43 (86.0)	25 (62.5)	277 (71.0)
Streptococcus spp.	29 (20.0)	32 (20.6)	4 (8.0)	9 (22.3)	75 (19.2)
Bacillus spp.	18 (12.4)	8 (5.2)	2 (4.0)	5 (12.5)	33 (8.5)
Others	3 (2.1)	1 (0.6)	1 (2.0)	1 (2.5)	5 (1.3)
Fungal Isolates					
Septate hypha	28 (19.3)	133 (85.8)	45 (90.0)	27 (67.5)	233 (59.7)
Aspergillus spp.	113 (77.8)	16 (10.3)	4 (8.0)	12 (30.0)	145 (37.2)
Penicilium spp.	3 (2.1)	5 (3.0)	1 (2.0)	1 (2.5)	10 (2.6)
Others	1 (0.7)	1 (0.6)	0 (0.0)	0 (0.0)	2 (0.5)

Remark: (1) Most common bacterial isolates in outdoor air samples (n = 156) were 57.1% of *Staphylococcus* spp. and 33.3% of *Streptococcus* spp. (2) Most common fungal isolates in outdoor air samples (n = 156) were 63.5% of *Aspergillus* spp. and 35.9% of septate hypha fungi

Discussion

Most big cities in the world that serve as economic and travel centers experience heavy traffic and pollution. Many people spend the greater part of their day indoors, away from the heat and pollution from the concrete jungle and often spend most of their time at home, in school or at the office in relative comfort[1,19]. Poor indoor air quality has the potential to reduce not only the quality of life but also can result in economic losses[20]. Reports about buildings with air related problems first appeared in the early 1970s and have increased thereafter. Although more often reported now, it is a problem that has plagued mankind for centuries[1,4]. Respiratory disease is a major cause of illness and absence from school for children[12,15]. The present study was a short-term assessment of bacterial and fungal counts along with PM_{10} levels in indoor air samples at the child home-care center where several hospitals and office buildings are along the roads. It was found that the mean ± standard deviation for bacterial counts was 527.8 ± 230.9 cfu/m^3 (maximum = 1,152 cfu/m^3, minimum = 96 cfu/m^3) (Geometric mean = 509.8 ± 241.6 cfu/m^3). When compared with the guidelines of the ACGIH[21], it was found that 47.2% of studied air samples (100/212 samples) had bacterial counts higher than the recommended level (< 500 cfu/m^3). Additionally, the mean ± standard deviation of fungal counts was 514.6 ± 256.7 cfu/m^3 (maximum = 1,088 cfu/m^3, minimum = 40 cfu/m^3) (Geometric mean = 501.4 ± 262.5 cfu/m^3), when compared with the guideline levels of the ACGIH, it showed 47.6% of air samples studied had a fungal count above the recommended level (< 500 cfu/m^3). By contrast, outdoor air samples were 264.6 ± 179.7 cfu/m^3 and 308.7 ± 217.3 cfu/m^3. The microbial count ratio between indoor air and outdoor air was greater than 1.0 and was thus an indication that the source of microbial contamination was to be found in the indoor environment[22]. High counts of bacteria or fungi indicate overcrowding and poor ventilation[19,21]. The World Health Organization[10] suggested that the microbial counts in the general workplace should be less than 300 cfu/m^3. For individuals with immunosuppression issues, the microbial air count should be less than 100 cfu/m^3.

Additionally, the mean ± standard deviation of PM_{10} levels in indoor air samples in the child home-care center studied was 125.1 ± 48.0 μg/m^3 which was higher than the recommended level of the National Ambient Air Quality Standard (NAAQs) (< 120 μg/m^3 in 24-hour)[23]. In the present study, 47% of total air samples had PM_{10} levels greater than the recommended level for outdoor air and the highest level of PM_{10} was found in the care provider's room (134.4 ± 66.3). Forty-five percent of air samples collected from care provider's room had levels of PM_{10} which exceeded the recommended level (> 120 μg/m^3). While, the mean ± SD of PM_{10} levels in the classroom was 118.2 ± 18.4 μg/m^3 (Min = 94 μg/m^3, Max = 140 μg/m^3), 50% of total air samples had PM_{10} levels higher than the recommended level. Lee and Chang[24] studied indoor air quality, including PM_{10} levels, in five classrooms in Hong Kong. The concentrations ranged from 21 μg/m^3 to 617 μg/m^3. It seemed very high in comparison to those of the presented study. It is generally accepted that indoor concentrations of particles were derived from two sources: indoor sources and outdoor sources. The significance of both sources depends on a number of variables, *e.g.*, air-exchange rate, levels of outdoor air pollution, types of indoor activities and aerodynamic diameter of particles emitted[24-27].

The microbial counts and PM_{10} quantity depend on several variables, such as velocity, humidity, temperature, number of occupants, activities and ventilation[19,28,29]. A concentration of particulate matter or dust was associated with bioaerosol levels because the dust provided many organisms with a medium for microbial growth[28]. Previous studies showed that road traffic can effect an increase in microbial counts and ambient particulate pollution, especially for finer particles (PM_{10} and less)[28-30]. Both number and types of bacteria and fungi might be different along the roadside, depending upon the ecology of environment and the season in which the air sample was collected[29,30]. The present study found that most bacterial cultures were *Staphylococcus* spp. and most fungal cultures were the *septate hypha fungi* and *Aspergillus* spp., which was likely as the present study of roadside air samples were taken under sky-train station in Bangkok[30]. A study in Korea found four mold genera grown from airborne fungi including *Fusarium* spp., *Aspergillus* spp., *Penicillium* spp. and *Basipetospora* spp.[31]. These fungi could cause allergic and asthma-like reactions in some individuals who were susceptible[31,32].

Children, older people and immune-compromised persons are particularly sensitive to air pollution from various sources including dust and particulate matter, bio-aerosols, and others[1,8,10,26,27,32]. These pollutants in indoor and outdoor air can directly or indirectly cause a number of health problems relating to heart and lung diseases. It can increase susceptibility to respiratory infections and aggravate existing respiratory diseases, such as asthma and chronic bronchitis[10-15]. PM_{10} can cause or aggravate a number of health problems and have been linked with illnesses and deaths from heart or lung diseases. It can increase susceptibility to respiratory infections and can aggravate existing respiratory diseases, such as asthma and chronic bronchitis[1,26,29,34]. In addition, some biological contaminants trigger allergic reactions including hypersensitivity pneumonitis, allergic rhinitis and some types of asthma[1,10,19,32]. The symptoms might depend on the exposure doses of PM_{10} levels and/or bacterial counts and/or other agents, such as the temperature, noise and volatile organic compounds (VOCs). The present study provides preliminary findings as a result of the limitations in the present study design (cross-sectional study). A longitudinal study, or surveillance, should be done and other air quality indicators, especially, VOCs and $PM_{2.5}$ levels should be included.

In conclusion, the present study found that about 47% of total air samples collected from the child home-care center had bacterial and fungal counts and PM_{10} levels higher than the recommended levels. These may affect health, especially of the children, who spent most of their time at this center. Interventions in the form circulating guidelines, along with encouragement in improving ventilation, coupled with the establishment of regular maintenance and cleaning schedules would go a long way in educating the public and affecting genuine change for the betterment of the general health of all.

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Potential conflicts of interest

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ปริมาณเชื้อจุลินทรีย์และฝุ่นขนาดเล็กกว่า 10 ไมครอน ในตัวอย่างอากาศภายในอาคารสถานสงเคราะห์เด็กแห่งหนึ่งในกรุงเทพมหานคร

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***วัตถุประสงค์**: เพื่อประเมินปริมาณเชื้อจุลินทรีย์ (เชื้อแบคทีเรียและเชื้อรา) และฝุ่นขนาดเล็กกว่า 10 ไมครอน ในตัวอย่างอากาศที่เก็บจากภายในอาคารของสถานสงเคราะห์เด็กแห่งหนึ่งในกรุงเทพมหานคร*

***วัสดุและวิธีการ**: ทำการเก็บตัวอย่างอากาศภายในอาคาร 20 หลัง จำนวนทั้งสิ้น 287 ตัวอย่าง โดยแบ่งเป็น 212 ตัวอย่าง ตรวจเชื้อแบคทีเรียและเชื้อราและ 66 ตัวอย่าง ตรวจฝุ่นขนาดเล็กกว่า 10 ไมครอน นอกจากนี้ยังได้เก็บตัวอย่างอากาศภายนอกอาคารจำนวน 52 ตัวอย่างและ 26 ตัวอย่าง เพื่อเปรียบเทียบปริมาณเชื้อจุลินทรีย์ (เชื้อแบคทีเรียและเชื้อรา) และฝุ่นขนาดเล็กกว่า 10 ไมครอน*

***ผลการศึกษา**: พบว่าค่าเฉลี่ยปริมาณเชื้อแบคทีเรียและเชื้อราเท่ากับ 527.8 $\pm$ 230.9 cfu/m^3 และ 514.6 $\pm$ 256.7 cfu/m^3 ตามลำดับ (อากาศภายนอกอาคารเท่ากับ 264.6 $\pm$ 179.7 cfu/m^3 และ 308.7 $\pm$ 217.3 cfu/m^3 ตามลำดับ) ขณะที่ค่าเฉลี่ยปริมาณฝุ่นเท่ากับ 125.1 $\pm$ 48.0 μg/m^3 (อากาศภายนอกอาคารเท่ากับ 120.1 $\pm$ 66.9 μg/m^3) เมื่อเปรียบเทียบกับค่าคุณภาพอากาศภายในอาคารที่แนะนำพบว่าร้อยละ 47.2 และ 47.6 ของตัวอย่างอากาศมีปริมาณเชื้อแบคทีเรียและเชื้อราสูงกว่าค่าที่แนะนำและร้อยละ 47.0 ของตัวอย่างอากาศมีปริมาณฝุ่นขนาดเล็กกว่า 10 ไมครอน สูงกว่าค่าที่แนะนำ*

***สรุป**: การศึกษานี้พบว่าประมาณร้อยละ 47 ของตัวอย่างอากาศที่เก็บจากภายในอาคารของสถานสงเคราะห์เด็กแห่งหนึ่งในกรุงเทพมหานคร มีปริมาณเชื้อแบคทีเรีย เชื้อราและฝุ่นขนาดเล็กกว่า 10 ไมครอน สูงกว่าค่าที่แนะนำ อาจมีผลต่อสุขภาพของเด็กที่ต้องใช้เวลาส่วนใหญ่อยู่ภายในอาคาร จึงควรมีการปรับปรุงการระบายอากาศ การทำความสะอาดห้องและการจัดการสิ่งแวดล้อมภายในอาคารเพื่อลดปริมาณเชื้อจุลินทรีย์และฝุ่นในอากาศ*