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EFFECT OF TRAFFIC-RELATED AIR POLLUTANTS IN BANGKOK METROPOLITAN DCCS (DAY CARE CENTERS) ON RESPIRATORY SYMPTOMS OF CHILDREN

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List of Abbreviations and Acronyms

ADHD	Attention Deficit Hyperactive Disorder
CCAAPS	Cincinnati Childhood Allergy and Air Pollution Study
CFU	Colony forming unit
CO	Carbon monoxide
COHb	Carboxy hemoglobin
DCCs	Day Care Centers
DSM-5	American Psychiatric Association's Diagnostic and Statistical Manual, Fifth edition
ECAT	elemental carbon attributed to traffic
F_ENO	Fractional Exhaled Nitric Oxide
NO_2	Nitrogen dioxide
NOS	Nitric oxide synthase
O_3	Ozone
PM10	particles with an aerodynamic diameter smaller than 10 µm
ppm	Part per million
SO_2	Sulfur dioxide

CHAPTER I INTRODUCTION

1.1 Rationale

Clean air is a fundamental requirement for human health and well-being [1]. During the past few decades, human activities, industrial activities, and transportation have contributed to increasing contamination of the ambient air environment. Human are exposing to a variety of air pollutants, and air pollution is becoming a major problem throughout the world.

Nowadays, people are spending more time indoors. Indoor air pollution and its effect on health has become an issue of concern worldwide. Indoor air can be contaminated by chemical, physical, and biological agents. There are two important factors that influence the level of indoor air pollutants: the pollutant source, and the amount of ventilation. Sources of indoor air pollution range from combustion of solid fuels, such as biomass and coal, in the developing world, which emit CO and respirable particles, to volatile organic compounds from construction material, furnishing, and consumer products used in modern homes. Outdoor air pollution is also a source of indoor air pollution. Outdoor air can enter and leave a building by infiltration, natural ventilation, and mechanical ventilation. In the presence of indoor pollution source, poor ventilation will aggravate the accumulation of the pollutants [2].

For many reasons, children are more susceptible to health effects from indoor air pollution than adults. Infants and preschool children spend most of their time indoor, and therefore are exposing more to indoor air pollutants. The immature lungs and immune system of children also make them more vulnerable to the environmental insults. A term infant is born with about 25 million alveoli in the lungs, where most of new alveoli are formed in the first two years of life, then, alveolar growth continues until age of 8 years old with the number of alveoli reaching 300 million. After that, linear growth of lung volume occurs without forming new alveoli. Exposure to pollutants at this developmental stage can cause adverse effects on lung structure, as well as function. Children’s respiratory rate is higher than that of adult, resulting in higher minute ventilation. Children also have larger lung surface area per body weight compared to adult. Therefore, children are exposed to proportionately larger dose of pollutants than adults. Furthermore, many aerosolized pollutants are heavier than air. Since children’s breathing zone is closer to the ground than that of adults, they are exposed to higher concentration of various pollutants when staying in the same indoor space [3].

Bangkok is the most highly populated city in Thailand, with over 7 million people and over 2.5 million households. It is also a highly polluted city. There are approximately 300 day care centers (DCCs) in Bangkok. Increasing numbers of preschool children are going to DCCs, and these children spend time at DCCs about 40-45 hours per week. Preschool

children's exposure to air pollution comes primarily from indoor. For children attending DCCs, indoor air in DCCs is a significant source of pollutants exposure.

There have been environmental studies done for assessing level of some indoor air pollutants in DCCs from countries in different parts of the world. A study in Paris found that NO_2 and airborne endotoxin level was significantly higher in DCCs compared to in homes, and 1 out of 28 DCCs had total dust mite allergen in cold season greater than the proposed sensitization threshold level [4]. In Nigeria, a study of particulate matter burden in 48 DCCs found that mean indoor PM_{10} level significantly exceeds WHO (World Health Organization) guideline limit [5]. Dampness and biological indoor air pollution is also a subject of interest. A study was conducted in Norway in 2005, where inspection of the 175 DCCs was done, and dampness problems, such as sign of molds and water leakage, were observed in 51% of DCCs. Nonetheless, no significant effects on respiratory symptoms of children were found in the study [6]. In Taiwan, airborne fungi and bacteria count in two DCCs was studied, and levels of indoor microbial were above the IAQ (Indoor Air Quality) recommendations [7].

From the Cincinnati Childhood Allergy and Air Pollution Study (CCAAPS), birth cohort study on exposure to Elemental Carbon Attributed to Traffic (ECAT) during infancy and behavioral scores at 7 years of age found that exposure to the highest tertile of ECAT during the child's first year of life was significantly associated with Hyperactivity T-scores in the "at risk" range at 7 years of age. Other previous studies showed negative correlation between air pollutants and neurocognitive development in children [8].

In Thailand, only a few studies were carried out on this subject. There was a study in 2005 on 24-hour indoor PM_{10} level done in 25 DCCs in high-polluted area, and 25 DCCs in low-polluted area in Bangkok. No significant difference in PM_{10} concentrations was found between the two areas. Both areas had level of PM_{10} concentration above the WHO recommendation. The study also found positive correlation between PM_{10} concentrations and number of children complaining about cough in the high-polluted area [9, 10]. Another study was done in a child home care center in Bangkok in 2006, where microbial count and PM_{10} levels were measured in 20 households. Almost half of the total air samples had bacterial, fungal counts, and PM_{10} levels higher than the recommended level [11].

1.2 Objectives

Today, there is still very limited information about the indoor air pollution level in DCCs in Thailand. Although effects of indoor air pollution on health have been widely studied in adults and older children, there are not many studies in the preschool age group, especially in tropical climate regions. Hence, this project aims

1. **To assess the level of indoor air pollutants (including traffic related air pollutants) in DCCs in Bangkok**
2. **To determine environmental characteristics of DCCS that influence the indoor air pollutants level**

3. To determine the association between exposure to indoor air pollution in DCCs in Bangkok and respiratory symptoms, Fractional Exhaled Nitric Oxide (FENO) of Children under 6 years old

1.3 Methodology

Details of methodology employed in the present investigation are described as follows.

1.3.1 Study Design

Prospective and descriptive studies were followed.

1.3.2 Population

Population were included and excluded according to the following criteria.

Inclusion Criteria

- For day care centers (DCCs): DCCs located in Bangkok with signed informed consent to participate in the study
- For Children: children under 6 years old attending the DCCs for at least a year before the period of study whose parent give signed informed consent to participate in the study

Exclusion Criteria

- Day care centers and children whose parents do not consent for participating
- Children leaving the day care centers during the time of study

1.3.3 Methods of Data Collections

This is a descriptive study. Data will be collected on *Day Care environmental characteristics* by direct inspection and question on

- total indoor area,
- type of building material,
- year of construction,
- ventilation system,
- number of children,
- presence of pet indoor,
- indoor cooking,
- proximity to traffic or water resources,
- visible signs of dampness or mold.

Children demographic data and home environment will be collected by questionnaire including

- age, gender, ethnicity of children, as well as history of drug and food allergy,
- immunization for influenza,
- maternal and paternal atopy,

- history of breastfeeding,
- exposure to smoking at home,
- current pet exposure,
- socio-economic status and
- number of siblings.

Data on housing characteristics will also be collected on

- indoor combustion of fuel for cooking,
- indoor smoking,
- ventilation device used at home,
- molds, dampness or water leakage in home.

Pollutant level will be measured. Samples of indoor air will be collected from DCCs and measure for

- PM_{10},
- CO,
- NO_2,
- SO_2,
- O_3,
- Benzene,
- bacteria count,
- fungi count and
- dust mite level.

Respiratory symptoms of children will be assessed by using questionnaire on symptoms including

- Upper respiratory symptoms: cough, runny nose, sneezing, blocked nose, itchy nose,
- Lower respiratory symptoms: dyspnea
- Absence from school due to respiratory symptoms
- Doctor visit and admission due to respiratory symptoms

For each four-week period, the questionnaires will be sent to parents weekly for four consecutive weeks. At DCCs, teachers will also observe and record respiratory symptoms for each child every Monday for four weeks. *Exhaled Nitric Oxide level* representing airway inflammation will be measured in children from each DCCs. Pollutant levels, respiratory symptoms and exhaled nitric oxide levels will be measured during rainy and winter seasons due to possible seasonal variation of air pollution.

1.3.4 Statistical Analyses

Association of the data will be determined, as indicated in the following chapter.

CHAPTER 2 LITERATURE REVIEW

2.1 Air Pollutants and Indoor Air Pollution

Air pollution is a contamination of indoor or outdoor air environment by chemical, physical or biological agents. The quality of air inside homes, offices, schools, day care centers, public buildings, health care facilities or other private and public buildings, where people spend a large part of their life, is an essential determinant of healthy life and people's well-being.

Indoor air pollutions come from indoor and outdoor sources. Outdoor air can enter and leave building by infiltration, natural ventilation, and mechanical ventilation. For infiltration, air come in and out through any openings, joints, cracks in walls, floors and ceilings, and also around windows and doors. Natural ventilation is when air moves through windows and doors that are opened. These two methods of ventilation occur due to differences in temperature between indoor and outdoor space, and also by wind. There are many mechanical ventilation devices, such as fans, air conditioner, air handling systems. Accumulation of indoor air pollutants occurs when the air exchange rate inside a close space is low.

Exposure to air pollutants can cause both short term and long term health effects. Sources and health effects of the pollutants in this study are shown in Table 1.

Table 1: Sources and health effects of common air pollutants

Pollutant	Source	Health effects
CO	Incomplete combustion of carbonaceous fuels	- Asphyxiating effect - Ischemic heart disease - Respiratory symptoms
NO_2	Fuel combustion, Tobacco, Traffic smoke	- Increased bronchial reactivity - Airway inflammation
Ozone	Mostly from outdoor	- Airway irritation - Aggravate asthma and COPD
SO_2	Fossil fuel combustion	- Trigger bronchoconstriction
Benzene	Furnishing material, tobacco, fuel combustion	- Increased lifetime risk for leukemia
PM_{10}	Combustion, traffic	- Worsening respiratory symptoms - Decreased lung function
Mold	Damp environment, bathroom, kitchen	- Respiratory infection - Allergic reaction

Bacteria	Human activity	- Increased risk for infection - Endotoxin can trigger wheezing
Dust mite	Pillow , mattress, cushion, carpet	- Allergic reaction - Increased risk for asthma

2.1.1 Specific pollutants and their health effects

Carbon monoxide

Carbon monoxide is a product of incomplete combustion of carbonaceous fuels; therefore, a major source is from combustion such as cooking, heating, and traffic. It is a colorless, non-irritant, odorless and tasteless gas. The only exogenous exposure route is by inhalation.

Carbon monoxide strongly binds to hemoglobin, forming carboxyhemoglobin (COHb) and causes hypoxemia and leftward shift in the oxyhemoglobin dissociation curve which means less oxygen release to tissue. Carbon monoxide has asphyxiating effect. Other health effects from carbon monoxide exposure include increase of ischemic heart disease symptoms and decrease of exercise tolerance, hospital admission or emergency department visit due to respiratory symptoms.

Nitrogen dioxide

Nitrogen dioxide is a free radical, a strong oxidant and corrosive, it is heavier than air. The principal source is road traffic; whereas, indoor sources also include tobacco smoke, burning of solid fuel, candles, mosquito coils.

It causes airway injury and inflammation, bronchoconstriction, decreases in immune defense, which can result in respiratory infection. There is suggestive evidence that exposure to indoor nitrogen dioxide is associated with increased respiratory symptoms both in children and adults.

Ozone

Ground level ozone is also a strong oxidant. The source is primarily from outdoor when pollutants such as oxides of nitrogen and volatile organic compounds are exposed to sunlight. It is irritative to airway causing respiratory symptoms, wheezing and shortness of breath, it can also aggravate asthma.

Sulfur Dioxide

Sulfur Dioxide can form harmful compounds such as sulfuric acid, sulfurous acid and sulfate particles. Its major sources come from fossil fuel combustion at power plants and other industrial processes such as extracting metal from ore, and the burning fuel containing sulfur.

SO_2 has many adverse effects on the respiratory system such as bronchoconstriction, increased asthma symptoms, increased emergency room visits, increased hospital admissions due to respiratory diseases, especially in children, elderly, and asthmatics.

Benzene

Benzene is a pollutant that usually has higher level indoors compared to outdoors. The sources are from materials used in building or furnishing such as polymer, rubber, adhesives, particleboard, paints. Fuel combustion and smoking can also be a source of Benzene. High level can result in death. Benzene exposure also impairs respiratory health.

According to the French National Research and Safety Institute, acute benzene exposure will cause no effect at 25 ppm (81 mg/m^3), headaches and asthenia from 50 to 100 ppm (162–325 mg/m^3, more accentuated symptoms at 500 ppm (1625 mg/m^3), tolerance for only 30–60 minutes at 3,000 ppm (9720 mg/m^3), and death in 5–15 minutes at 20,000 ppm (64 980 mg/m^3) due to asphyxia or central nervous system depression. Exposure to benzene also associated with haematologic diseases such as aplastic anaemia, pancytopenia, thrombocytopenia, granulopenia, lymphopenia and increased lifetime risk for leukaemia.

PM_{10}

PM_{10} or particles with an aerodynamic diameter smaller than 10 µm represents the particle mass that can enter the respiratory tract. Particulate matter includes coarse and fine particles. Course particles (diameter between 2.5 and 10 µm) can pass through upper airway, while fine particles (diameter less than 2.5 µm, known as $PM_{2.5}$) are small enough to pass through the lower airway.

Sources of PM10 are dust from traffic, construction, agriculture, and other activities. Particulate matters are associated with worsening respiratory symptoms, decreased lung function recurrent health care utilization, and also shown to have a small but significant adverse effect on cardiovascular and cerebrovascular disease.

Biological Pollutants

Biological pollutants include microorganisms and by-products such as bacteria, fungus, viruses, house dust mite, animal danders. These indoor pollutants level is usually linked to dampness and inadequate air exchange rate in the indoor space. Excess moisture promotes growth of these microbes.

Molds

Molds can cause infection and allergic reaction. They can also produce toxins. Exposure to indoor molds can lead to respiratory symptoms, respiratory infections, and exacerbation of asthma.

House dust mites

House dust mites are usually found in the pillows, mattresses, carpets, curtains, or cushions. Dermatophagoides (Der P1) is most prominent dust mite allergen.

There are evidence that exposure to Dermatophagoides in infancy is associated with increased prevalence of positive skin prick test and increased concentration of IgE specific to dust mite by age 5 in children of atopic parents [12]. Dermatophagoides level higher than 10 mcg/g are associated with 5 fold increase in the risk of asthma by age 11 years old [13].

Bacteria

Many human activities, such as sneezing, coughing, toilet flushing can generate airborne bacteria. Airborne bacteria can cause infections including respiratory and skin infections. Gram negative bacilli can produce endotoxin, and there is evidence that exposure to high endotoxin levels is associated with wheezing in childhood [14]

Summary of standards for indoor air quality is shown in Table 2.

Table 2: Standards for indoor air quality

Pollutants	*Short term (24 hr)*	*Long term (annual)*	*Reference*
PM_{10}	50 μg/m^3	20 μg/m^3	WHO
CO	100 mg/m^3 (15 min) 35 mg/m^3 (1 hr) 10 mg/m^3 (8 hr) 7 mg/m^3 (24 hr)	-	WHO
NO_2	200 μg/m^3	40 μg/m^3	WHO
Ozone	100 μg/m^3 (8 hr)	-	WHO
SO_2	20 μg/m^3	-	WHO
Microbial count (fungi/bacteria)	500 CFU/m^3		American Industrial Hygiene Association
Dust Mite Antigen	2 μg/g Threshold for sensitization		Peat JK et al.

2.1.2 Indoor air pollution in day care centers

DCCs are important sources of indoor air pollutants exposure for preschool children. There are more than 300 DCCs in Bangkok. Children usually spend five days a week at the DCCs during daytime, which account for approximately 40 – 45 hour per week.

There are a number of studies on the level of indoor air pollutants concentration in DCCs from different part of the world. The studies and results are summarized in Table 3.

Table 3: Previous studies on indoor air pollution in day care centers

Study	Place/Time	Data collected	Pollution data
Microbial counts and particulate matter levels in indoor air samples collected from a child home-care center in Bangkok, Thailand. J Med Assoc Thai 2012; 95 (Suppl. 6): S161-S168	20 households which were part of a child home-care center in Bangkok 2006-2007	- Microbial count - PM10 levels	- 47.2% and 47.6% of total air samples had bacterial and fungal counts higher than recommended levels - 47.0% of total air samples had PM10 levels higher than recommended level
Assessment of indoor environment in Paris child day care centers C. Roda et al. Environmental Research 111 (2011) 1010–1017	28 child day care centers	- Dust mite allergens - Endotoxins - Airborne fungi - Aldehydes - VOCs - NO_2 - CO_2 - temperature - Relative humidity	- Only one child day care center in cold season had total group1 House Dust Mite allergen levels greater than proposed sensitization threshold level of 2 mg/g - Airborne endotoxin levels in child day care centers were higher than those found in Paris dwellings - the levels for NO_2 being significantly higher than those measured in homes
Indoor air quality differences between urban and rural preschools in Korea Environ Sci Pollut Res (2011) 18:333–345	71 classrooms at 17 Korean preschools	- total suspended particulates - respirable particulates - lead - asbestos - volatile organic compounds - formaldehyde - CO_2	- Total dust concentration was highest in urban indoor settings followed by urban outdoor, rural indoor, and rural outdoor locations - Lead concentrations were much higher in urban than in rural areas
Inhalable particulate matter burden in selected day-care centres in Ibadan, Nigeria Godson R. E. E. Ana *International Journal of Environmental Monitoring and Analysis 2013; 1(6): 296-301*	48 day-care centres (DCCs) in Ibadan, South western Nigeria	- PM_{10}	- Mean indoor PM_{10} for wet season 73.4 ± 54.4µg/m³ and dry season 296.3 ± 61.6µg/m³ significantly exceeded guideline limit ($P<0.05$).
Airborne fungi and bacteria in child daycare centers and the effectiveness of weak acid hypochlorous water on controlling microbes	two child daycare centers in Tainan City in Taiwan	- indoor and outdoor airborne fungi and bacteria	- indoor microbial levels were above the IAQ recommendations/ standards of Taiwan, Korea, and Hong Kong (ranging from 500 to 1000 CFU/m_3 for both fungi and bacteria)

Nai-Tzu Chen, *J. Environ. Monit., 2012, 14, 2692*	2008		
Indoor Concentrations of PM10 and Factors Influencing Its Concentrations in Day Care Centres in Bangkok, Thailand Nareerut Pudpong *Asia J Public Health 2011;2(1):3-12*	25 DCCs in high-polluted area (H), 25 DCCs in low-polluted area (L) in Bangkok 2005	24-hour indoor PM_{10} level	- no significant difference in PM10 concentrations between the H (75.08μg/m^3) and L (69.93μg/m^3) area

2.2 Vulnerability of Children to Air Pollution

Children are more vulnerable to indoor air pollutants than adults, especially infants and preschool children because they spend most of their time indoor, and therefore are exposing more to indoor air pollutants. Children are exposed to proportionately larger dose of pollutants than adults because they have higher respiratory rate and minute ventilation by their physiology, and children also have larger lung surface area per body weight compared to adult. Furthermore, a child's breathing zone is closer to the ground than that of adults, and many aerosolized pollutants are heavier than air. These pollutants tend to have higher concentration near the ground so children will be exposed to a higher concentration of many pollutants when staying in the same indoor space with an adult.

Inflammation of the airway caused by exposure to air pollutants can cause airway edema. Airway diameter is smaller in children compared to adults so edema to the airway will have greater effect. Note that resistance to air flow is inversely proportional to the radius of the lumen to the fourth power for laminar flow, and to the radius of the fifth power for turbulent flow. A 1 mm circumferential edema in children results in 75% reduction in cross-sectional area and a 16-fold increase in airway resistance, compared to in adults. The same 1 mm of circumferential airway edema causes 44% reduction in cross-sectional area and only three-fold increase in airway resistance. The difference between effects of airway edema in children and adults is shown in Figure 1.

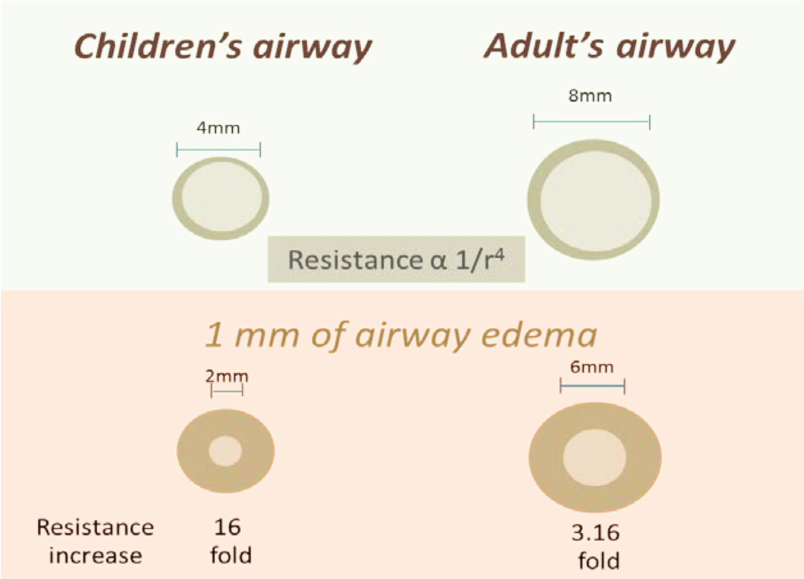


Figure 1: Effect of airway edema in children compared to adults

An adult has approximately 300 million alveoli in the lungs. A term newborn infant is born with 25 million alveoli. Alveolar development occurs rapidly during the first two years of life; after that, it slows down and stops at about 6-8 years old when the alveoli number reaches the same number with that in adult. After 6-8 years of age, linear increase in lung volume takes place until adolescence. Exposure to air pollutants at this developmental stage can cause more severe respiratory symptoms, including death from respiratory causes, and can cause long-term adverse effects on lung structure, as well as function. Furthermore, because of early exposure and longer life span of children compared to adult, children also have higher risk of developing cancers from air pollutants with carcinogenic property, as shown in Figure 2.

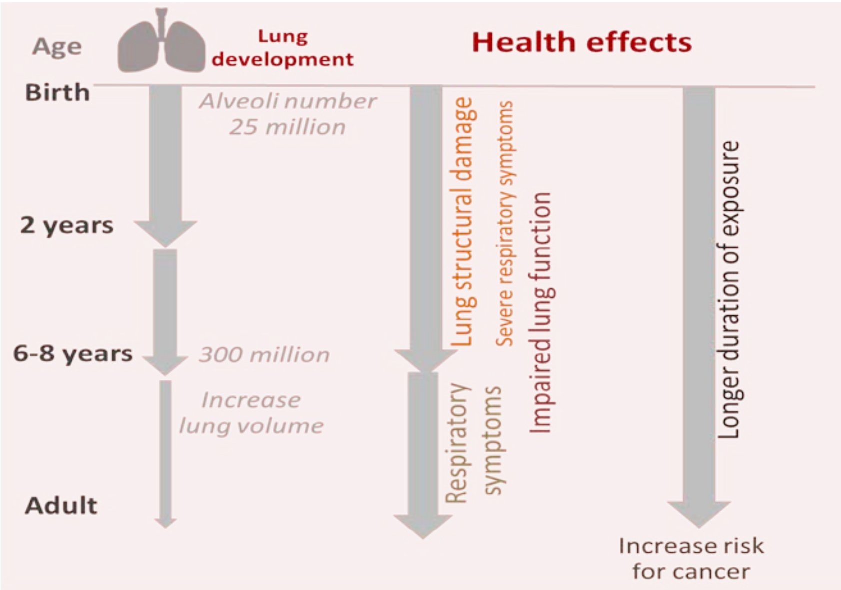


Figure 2: Lung development and risks from air pollution exposure

2.3 FENO (Fractional Exhaled Nitric Oxide)

Nitric oxide is a biological mediator, which is produced in the lung and present in the exhaled breath. Exhaled nitric oxide has been a standardized clinical test. The measurement is quantitative, noninvasive, simple, and safe. Nitric oxide synthase (NOS) is the enzyme required in formation of Nitric oxide.

There are three isoforms of NOS including neuronal cell NOS, inducible NOS, endothelial cell NOS. Inflammator cytokines upregulate inducible NOS, which can generate large quantities of NO.

The American Thoracic Association recommends the use of FENO in the diagnosis of eosinophilic airway inflammation, including asthma. There are also other diseases that can cause elevated level of exhaled NO such as atopy, nonasthmatic eosinophilic bronchitis, chronic obstructive pulmonary disease, exacerbations, noncystic fibrosis bronchiectasis, viral upper respiratory tract infection. Low levels of FENO can occur in cystic fibrosis, smoking, pulmonary hypertension, hypothermia, pulmonary ciliary dysfunction, bronchopulmonary dysplasia. Some of interpretation of FeNO values are shown in Table 4.

Table 4: Clinical guide to interpretation of FeNO values

	Low	Intermediate	High
FENO level for patient <12 years old	<20 ppb	20-35 ppb	>35 ppb
Diagnosis In patient with symptoms during past 6 weeks	Eosinophilic airway inflammation unlikely	Be cautious	Eosinophilic airway inflammation likely
Possible alternative diagnosis	▪ Hyperventiltion ▪ Cardiac disease ▪ COPD ▪ GERD ▪ Noneosinophilic asthma ▪ Rhinosinusitis ▪ Vocal cord dysfunction ▪ Cystic fibrosis ▪ Primary ciliary dyskinesis	▪ High level of allergen exposure ▪ Infection	▪ High level of allergen exposure ▪ Infection ▪ Eosinophilic bronchitis

CHAPTER 3 RESEARCH PLAN

3.1 Project Schedule

Table 5 shows the project planning schedule. All project members are scheduled to meet regularly to discuss the technical results performed by project research assistant, and directions of the project. Occasionally, the progress report will be presented to the advisors to further seek guidelines and comments of the results and future direction.

Table 5: Project planning schedule

Activity	2014									2015		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Literature review and ethics												
Questionnaire validation												
Collect data												
Statistical analysis												
Inception report submission	30-Apr											
Progress report presentation			24-Jun									
Interim report presentation						04-Sep						
Interim report submission						30-Sep						
Roundtable discussion/workshop												
Final report presentation												
Final report submission												31-Mar

3.2 Project Expenditure

Table 6 shows the breakdown of the project expenditure, which is mainly composed of the participation of the members and advisors. One research assistant (RA) is planned to be employed on the part time basis. Main expenses are for various measurements of indoor air pollutants; whereas, other necessary expenses such as transportation to gather data and office/computer supply are included. The project aims to present the preliminary result at a conference upon approval from ATRANS. Lastly, the expenses of secretariat's participation and report publishing are included.

Table 6: Project expenditure

No.	Item	Unit cost	Number of units	Sub total
1	Project leader & co-leader	3,000	12	36,000
2	Advisors participation in project meeting (1,000 THB/day x 2 persons x 4 days)	1,000	8	8,000
3	Members participation in bi-monthly project meeting (1,000 THB/day x 3 persons x 6 days)	1,000	18	18,000
4	Research assistants (200 THB/hr x 5 hrs/day x 5 days/month) for 12 months)	5,000	12	60,000
5	Misc. expenses for bi-monthly project meeting	1,500	6	9,000
6	Indoor air quality measurement for 40 visits -Particulate matter 400 THB/DCC -CO 400 THB/DCC -NO2 400 THB/DCC -SO2 400 THB/DCC -O3 400 THB/DCC -Benzene 400 THB/DCC -Bacteria count 400 THB/DCC -Fungi count 400 THB/DCC -Examinee/transports 1,500 THB/DCC -Dust mite level 2,000 THB/DCC - Questionaires/data collection 700 THB/DCC	7,400	40	296,000
7	FENO measurement for 100 children	100	100	10,000
8	Office & computer supply	1,500	6	9,000
9	Secretariat's participation portion	10,000	1	10,000
10	Publishing proportion of the report book	50,000	1	50,000
			Total	506,000

CHAPTER 4 STUDY PROCESS

4.1 Inclusion of day care centers and children

Eleven from total number of 301 day care centers in Bangkok were included into the study. We used computer-generated stratified random sampling to select day care centers from each region of Bangkok. The distribution of day care centers are as shown in Error! Reference source not found.**. Each day care center was contacted and invited to participate in the study. As shown in Figure 4, a meeting was held in May 2014 to give background information on the study, as well as detailed information on data collection and study process. Informed consents were obtained from every day care center. The day care centers included are listed in Table 8. Parents of all children in the 11 day care centers, who fit the inclusion criteria listed above, were sent an invitation letter to join in the study.**

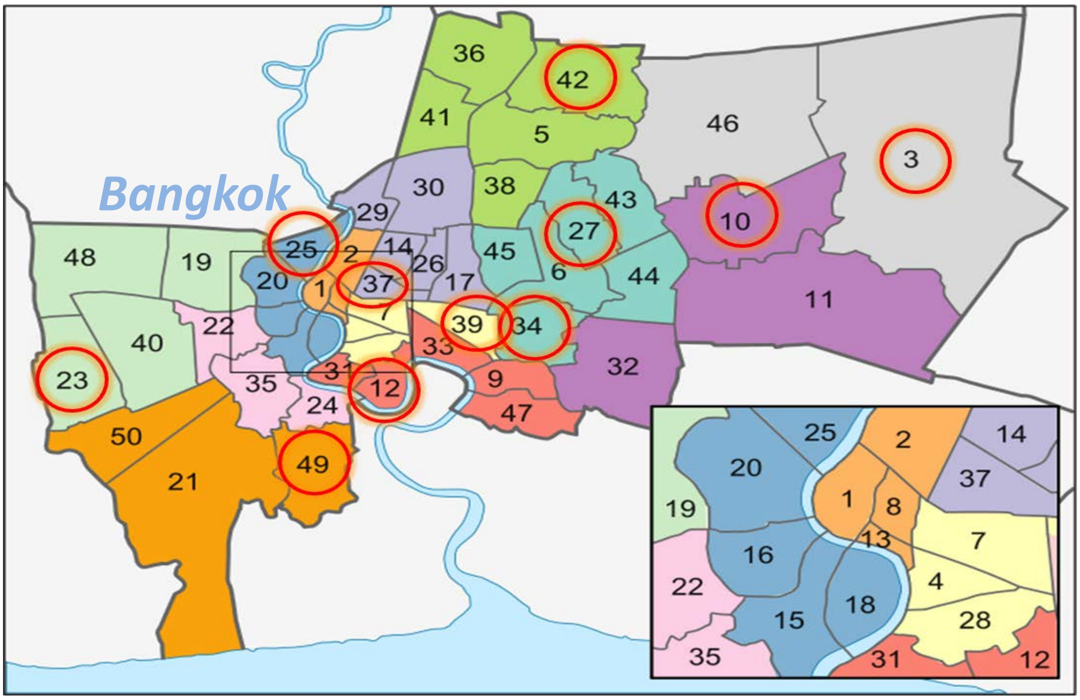


Figure 3: Distribution of Day Care Centers in the Study

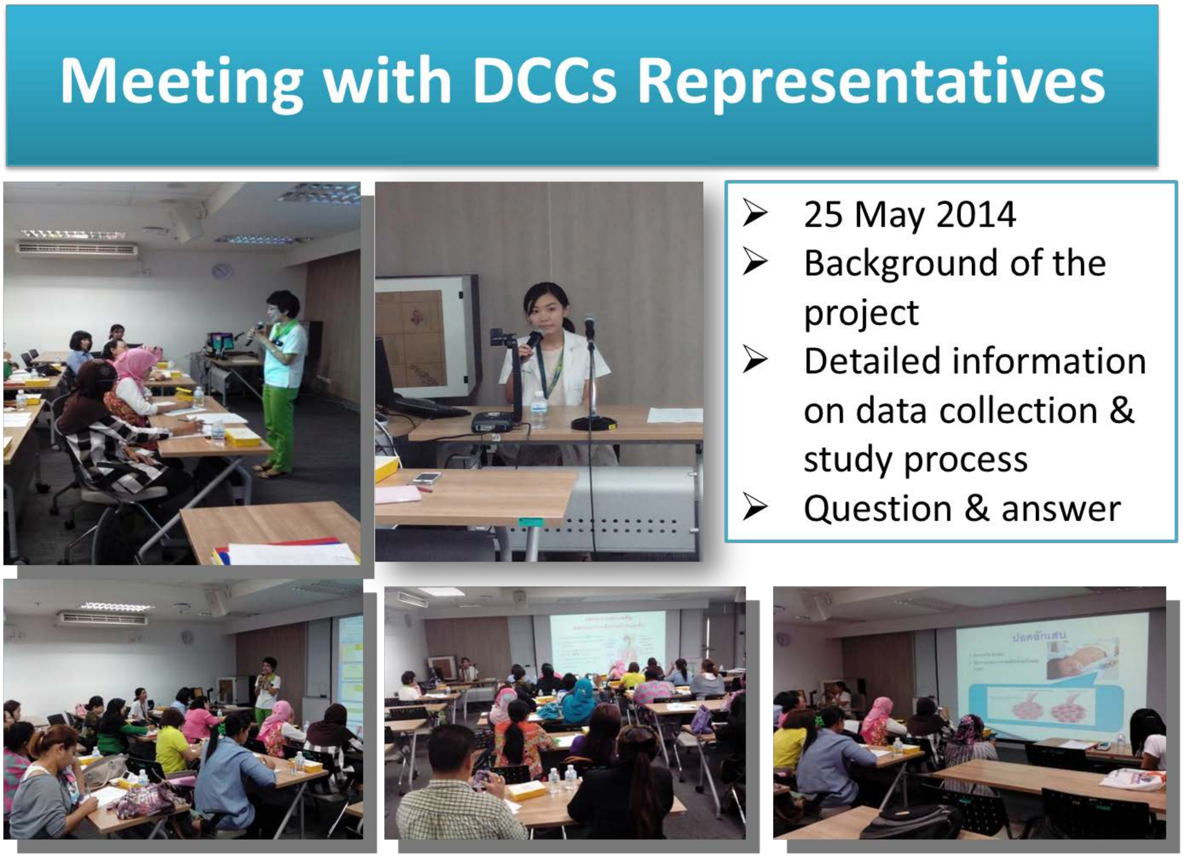


Figure 4: Meeting with DCCs representatives at the beginning of the project

Table 7: List of day care centers included in the study

Day Care Center	District	No. of children eligible	No. of children included	Response rate
DCC #1	Nong Jok	85	84	98.8%
DCC #2	Suan Luang	21	21	100%
DCC #3	Mean Buri	22	22	100%
DCC #4	Bung Koom	40	40	100%
DCC #5	Sai Mhai	20	15	75%
DCC #6	Yan Nawa	30	30	100%
DCC #7	Wattana	25	18	72%
DCC #8	Toong Kru	21	21	100%
DCC #9	Bangkok Noi	40	40	100%
DCC #10	Rachathewi	70	70	100%
DCC #11	Nong Khaem	105	75	71.4%

4.2 Day cay center visit and survey of environment

The day care centers were visited during their operation time, as shown in **Figure 5.** The research team surveyed every room in each day care center and nearby area to record data on the environmental characteristics including total indoor area, type of building material, ventilation system, proximity to traffic or water sources, visible signs of dampness or mold. Some information, such as year of construction, number of children, indoor cooking, presence of indoor pets, were obtained by interviewing of day care center staff.

Figure 5: Day care center (DCCs) visit for survey

4.3 The Questionnaires

As shown in **Figure 6**, two sets of questionnaires and one record form were used in the process of data collection in this study, namely.

แบบสอบถามสิ่งแวดล้อมในบ้าน และอาการทางระบบทางเดินหายใจของเด็กอายุต่ำกว่า 6 ปี

Home environment and respiratory symptoms questionnaire

ข้อมูลทั่วไปของเด็กในความปกครองของท่าน(Basic information)

1. ชื่อศูนย์พัฒนาเด็กก่อนวัยเรียน (name of day care center)________________

เด็กในความปกครองของท่านเข้าศูนย์พัฒนาเด็กก่อนวัยเรียนมาแล้วเป็นระยะเวลา____ปี_____เดือน (your child has attended the day care center for)_______(year)_______(month)

2. ชื่อเด็ก (child's name)________________อายุของเด็ก (age)______ปี(years)

วันเดือนปีเกิดของเด็ก(child's date of birth)________________

เพศของเด็ก(gender) ☐ ชาย (male) ☐ หญิง (female)

น้ำหนักของเด็ก (weight)_______กิโลกรัม (kg) ส่วนสูงของเด็ก (height)_______เซนติเมตร (cm)

น้ำหนักแรกเกิดของเด็ก(birth weight)_____กิโลกรัม(kg) มีพี่น้องรวม(number of siblings)_____คน

3. โรคประจำตัวของเด็ก (child's underlying disease) ☐ ไม่มี (no) ☐ มี (yes)

ระบุ (please specify)________________

ประวัติการแพ้ยา แพ้อาหารของเด็ก (child's history of drug/food allergy) ☐ ไม่มี (no) ☐ มี(yes)

ระบุ (please specify)________________

4. ใน 1 ปีที่ผ่านมาเด็กได้รับการฉีดวัคซีนป้องกันโรคไข้หวัดใหญ่หรือไม่ (During the past one year, has your child received influenza vaccine?)

☐ ได้รับ (yes) ☐ ไม่ได้รับ (no)

5. เด็กเคยได้รับนมมารดาหลังเกิดหรือไม่ (Had the child ever been breast-fed?)

☐ เคย (yes) นาน (for)____เดือน (months) ☐ ไม่เคย (no)

ข้อมูลครอบครัวและสิ่งแวดล้อมในบ้าน

1. จำนวนคนที่อาศัยในบ้าน (number of house members)_______คน

จำนวนผู้ใหญ่ (number of adults)________________คน

เด็กอายุต่ำกว่า 6 ปี (number of children under 6 years old)______________คน

เด็กอายุมากกว่า 6 ปี (number of children over 6 years old)______________คน

2. ผู้ดูแลหลักของเด็ก คือ (who is the child's main care taker?)

☐ บิดา (father) ☐ มารดา (mother) ☐ อื่นๆ (other) ระบุ please specify____________

บิดาของเด็กสูบบุหรี่หรือไม่ (Does the child's father smoke cigarettes?)

☐ สูบ (yes) ☐ ไม่สูบ (no)

ถ้าใช่ บิดาของเด็กสูบบุหรี่ประมาณวันละ_______มวน

(if yes, how many cigarettes does the child's father smoke each day?)______(cigarettes)

7. บ้านอยู่ห่างจากศูนย์พัฒนาเด็กก่อนวัยเรียนเป็นระยะทางประมาณ_______กิโลเมตร (The distance between your home and the day care center is about_____ kilometer)

เดินทางโดย________________(mean of transportation________________)

8. สัตว์เลี้ยงในบ้าน (Presence of pet indoors)

<u>ในช่วง 1 ปีที่ผ่านมา</u> คุณมีสัตว์เหล่านี้ในบ้านหรือไม่ (<u>in the past 1 year</u>, have you had these pets in your home?)

สุนัข (dogs) ☐ มี (yes) ☐ ไม่มี (no) แมว (Cats) ☐ มี (yes) ☐ ไม่มี (no)

<u>ในช่วง 1 ขวบปีแรกของเด็ก</u> คุณมีสัตว์เหล่านี้ในบ้านหรือไม่ (during the first year of your child's life, have you had these pets in your home?)

สุนัข (dogs) ☐ มี (yes) ☐ ไม่มี (no) แมว (Cats) ☐ มี (yes) ☐ ไม่มี (no)

9. ท่านใช้เครื่องปรับอากาศในบ้านหรือไม่ (Do you use air-conditioner in your home?)

☐ ใช้เครื่องปรับอากาศ (Use air-conditioner)

☐ ใช้พัดลม (use electrical fan) ☐ ไม่ใช้ (none)

10. ท่านใช้เชื้อเพลิงชนิดใดในการประกอบอาหารในบ้านของท่าน (in your house, what fuel is usually used for cooking?)

☐ ไฟฟ้า (electricity) ☐ แก๊ส (gas) ☐ กองไฟ,เตาถ่าน (open fire)

11. ถนนบ้านของท่านมีรถบรรทุกวิ่งผ่านไปมาบ่อยเพียงใด (how often do trucks pass through the street where you live?)

☐ ไม่มีเลย (never) ☐ นานๆครั้ง (seldom)

☐ มีบ้างในแต่ละวัน (Frequently through the day) ☐ มีเกือบทั้งวัน (Almost the whole day)

12. บ้านของคุณมีรอยน้ำรั่ว หรือรอยเชื้อราในบ้านบ้างหรือไม่ (Do you have any water leakage or visible sign of molds in your home?)

☐ มี (yes) ☐ ไม่มี (no)

3. ระดับการศึกษา (Education)

<u>บิดา</u> (Child's father)

☐ น้อยกว่าประถมศึกษา (lower than primary school) ☐ ประถมศึกษา (primary school)

☐ มัธยมศึกษา/ปวช./ปวส. (Secondary school) ☐ ปริญญาตรี Bachelor degree

☐ สูงกว่าปริญญาตรี (higher than Bachelor degree)

<u>มารดา</u> (Child's mother)

☐ น้อยกว่าประถมศึกษา (lower than primary school) ☐ ประถมศึกษา (primary school)

☐ มัธยมศึกษา/ปวช./ปวส. (Secondary school) ☐ ปริญญาตรี Bachelor degree

☐ สูงกว่าปริญญาตรี (higher than Bachelor degree)

<u>ผู้ดูแลหลัก</u> (หากผู้ดูแลหลักเป็นบิดาหรือมารดา ไม่ต้องตอบ)

Child's main care taker (if the main care taker is father or mother, skip to 4.)

☐ น้อยกว่าประถมศึกษา (lower than primary school) ☐ ประถมศึกษา (primary school)

☐ มัธยมศึกษา/ปวช./ปวส. (Secondary school) ☐ ปริญญาตรี Bachelor degree

☐ สูงกว่าปริญญาตรี (higher than Bachelor degree)

4. รายได้รวมเฉลี่ยต่อเดือนของครอบครัว (total monthly family income)

☐ <10,000 บาท (Baht) ☐ 10,000-30,000 บาท (Baht) ☐ >30,000 บาท (Baht)

5. ประวัติโรคภูมิแพ้ของบิดามารดา (parents allergic diseases)

บิดา (Child's father)

☐ แพ้อากาศ (hay fever) ☐ หอบหืด (asthma)

☐ ผื่นแพ้ผิวหนัง (eczema) ☐ ไม่มี (none)

มารดา (Child's mother)

☐ แพ้อากาศ (hay fever) ☐ หอบหืด (asthma)

☐ ผื่นแพ้ผิวหนัง (eczema) ☐ ไม่มี (none)

6. การสูบบุหรี่ในบ้าน (indoor cigarette smoking) ☐ มี (yes) ☐ ไม่มี (no)

จำนวนคนที่สูบบุหรี่ (Number of smokers in home)______คน (persons)

มารดาของเด็กสูบบุหรี่หรือไม่ (Does the child's mother smoke cigarettes?)

☐ สูบ (yes) ☐ ไม่สูบ (no)

ถ้าใช่ มารดาของเด็กสูบบุหรี่ประมาณวันละ____มวน

(if yes, how many cigarettes does the child's mother smoke each day?)______(cigarettes)

มารดาของเด็กสูบบุหรี่ในช่วงขวบปีแรกของเด็กหรือไม่ (Does the child's mother smoke cigarettes during the child's first year of life?) ☐ ใช่ (yes) ☐ ไม่ใช่ (no)

***ข้อมูลเกี่ยวกับอาการหอบ** (Questionnaire for asthma)*

กรุณาทำเครื่องหมาย ✓ ลงในช่องคำตอบที่ตรงกับอาการของลูกของคุณ

(Please put a tick ✓ in your answer box)

1. ลูกของคุณ<u>เคย</u>หายใจมีเสียงวี้ด หรือหายใจมีเสียงคล้ายนกหวีดในทรวงอก (หน้าอก) ของลูกของคุณมาก่อนหรือไม่ ☐ เคย (yes) ☐ ไม่เคย (No)

   หากไม่เคย ข้ามไปข้อ 6

   (Has your child <u>ever</u> had wheezing or whistling in the chest at any time in the past?)

   (IF YOU HAV ANSWERED "NO" PLEASE SKIP TO QUESTION 6)

2. <u>ในช่วงเวลา 12 เดือนที่ผ่านมา</u> ลูกของคุณเคยหายใจมีเสียงวี้ด หรือหายใจมีเสียงคล้าย นกหวีดในทรวงอกบ้างหรือไม่ ☐ เคย (yes) ☐ ไม่เคย (No)

   หากไม่เคย ข้ามไปข้อ 6

   (Has your child had wheezing or whistling in the chest <u>in the past 12 months</u>?)

   (IF YOU HAV ANSWERED "NO" PLEASE SKIP TO QUESTION 6)

3. <u>ในช่วง 12 เดือนที่ผ่านมา</u> ลูกของคุณมีอาการหายใจมีเสียงวี้ด หรือมีอาการหอบหืดเป็นจำนวนกี่ครั้ง ☐ 1-3 ครั้ง (1-3 times) ☐ 4-12 ครั้ง (4-12 times) ☐ มากกว่า 12 ครั้ง (over 12)

   (How many attacks of wheezing has your child had <u>in the past 12 months</u>?)

4. <u>ในช่วง 12 เดือนที่ผ่านมา</u> ลูกของคุณเคยต้องตื่นจากการนอนหลับเพราะหายใจมีเสียงวี้ดโดยเฉลี่ยกี่ครั้งต่อ 1 สัปดาห์

   (<u>In the past 12 months</u>, how often, on average, has your child's sleep been disturbed due to wheezing?)

   ☐ ไม่เคย (never woken with wheezing)

   ☐ น้อยกว่า 1 ครั้ง/สัปดาห์ (Less than one night per week)

   ☐ เท่ากับหรือมากกว่า 1 ครั้ง/สัปดาห์ (one or more nights per week)

5. <u>ในช่วง 12 เดือนที่ผ่านมา</u> ลูกของคุณเคยหอบหรือหายใจมีเสียงวี้ดรุนแรงจนเหนื่อยมากและทำให้พูดได้เพียง 1-2 คำต่อเนื่องกันแล้วต้องหยุดหายใจหรือไม่

   (<u>in the past 12 months</u>, has wheezing ever been severe enough to limit your child speech to only one or two words at a time between breaths?)

   ☐ เคย (yes)

   ☐ ไม่เคย (No)

6. ลูกของคุณเคยเป็นโรคหอบหืดหรือไม่ (Has your child ever had asthma?)
☐ เคย (yes)
☐ ไม่เคย (no)

7. ในช่วง 12 เดือนที่ผ่านมา ลูกของคุณเคยหายใจมีเสียงวี๊ดในระหว่างหรือหลังจากการออกกำลังกายหรือไม่
(In the past 12 months, has your child's chest sounded wheezy during or after exercise?)
☐ เคย (yes)
☐ ไม่เคย (no)

8. ในช่วง 12 เดือนที่ผ่านมา ลูกของคุณเคยมีอาการไอแห้งๆ ในเวลากลางคืน โดยไม่ได้เป็นหวัดและไม่ได้มีอาการติดเชื้อของระบบทางเดินหายใจมาก่อนหรือไม่
(In the past 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or chest infection?)
☐ เคย (yes)
☐ ไม่เคย (no)

***ข้อมูลเกี่ยวกับอาการหวัด** (Questionnaire for rhinitis)*
กรุณาทำเครื่องหมาย ✓ ลงในช่องคำตอบที่ตรงกับอาการของลูกของคุณ
(Please put a tick ✓ in your answer box)

1. ลูกของคุณเคยมีอาการจาม น้ำมูกไหล แน่นจมูกหรือคัดจมูกในขณะที่ลูกของคุณไม่ได้เป็นหวัดหรือไข้หวัดใหญ่บ้างหรือไม่
(Has your child ever had a problem with sneezing, or a runny, or blocked nose when he/she DID NOT have a cold or the flu?)
☐ เคย (yes)
☐ ไม่เคย (no)

หากไม่เคย ข้ามไปข้อ 5 (IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 5)

2. ในช่วง 12 เดือนที่ผ่านมา ลูกของคุณเคยมีอาการจาม น้ำมูกไหลแน่นจมูกหรือคัดจมูกในขณะที่ลูกของคุณไม่ได้เป็นหวัดหรือไข้หวัดใหญ่บ้างหรือไม่
(In the past 12 months, has your child had a problem with sneezing, or a runny, or blocked nose when he/she DID NOT have a cold or the flu?)
☐ เคย (yes)
☐ ไม่เคย (no)

หากไม่เคย ข้ามไปข้อ 5 (IF YOU HAVE ANSWERED "NO" PLEASE SKIP TO QUESTION 5)

3. ในช่วง 12 เดือนที่ผ่านมา อาการจมูกของลูกคุณเคยเกิดร่วมกับอาการคันตาและมีน้ำตาไหลหรือไม่
(In the past 12 months, has this nose problem been accompanied by itchy-watery eyes?)
☐ เคย (yes)
☐ ไม่เคย (no)

4. ในช่วง 12 เดือนที่ผ่านมา ปัญหาทางจมูกรบกวนกิจวัตรประจำวันของลูกคุณมากเพียงใด
(In the past 12 months, how much did this nose problem interfere with your child's daily activities?)
☐ ไม่รบกวน (not at all) ☐ เล็กน้อย (a little)
☐ ปานกลาง (a moderate amount) ☐ มาก (a lot)

5. ลูกของคุณเป็นโรคแพ้อากาศหรือไม่ (Has your child ever had hayfever?)
☐ เป็น (yes)
☐ ไม่เป็น (no)

(a)

แบบสอบถามอาการทางระบบทางเดินหายใจของเด็กโดยผู้ปกครอง

Respiratory symptoms questionnaire by parents

ชื่อ(name)____________อายุ(age)___ชื่อศูนย์พัฒนาเด็กก่อนวัยเรียน(day care center)____________
*ในช่วง 1 สัปดาห์ที่ผ่านมาลูกของคุณไปศูนย์พัฒนาเด็กก่อนวัยเรียน__________ วัน
(*For the past week, your child has been to the day care center for_______days)

กรุณาทำเครื่องหมาย ✓ ลงในช่องคำตอบที่ตรงกับอาการของลูกของคุณ (Please put a tick ✓ in your answer box)
ในช่วง 1 สัปดาห์ที่ผ่านมา *(During the past 1 week)*

1. ลูกของคุณเคยมีอาการคัดจมูก (Has your child had blocked nose?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
2. ลูกของคุณเคยมีอาการจาม (Has your child had sneezing?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
3. ลูกของคุณเคยมีอาการคันจมูก (Has your child had itchy nose?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
4. ลูกของคุณเคยมีอาการน้ำมูกไหล (Has your child had runny nose?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
5. ลูกของคุณเคยมีอาการไอ (Has your child had cough?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
6. ลูกของคุณเคยมีอาการหอบ (Has your child had shortness of breath?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
7. ลูกของคุณเคยมีอาการตัวร้อน/มีไข้ (Has your child had fever?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
8. ลูกของคุณหยุดเรียนเพราะอาการใดๆในข้อ 1-7 หรือไม่ (Has your child been absent from class because of any symptoms from 1-7?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
ถ้าใช่ จำนวนวันที่หยุด _____ วัน (if yes, the number of absent days is _____ day(s))
9. ในช่วง 1 สัปดาห์ที่ผ่านมา ลูกของคุณต้องไปพบแพทย์เนื่องจากอาการใดๆในข้อ 1-7 หรือไม่ (Has your child visited a doctor because of any symptoms from 1-7?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
ถ้าใช่ การวินิจฉัย (if yes, diagnosis was)____________________________
ยาที่ได้รับ (medication received)____________________________
10. ในช่วง 1 สัปดาห์ที่ผ่านมา ลูกของคุณต้องนอนโรงพยาบาลเนื่องจากอาการใดๆในข้อ 1-7 หรือไม่ (Has your child been admitted to a hospital because of any symptoms from 1-7?)
☐ ใช่ (yes) ☐ ไม่ใช่ (No)
ถ้าใช่ การวินิจฉัย (if yes, diagnosis was)____________________________
จำนวนวันที่นอนโรงพยาบาล (length of hospital stay)______วัน (day(s))

(b)

Teacher Respiratory symptoms Report

แบบบันทึกอาการทางระบบทางเดินหายใจรายสัปดาห์โดยครู

ชื่อ(Name)________________________________ อายุ (Age) __________ปี (Year)

คำชี้แจง: บันทึกอาการทางระบบทางเดินหายใจของนักเรียน สัปดาห์ละครั้งทุกวันจันทร์ รวม 4 สัปดาห์

กรุณาทำเครื่องหมาย ✓ ลงในช่องหากเด็กมีอาการดังกล่าว ในวันที่ทำการบันทึก

Instructions :Please record respiratory symptoms of the student once a week on every Monday for 4 weeks,

Please check ✓ in the box if the student has these following symptoms

อาการ(Symptoms) / วันที่ทำการบันทึก (Date)	คันหรือเคืองตา หรือตาแดง ตาแฉะ (Itchy or irritated eye/red eye/eye discharge)	คัดจมูก (Blocked nose)	คันจมูก (itchy nose)	จาม (Sneezing)	น้ำมูกไหล (Runny Nose)	ไอ (Cough)	หอบ (Shortness of breath)	ตัวร้อนหรือมีไข้ (Fever)
วันจันทร์ที่__________ (Monday)								
วันจันทร์ที่__________ (Monday)								
วันจันทร์ที่__________ (Monday)								
วันจันทร์ที่__________ (Monday)								

(c)

Figure 6: Questionnaires for (a) baseline characteristic and home environment, (b) parent respiratory symptoms and record form for (c) teacher respiratory symptoms

4.3.1 Baseline Characteristic and Home Environment Questionnaire

This questionnaire, as shown in Figure 6(a), was distributed at the beginning of the study. The questionnaire is divided into 4 parts. The first part contained questions on the child's general information and health status such as date of birth, current height and weight, birth weight, underlying diseases, drug or food allergy, number of siblings, history and duration of breast feeding, immunization for influenza in the past year, duration of attendant to day care center. The second part focuses on family background and home environment. Questions consist of total number of people in the household, relationship of main caretaker with the child, education level of parents and main caretaker, family income, maternal and paternal atopic diseases, indoor smoking, paternal and maternal smoking, indoor pets exposure, indoor cooking fuels, home ventilation system, visible sign of water leakage or mold, home proximity to traffic, transportation to daycare center, distance between home and day care center. The third and the fourth parts of the questionnaire are about symptoms of asthma and allergic rhinitis, respectively.

4.3.2. Parent Respiratory Symptoms Questionnaire

This questionnaire, as shown in Figure 6(b), was distributed weekly for 4 weeks during each season of data collection. The questions are on parent-report respiratory symptoms including blocked nose, sneezing, itchy nose, runny nose, cough, shortness of breath, and also fever to suggest infectious etiology. Questions on the number of days the child was presented to the day care center and the number of days absent for respiratory illness during the week were also included, as well as doctor visit attributable to respiratory illness, diagnosis, prescribed medication, hospital admission and length of hospital stay.

The two questionnaires above were pilot tested on 30 parents of children attending Ramathibodi hospital's day care center before distribution to parents of all children in the study.

4.3.3. Teacher Respiratory Symptom Record Form

As shown in **Figure 6(c)**, teachers record respiratory symptoms of children including blocked nose, sneezing, itchy nose, runny nose, cough, shortness of breath, and fever on every Monday for 4 consecutive weeks. The record also includes information on any medication the child took during the day at the day care center.

4.4 Pollutant measurement

During each day care center visit, research member team collect air sample from the children's room and measure for pollutants, as shown in **Figure 7.** PM_{10} was measured by gravimetric techniques. Measurement of benzene, CO and Ozone use gas chromatography technique, whereas NO_2 and SO_2 use ion chromatography technique. For biological pollutants, bacterial and fungus count are carried out by air sampling equipment connected to a cell-culture dish container, microbes then are incubated in the laboratory and measured for colony forming units. Specimen for dust mite antigen level measurement is collected from children's bedding material using vacuum pump and send for laboratory analysis.

(a) PM_{10}, CO, O_3, NO_2, SO_2 (b) Microbial count (c) Dust mite antigen

Figure 7: Specimen collection for pollutant measurement

4.5 FENO measurement

Ten children were randomly selected from each day care center and scheduled for exhaled nitric oxide level measurement. Written informed consents by parents were acquired. Details on the test procedure were provided to parents before the scheduled test by letters, and also by demonstration of the process before performing the test. The technique used in children is multiple-breath FENO measurement, requiring each child to breath into a face mask for one minute, as shown in **Figure 8.** The tests were performed three times on each child to obtain the mean FENO value.

Figure 8: FENO measurement

CHAPTER 5 RESULTS

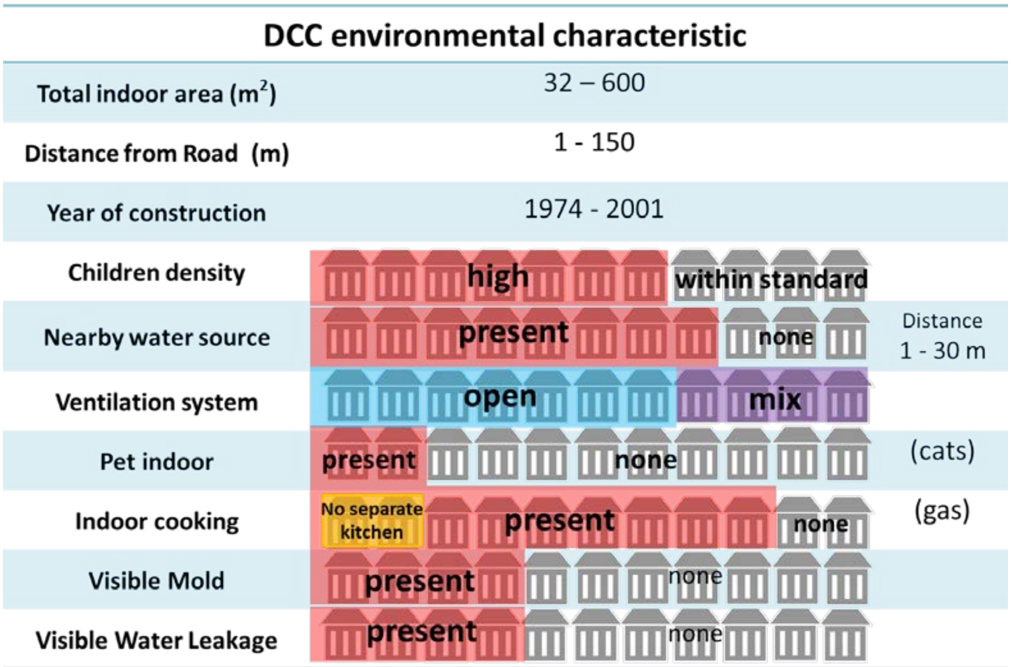
5.1 Day care center environmental characteristics

As shown in Figure 9, the size of indoor area of the day care centers in this study range from 32 to 600 meter square. Total number of children in each day care center ranges from 40 to 630 children. According to Thailand day care center standard formulated by Ministry of Public Health, each child should have a space of at least 2 meter square. Therefore, children density should be lower than 0.5 person per meter square. In this study, children density range from 0.27 to 2.34 persons per meter square, where 6 out of 11 (54.5%) day care centers have higher children density than the standard recommendation.

The building materials of all day care centers in our study are of concrete, where 36.4% were built from concrete and wood in combination. The time since construction of these day care centers ranges from 13 to 40 years, with the mean value of 23.72 years. Most day care centers (81.8%) are within 100 meters distance from road traffic. There is one day care center located very close to the railroad traffic. 7 from 11 day care centers (63.6%) have a water resource in the nearby area.

For ventilation system, open ventilation is used exclusively in 7 day care centers, while the rest use both open and close (mixed) ventilation system. Indoor cats are also reported in two day care centers. Total number of 9 day care centers have indoor cooking activity, mostly in a separate kitchen; whereas, two day cares center has cooking activity with no separate kitchen. Cooking fuel used is gas in all day care centers. More than half (54.5%) of the day care centers in this study have visible sign of dampness or mold indoor.

Figure 9: Environmental characteristics data of day care centers



5.2 Pollutant level

The pollutant levels measured from each day care center are as shown in Table 8, which show that PM_{10} level is higher than WHO indoor air quality standard level (50 mcg/m^3) in 7 and 6 out of 11 DCCs (63.6%) in rainy season and winter, respectively.

Table 8: Pollutants level data

DCC	Particulate matter and Chemicals (mg/m^3)											
	PM_{10}		Benzene		O_3		NO_2		SO_2		CO	
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
DCC 1	0.081	0.039	<0.003	<0.003	0.018	0.156	0.018	0.020	0.012	0.021	0.502	0.78
DCC 2	0.042	0.058	<0.003	<0.003	0.028	0.196	0.025	0.015	0.014	0.012	0.707	1.10
DCC 3	0.076	0.042	<0.003	<0.003	0.014	0.088	0.020	0.022	0.010	0.012	0.536	0.75
DCC 4	0.082	0.063	<0.003	<0.003	0.012	0.110	0.028	0.020	0.020	0.018	0.524	0.70
DCC 5	0.042	-	<0.003	-	0.010	-	0.018	-	0.010	-	0.741	-
DCC 6	0.041	0.205	<0.003	<0.003	0.024	0.124	0.032	0.025	0.021	0.014	0.638	0.97
DCC 7	0.168	0.021	0.105	<0.003	0.010	0.150	0.018	0.028	0.011	0.014	0.536	1.43
DCC 8	0.084	0.042	0.054	<0.003	0.024	0.184	0.015	0.024	0.014	0.016	0.729	0.67
DCC 9	0.089	0.105	<0.003	<0.003	0.044	0.164	0.015	0.022	0.020	0.015	0.559	1.17
DCC 10	0.021	0.097	<0.003	<0.003	0.056	0.104	0.020	0.018	0.011	0.012	0.901	1.12
DCC 11	0.133	0.084	<0.003	<0.003	0.008	0.044	0.028	0.018	0.014	0.012	0.410	0.56
WHO Standard indoor air	0.050 (24hr)		-		0.10 (8hr)		0.040		0.020 (24 hr)		10 (8 hr.)	

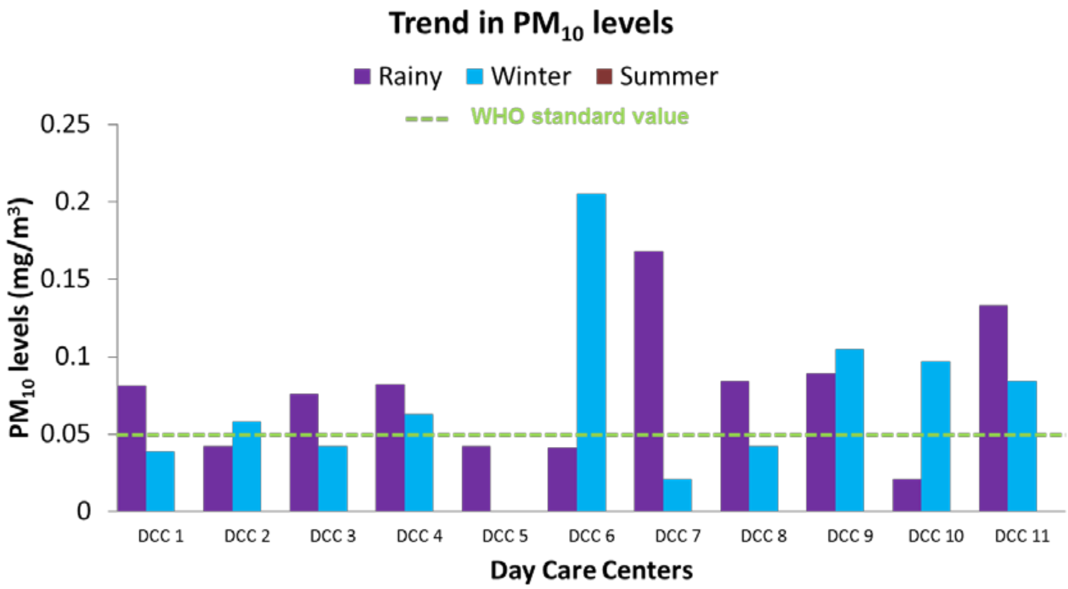
(a)

DCC	Microbes (CFU/m^3) Standard < 500 CFU/m^3				Dust Mites(ug/g) ST < 2mcg/g			
	Bacteria		Fungi		Der P1		Der F1	
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
DCC 1	254	120	240	332	<0.2	<0.2	<0.2	<0.2
DCC 2	1322	3534	989	1456	<0.2	1.48	<0.2	<0.2
DCC 3	346	452	261	240	<0.2	<0.2	<0.2	<0.2
DCC 4	989	1647	537	792	<0.2	0.38	<0.2	<0.2
DCC 5	367	-	325	-	<0.2	-	<0.2	-
DCC 6	276	622	410	975	3.13	<0.2	<0.2	<0.2
DCC 7	2989	3767	530	551	<0.2	0.83	<0.2	<0.2
DCC 8	926	572	601	346	<0.2	0.41	<0.2	0.17
DCC 9	721	1689	163	1138	<0.2	<0.2	<0.2	<0.2
DCC 10	982	1223	325	728	<0.2	4.25	<0.2	<0.2
DCC 11	509	1223	205	636	<0.2	<0.2	<0.2	<0.2

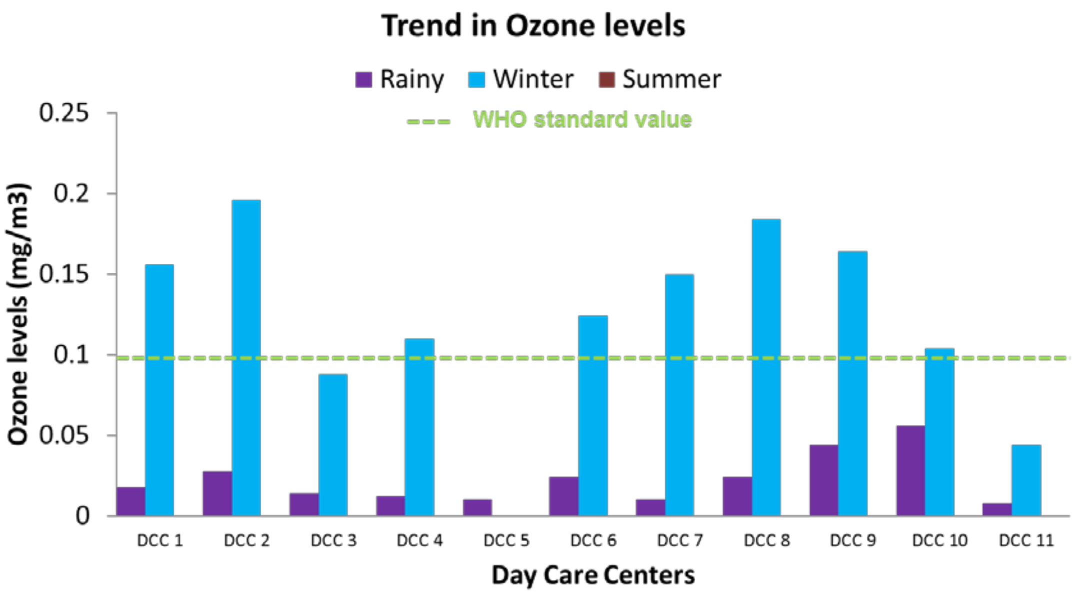
(b)

As shown in Figure 10 for chemical pollutants, indoor levels of PM_{10}, ozone and SO_2 in some day care centers exceed WHO limit; whereas, CO and NO_2 are within the standard values in both seasons. Ozone levels in rainy season in all DCCs are within normal limit; whereas, in winter, ozone level exceeds standard in 8 out of 11 DCCs. SO_2 levels are slightly higher than recommended level in 3 day care centers in rainy season and 1 day care center in winter.

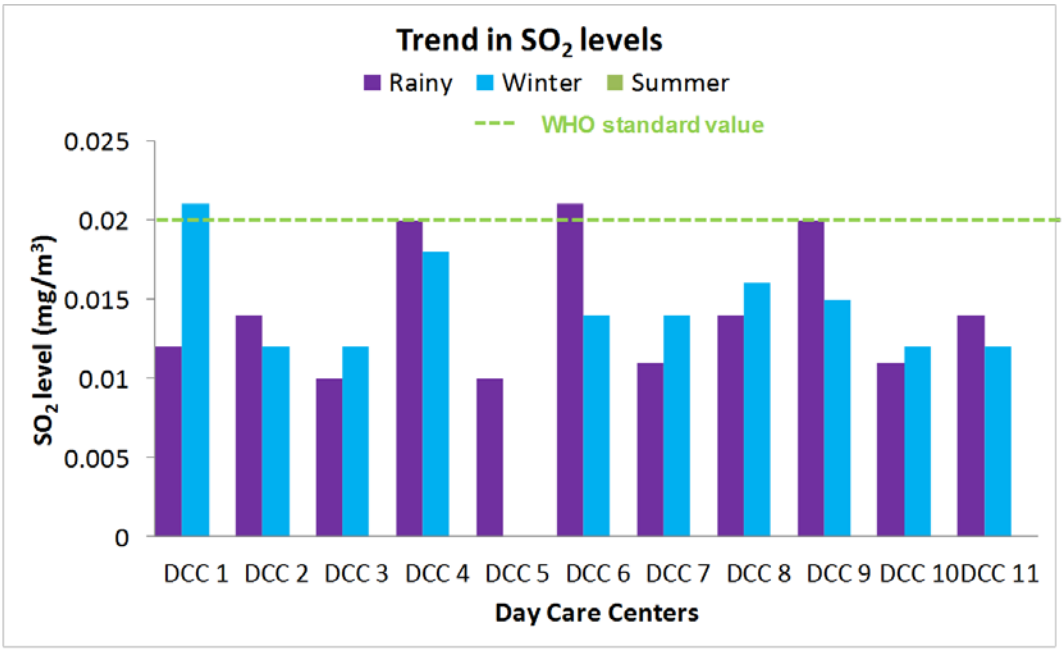
For benzene, due to its carcinogenic effect, World Health Organization states that no safe level of exposure can be recommended. Studies revealed that every 1 mcg/m^3 of benzene concentration, excess lifetime risk for leukemia increase by 6 x 10^{-6}. In Hong Kong, the airborne benzene level of less than 0.0161 mg/m^3 is used as an objective for good indoor air quality. In the present study, there are two day care centers with benzene level exceeding 0.0161 mg/m^3 in rainy season; while in winter, benzene levels are within standard in all day care centers.


Trend in PM_{10} levels
Rainy
Winter
Summer
WHO standard value
0.25
0.2
0.15
0.1
0.05
0
PM_{10} levels (mg/m^3)
DCC 1
DCC 2
DCC 3
DCC 4
DCC 5
DCC 6
DCC 7
DCC 8
DCC 9
DCC 10
DCC 11
Day Care Centers

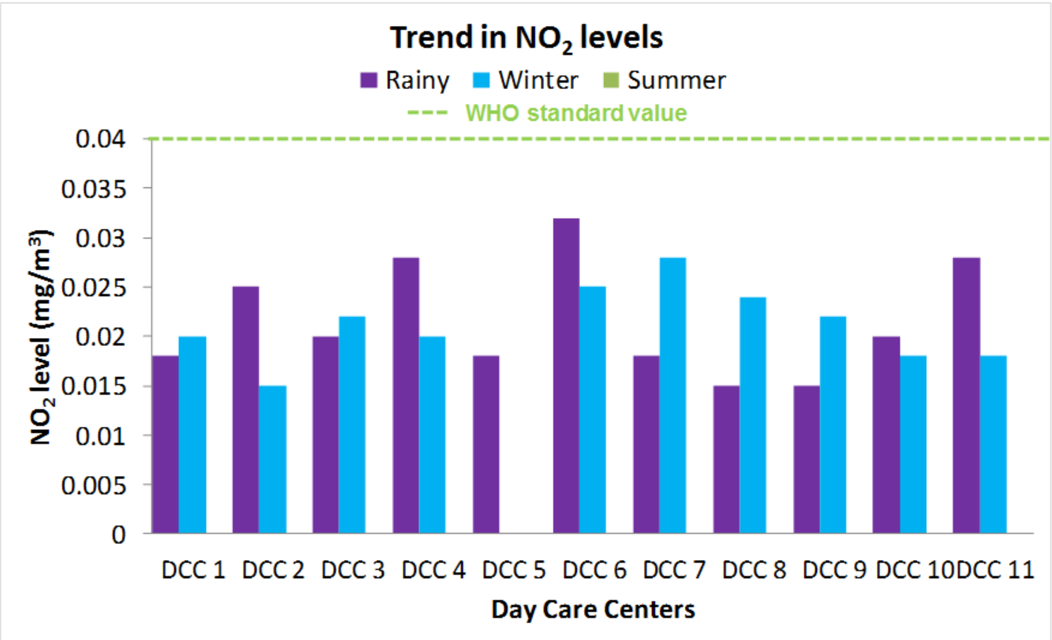
(a)


Trend in Ozone levels
Rainy
Winter
Summer
WHO standard value
0.25
0.2
0.15
0.1
0.05
0
Ozone levels (mg/m3)
DCC 1
DCC 2
DCC 3
DCC 4
DCC 5
DCC 6
DCC 7
DCC 8
DCC 9
DCC 10
DCC 11
Day Care Centers

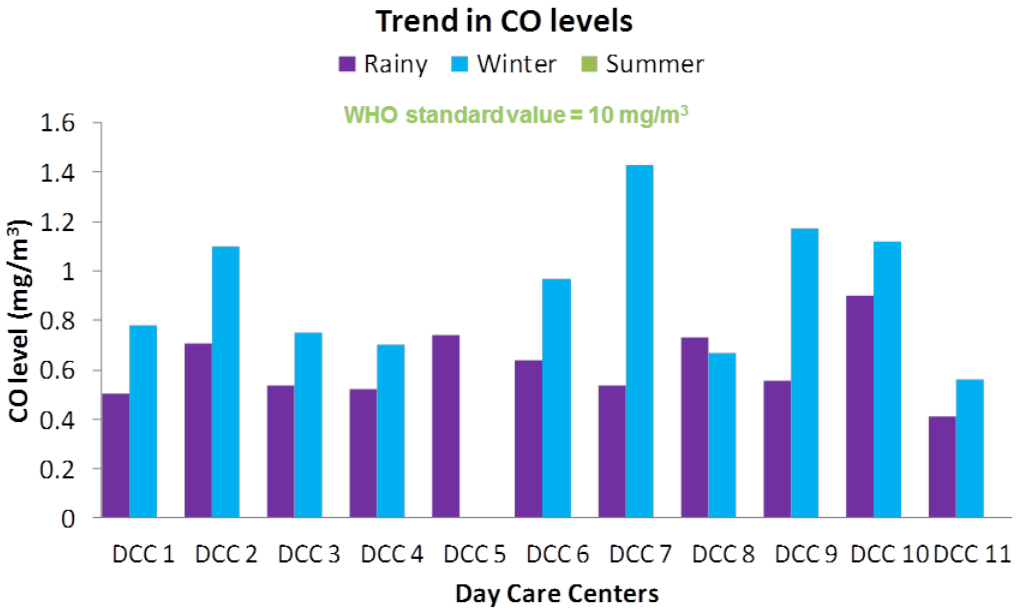
(b)


Trend in SO_2 levels
Rainy
Winter
Summer
WHO standard value
0.025
0.02
0.015
0.01
0.005
0
SO_2 level (mg/m^3)
DCC 1
DCC 2
DCC 3
DCC 4
DCC 5
DCC 6
DCC 7
DCC 8
DCC 9
DCC 10
DCC 11
Day Care Centers

(c)


Trend in NO_2 levels
Rainy
Winter
Summer
WHO standard value
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
NO_2 level (mg/m^3)
DCC 1
DCC 2
DCC 3
DCC 4
DCC 5
DCC 6
DCC 7
DCC 8
DCC 9
DCC 10
DCC 11
Day Care Centers

(d)



(e)

Figure 10: Seasonal trend of chemical pollutants: (a) PM10, (b) ozone, (c) SO2, (d) NO2 and (e) CO in all DCCs during rainy and winter seasons

As for biological pollutants shown in Table 8(b), bacterial counts are high in specimens from 7 day care centers (63.6%) in rainy season, with highest level of 2,989 CFU/m^3, which can be harmful to health. In winter, levels of airborn bacteria are high in 8 day care centers, 7 of which also have high bacterial count in rainy season. Airborne fungi counts are high in 4 day care centers in rainy season and 7 day care centers in winter, all of which also have high bacterial count. Dust mite antigen measurement reveals that only one day care center in each season has DerP1 antigen level higher than the sensitization threshold of 2 mcg/g.

In order to investigate the effect of outdoor pollutants to indoor level, outdoor and indoor pollutants are compared in 4 DCCs located not far away from Thai Pollution Control Department's pollution monitoring stations, as shown in Figure 11, where one DCC is as close as 40 meters from the pollution monitoring station. The comparison of indoor and outdoor pollutant levels are shown in Figure 12. Most indoor pollutants levels are within the range between minimum and maximum outdoor levels, except for PM_{10} levels, which indoor levels exceed maximum outdoor levels in 2 DCCs. The other 7 DCCs are located far away from pollution monitoring station (over 4 kilometers); therefore, the outdoor and indoor levels might not be comparable in these DCCs.

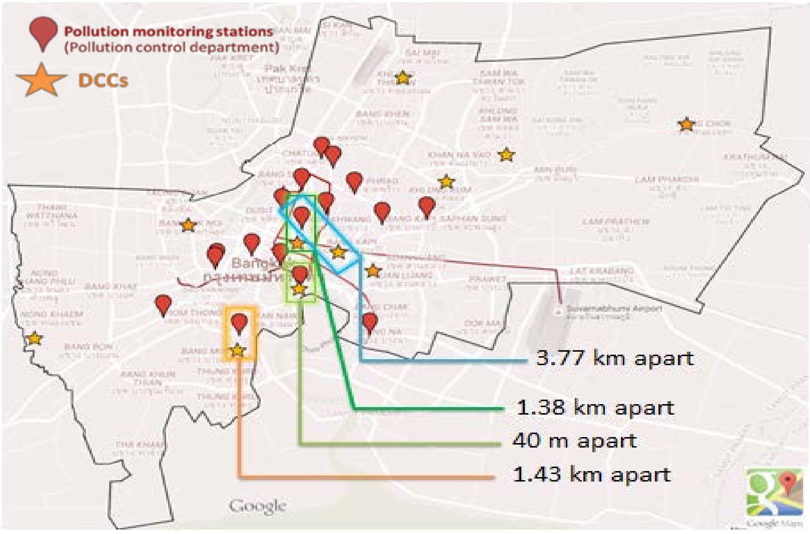
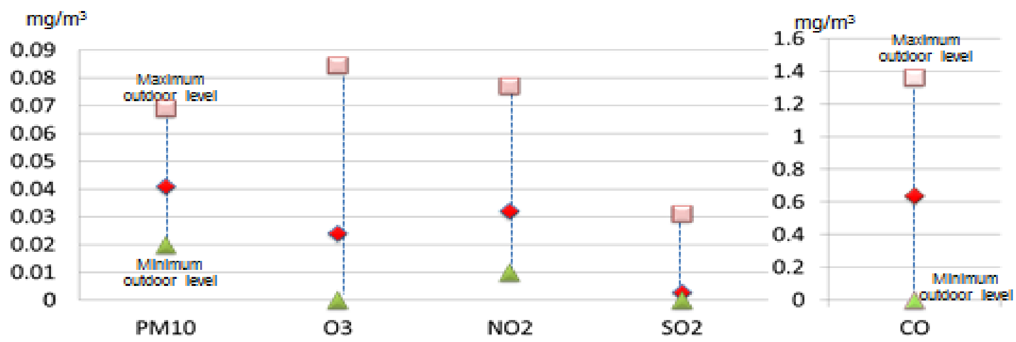
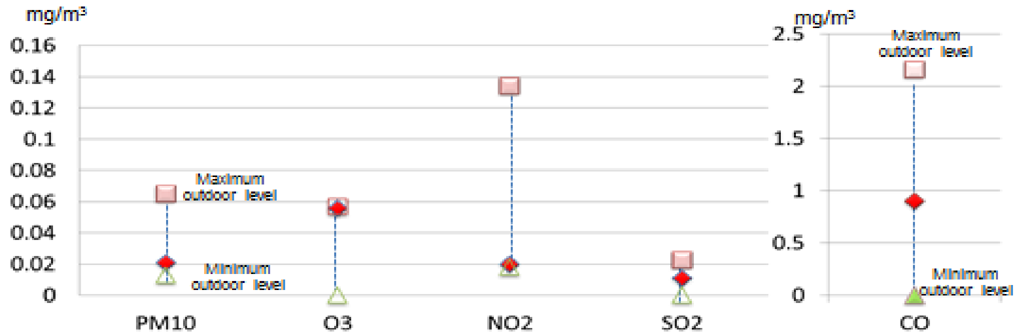


Figure 11: 4 selected DCCs and pollution monitoring stations.



(a)



(b)

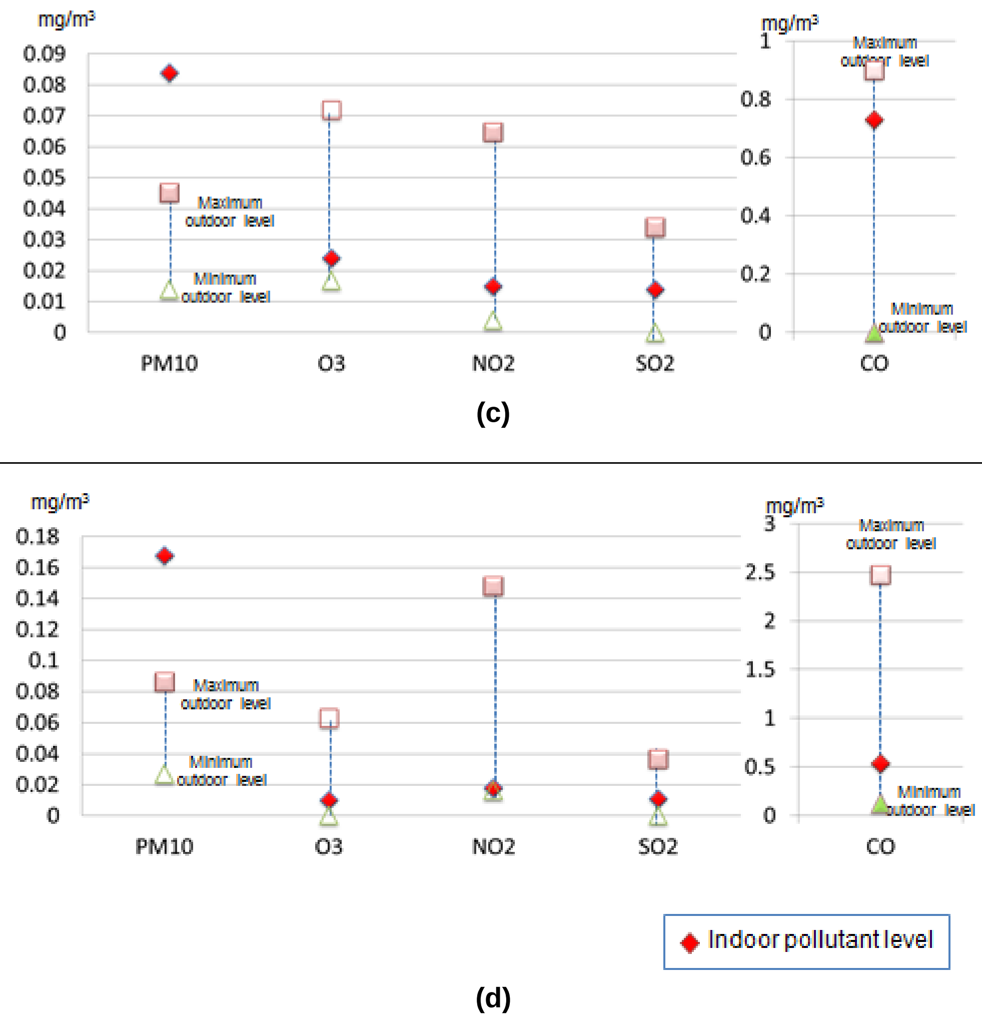


Figure 12: Indoor pollutants levels compared to outdoor pollutants levels from nearest pollution monitoring station in 4 selected DCCs

5.3 Statistical analysis

5.3.1 Correlation between DCCs environmental characteristics and pollutant levels

Statistical analyses were performed on various pollutants and DCCs characteristics, only three significant correlations could be obtained with 95% confidence interval ($p < 0.05$) as follows.

- ✓ **During rainy season, indoor ozone level and distance from road for day care centers with open ventilation yields correlation of $r^2 = 0.759$, $p = 0.011$; whereas, indoor CO level and presence of indoor cooking activity without separate kitchen yields correlation of $r^2 = 0.515$, $p = 0.013$.**
- ✓ **For winter season, indoor NO_2 level and distance from road yields significant correlation of $r^2 = 0.67$, $p = 0.004$.**

5.3.2 Children baseline and home environment characteristics

From Table 9, The total number of children participated in this study is 436, where 52% are male and 48% are female. Children have mean age of 50.1 months old, and mean duration of stay in DCC of 17.3 months. Regarding health status, 9.6% of children are known with case of allergic rhinitis while 7.3% are known with case of asthma. Only 25.9% of children receive influenza vaccination during the past year. 24.08% of children have main care taker who are not parents. Parent education level is mainly secondary school, and majority of the family have income of about 10,000 - 30,000 Baht per month.

Table 9: Children and familiy characteristics

Children characteristics	
Mean age	50.1 months (SD = 9.4)
Mean duration of DCC attendant	17.3 months (SD = 7.5)
Male	229 (52%)
Female	207 (48%)
Underlying diseases	
- Allergic rhinitis	42 (9.6%)
- Asthma	32 (7.3%)
- G6PD deficiency	6 (1.4%)
- Anemia	4 (0.9%)
- Hepatitis B	2 (0.5%)
- Epilepsy	1 (0.2%)
Influenza vaccination during 1 year	113 (25.9%)
Care taker not parents	105 (24.08%)
Family characteristics	
Father education	
- Below primary school	4 (0.9%)
- Primary school	88 (20.2%)
- Secondary school	289 (66.3%)
- Bachelor degree	52 (11.9%)
- Above Bachelor degree	3 (0.7%)
Mother education	
- Below primary school	11 (2.5%)
- Primary school	129 (29.6%)
- Secondary school	258 (59.2%)
- Bachelor degree	37 (8.5%)
- Above Bachelor degree	1 (0.2%)
Family income	
- <10,000 Baht/month	145 (33.3%)
- 10,000-30,000 Baht/month	251 (57.6%)
- >30,000 Baht/month	40 (9.2%)

About home environment shown in Table 10, on average each household consists of 5 people. Mean distance between home and DCC is 2.81 km with motorcycle as main transportation to DCC. Reported indoor smoking is as high as 51.4% of the households with 14.4% having more than one indoor smoker and 43.3% of the fathers smoke. Most houses use open ventilation with electric fan. Air conditioners are used in 21.1% of the houses. 23.3% of children are exposed to indoor cats and 15.6% to indoor dogs. 6.2% of the households still use solid fuel for cooking. Visible sign of dampness or mold are reported as high as 31.4% in the houses.

Table 10: Children baseline and home environment characteristic

Total household members	5.05
Distance from DCC	2.81 km
Indoor smoking	224 (51.4%)
- More than one indoor smokers	63 (14.4%)
- Father smoking	189 (43.3%)
- Mother smoking	5 (1.1%)
Presence of indoor pets	
- Cats	102 (23.4%)
- Dogs	68 (15.6%)
Ventilation	
- Electrical fan	309 (70.9%)
- Air conditioner	92 (21.1%)
- Air conditioner and electrical fan	23 (5.3%)
- None	14 (3.2%)
Cooking fuel	
- Gas	390 (73.4%)
- Electricity	76 (17.4%)
- Solid fuel	27 (6.2%)
Sign of water dampness or visible mold	137 (31.4%)
Transportation to DCC	
- Motorcycle	221 (50.7%)
- Cars	51 (11.7%)
- Walking	70 (16%)
- School bus	81 (18.6%)
- Bicycle	14 (3.2%)

5.3.3 Respiratory symptoms

Respiratory symptoms were recorded weekly by teachers and parents, as shown in Table 11. In rainy season, 86.7% of children had at least one upper respiratory symptom reported by teacher or parents while 8.3% had lower respiratory symptoms. School absence due to respiratory symptoms was as high as 52.7% in rainy season, and 22.9% had doctor visit due to respiratory symptoms during the 4 weeks period. In winter, upper and lower respiratory symptoms were reduced to 76.5% and 3.8%, respectively. School absence and

doctor visit due to respiratory symptoms were reduced to 35.9% and 15.7% respectively. Hospital admission due to respiratory symptoms were below 1% in both seasons.

Table 11: respiratory symptoms of children reported by parents and teachers

4 weeks respiratory symptoms	Rainy season (n=436)	Winter (n=396)
Upper respiratory symptoms	378 (86.7%)	303 (76.5%)
- Febrile respiratory symptoms	226 (51.8%)	130 (32.9%)
- Afebrile respiratory symptoms	302 (69.2%)	257 (64.9%)
Lower Respiratory Symptoms	36 (8.3%)	15 (3.8%)
Absence from DCC due to respiratory symptoms	230 (52.7%)	142 (35.9%)
absent days: 1-3 days	160 (36.7%)	115 (29%)
4-7 days	49 (11.2%)	20 (5%)
over 7 days	21 (4.8%)	-
Doctor visit due to respiratory symptoms	100 (22.9%)	62 (15.7%)
Admission due to respiratory symptoms	4 (0.9%)	3 (0.8%)

5.3.4 Correlation between pollutant exposure and respiratory symptoms of children

The correlation found between exposure to pollutants levels above standard recommendation and respiratory symptoms are as shown in Table 12. In rainy season, high PM_{10} levels were associated with increased frequency of afebrile upper respiratory symptoms. Benzene levels were high only in rainy season and found to be related with upper and lower respiratory symptoms, including school absence, doctor visit and hospital admission due to respiratory symptoms. High SO_2 level associated with occurrence of lower respiratory symptoms in rainy season and increased frequency of upper respiratory symptoms in winter. In rainy season, high bacterial count and high fungi count were associated with increased frequency of upper respiratory symptoms and occurrence of lower respiratory symptoms, respectively. High house dust mite antigen levels were associated with increased frequency of upper respiratory symptoms in rainy season and occurrence of lower respiratory symptoms and doctor visit due to respiratory symptoms in winter.

Table 12: Correlation between pollutants exposure and respiratory symptoms

	High PM10	High Benzene	High SO2	High Bacteria	High Fungi	High Dust Mite
Upper respiratory symptoms		✓ (Rainy)	✓ (Winter)	✓ (Rainy)		✓ (Rainy)
Afebrile upper respiratory symptoms	✓ (Rainy)					
Lower Respiratory Symptoms		✓ (Rainy)	✓ (Rainy)		✓ (Rainy)	✓ (Winter)
Absence from DCC due to respiratory symptoms		✓ (Rainy)				
Doctor visit due to respiratory symptoms		✓ (Rainy)				✓ (Winter)
Admission due to respiratory symptoms		✓ (Rainy)				

✓ Rainy ✓ Winter

(a)

Correlation (rainy season)	p-value
High PM_{10} level and • occurrence of >1 afebrile upper respiratory symptoms	0.039
High Benzene level and • occurrence of >1 upper respiratory symptoms • occurrence of lower respiratory symptoms • absence from DCC due to respiratory symptoms • doctor visit due to respiratory symptoms • hospital admission due to respiratory symptoms	<0.001 <0.001 0.013 <0.001 0.02
High SO2 level and • occurrence of lower respiratory symptoms	0.042
High bacterial count and • occurrence of >1 upper respiratory symptoms	<0.001
High Fungi count and • occurrence of lower respiratory symptoms	<0.001
High Dust mite level and • occurrence of >1 upper respiratory symptoms	0.009
Correlation (winter)	**p-value**
High SO2 level and • occurrence of >1 upper respiratory symptoms	0.01
High dust mite antigen (DP) • occurrence of lower respiratory symptoms • Hospital admission due to respiratory symptoms	0.021 0.029

(b)

5.3.5 Fractional exhaled nitric oxide

A total of 110 children in rainy season and 100 children in winter season were enrolled for FENO measurement. The test was successfully performed on 102 and 93 children in rainy season and winter, respectively. The FENO measurement failed in some children due to inevitable non-cooperation by children.

As shown in Table 13, the majority of children have FENO level lower than 20 ppb, which implies non-eosinophilic or no airway inflammation. In this study, there were no children having FENO level above 35 ppb, which implies uncontrolled or deteriorating eosinophilic airway inflammation. Only 9 children in rainy season and 3 children in winter have FENO level between 20 and 35, which is in the intermediate range cautioning for eosinophilic airway inflammation and monitoring on change in clinical and FENO level. Respiratory infection can also cause elevated level of FENO.

Table 13: Children numbers according to FENO level

	Enrolled	successful	Low (<20 ppb)	Intermediate (20-35 ppb)	High (>35 ppb)
Rainy	110	102	93	9	0
Winter	100	93	90	3	0

In Rainy season, correlation between intermediate FENO level and high PM_{10} level is found to be $p = 0.026$ according to Fischer-Exact test, and also high Benzene level with $p = 0.027$ according to chi-square test. The correlation between pollutant level and FENO level was not found in winter.

5.4 Discussion & Conclusion

From this study, indoor air pollution is found to be a problem in DCC in Bangkok with major pollutants as particulate matter, airborne bacterial count and fungi count, which are higher than standard in more than half of the DCCs. Ozone is also a main pollutant in winter. The environmental characteristics found to have influences on indoor pollutant levels are distance from road traffics and indoor cooking activity without separate kitchen. Shorter distance from road distance is associated with increase in indoor levels of ozone and nitrogen dioxide. Indoor cooking activity without separate kitchen is associated with increased indoor carbon monoxide level. No significant difference was found in pollutant level between DCC with open and mix ventilation system. Exposure to high level of indoor air pollutants in DCC also has effects on children's respiratory symptoms. Fractional exhaled nitric oxide level, which represents airway inflammation, was low in the majority of children in this study. None of the children have high fractional exhaled nitric oxide level,

while some have intermediate level of fractional exhaled nitric oxide associated with high levels of benzene and particulate matter.

Furthermore, it is found that outdoor pollution, including traffic, is important source of indoor air pollutant. Exposure to indoor air pollutants certainly affects children respiratory symptoms.

Although, the present study did not find association between ventilation system and pollutant levels, other study [15] found air-conditioned and mixed ventilation to be associated with higher level of pollutants with indoor sources when compared to naturally ventilated DCC. The present study did not find association between children density and airborne bacterial count while other study [16] found association between bacterial count and number of people in a closed space. The present study did not find significant correlation between visible signs of dampness or mold with level of airborne fungi while positive correlation was reported in other study [17].

Apart from the main objectives of this study, the present study found that a number of DCCs in Bangkok still has overcrowding problem. Presence of nearby water source is common for DCCs in Bangkok, and children safety should be an issue of concern. Home smoking rate is rather high, and this issue should receive attention and intervention. Also, Separate kitchen should be present in DCC with cooking activity.

Last, some limitations in the present study need to be remarked as follows. One DCC was temporary closed during winter and data collection could not be done. Indoor pollutant levels cannot be continuously monitored, and single-day measurement may not represent the actual average exposure to indoor pollutants in a season.

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