AIR POLLUTION EXPOSURE AND THE HEALTH IMPACT ON SCHOOL CHILDREN IN ASIAN CITIES

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CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

Lee Sin Hang

ABSTRACT

This study relates the pulmonary function of school children to the air quality they are exposed to inside and outside classrooms as well as on route to school using various public transport modes and walking in three Asian cities. The study focuses on primary Grades 5 and 6 pupils from schools in Hong Kong, Kathmandu, Nepal and Hanoi, Vietnam. A health record questionnaire was distributed to the schools and completed by the parents of sampled pupils. Each sampled pupil also had to fill in the daily travelling activity logbook for a week. They were also required to take a pulmonary function test.

The living style in the three sampled cities is very different. Most of the sampled students travelled to school on foot in Hong Kong and Nepal; however, 70% of the sampled students cycled to school in Vietnam. Beside the mode of transport to and from school, there are also large differences in the percentage of children keeping pets at home between the cities. In Hong Kong, only 13% of sampled students reported keeping pets at home, which is the lowest percentage of the three cities. Kathmandu, Nepal reported the highest percentage with 42.6% of sampled students keeping pets at home and Vietnam reported 37.5%. Statistical ANCOVA analyses were applied for testing the significance of the differences. The results showed that boys had a significantly better pulmonary function value than girls. The result is

similar to previous researches. The pulmonary function values of the three sampled cities were further compared by ANCOVA. The result shows that Nepal has the poorest performance for children’s lung function.

In Hong Kong, the ANCOVA results showed that there is a significant difference in the pupil’s lung function according to mode of transportation. Therefore, the air sampling was carried out inside the vehicles along the routes to school in the morning and returning home in the evening. The air sampling results revealed that those pupils who travelled by school buses had the poorest pulmonary function. This may well be explained by the poor air quality in school buses. The best air quality was found on trains. Children who travelled by rail to school had the best pulmonary function performance.

Stepwise regression was further applied to identify the significant contributors to pulmonary function. The parameters “family member smokes inside home”, “height”, “gender” and “weight” were shown to have significant contributions to the lung function value. Examining the change of R-square, we identified that “family member smokes inside home” has the major contribution to the model, representing around 13–25% information of the model. Finally a statistical regression model was developed to quantify the effect of each factor influencing pulmonary function. ”Family member smoking inside home” is great effect on allergic rhinitis.

In Nepal, 326 students were sampled in ten schools. Statistical ANCOVA showed that there was a significant difference in children's pulmonary function among sampled schools and gender. A negative correlation between CO concentration and children’s pulmonary function was identified.

In Vietnam, 511 students were sampled in ten schools. The results were similar to the Nepal study in that a significant difference was found in pulmonary function (FEV1) among the sampled schools and children keeping furry pet at home in the last 12 months. The correlation between pulmonary function and indoor air quality showed negatively for all indoor sampled air pollutants (PM_{10}, CO and TVOC), indicating the air quality had significant impacts on children’s pulmonary function.

LIST OF PUBLICATIONS

Conference Papers

Mak, K. L., **Lee, S. H.**, Loh, W. K., Kwong, W.M. (2013). Public transport air pollution impacts on children's lung function – A case study in Hong Kong. *Proceedings of the Conference in the 18th International Conference of Hong Kong Society for Transportation Studies, Hong Kong*, 275–282.

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1. Introduction

1.1 Background of research

Many studies have reported adverse effects of ambient air pollution on various aspects of respiratory health in children, including asthma exacerbations (Schildcrout et al., 2006), doctor-diagnosed asthma (Brauer, et al., 2002; Hwang, et al., 2005; Shima, et al., 2003), and asthmatic symptoms (Braun-Fahrlander, et al., 1997; Morgenstern, et al., 2007). Pulmonary function as a sensitive marker of respiratory health effects of the lower airway has been documented in previous studies (American Thoracic Society, 1996).

Secondhand smoke contains toxic substances that can easily reach the respiratory system of passive smokers (Fielding and Phenow, 1988). Passive smoking in childhood is a serious health problem, mainly arising from parental smoking. Animal studies have established that secondhand smoke reduces endothelium-dependent relaxation of the pulmonary artery by reducing the activity of nitric oxide synthase and the arginine content of the endothelium (Hutchison et al., 2001). The weight and volume of the lungs have also been shown to diminish significantly following prenatal exposure to nicotine. In the United States of America, approximately 15 million children are regularly exposed to passive smoking in the home. In Asia, the problem of parental smoking is far more serious than America. Therefore, the effect of parental smoking on the health of children should be studied in Asian countries.

Outdoor air pollution is also a major problem in developing countries. The World Health Organization found that the air quality in large cities in many developing countries is remarkably poor and that very large numbers of people in those countries are exposed to ambient concentrations of air pollutants well above the World Health Organization guidelines for air quality (WHO, 1999, 2006). Scientific understanding of the health effects of air pollution, including effects on children, has increased in the last decade. Motor vehicles and power plants are the main sources of air pollution in Asia. One of the greatest challenges is the local street-level pollution. Diesel vehicles, particularly trucks, buses and light buses, are the main sources of street-level pollution. Respirable suspended particulates (RSP), sulphur dioxide (SO_2), carbon monoxide (CO), nitric oxide (NO) and ozone (O_3) are the major air pollutants. These pollutants have adverse health effects on humans including on lung function. (American Thoracic Society, 1996; Ostro et al., 2001; Yu et al., 2000; Leonardi, et al., 2002; Hajat et al., 1999; Jedruchovski, Maugeri and Jedruchovski-Bianchi, 2000; Oftedal et al., 2008).)

In line with the ever increasing living standards in East Asian countries, the demand for energy and the number of vehicles have been growing. The process of extracting energy from fossil fuels and the increased number of vehicles unavoidably contribute to air pollution problems. Many researchers have proved that the impact of air pollution is broad and particularly bad on the health of the whole populations. Hong Kong, one of the key Southeast Asian cities, has a serious air pollution problem.

The effects of outdoor pollutants on health are of great public interest. The emission of potentially hazardous substances is increasing with motorization and mechanization throughout the world. One of the main sources of outdoor air pollution is road traffic, which produces suspended particulates, nitrogen oxides, ozone and carbon monoxide. Rosenlund et al. (2009) suggested that traffic-related air pollution exposure is associated with reduced expiratory flows in school-aged children.

Poor air quality has been believed to be a main contributor to pulmonary illnesses in children. Many researches have been carried out to identify the relationship between indoor/outdoor air quality and children's pulmonary function (Jedrychowski et al., 2005; Lee et al., 2011; Kasamatsu et al., 2006) However, few studies have been conducted to establish a direct linkage between the air quality of public transportation and pulmonary illnesses. Although the amount of time that children are exposed in transport is not as long as in the indoor environment like home or school, the concentration of pollutants in transportation is much higher than indoors. Therefore, this study has tried to establish a direct linkage between children's daily exposure to the air quality of public transport and their current lung function. This study comprised a pulmonary function test on selected children and an air quality survey along the children's typical travelling routes and in particular on various public transportation modes. We then examined, with statistical analysis techniques, the relationship of the air quality of public transportation and the pulmonary function / respiratory illnesses in children. We also tried to identify the differences (if any) in the impacts of air pollution exposure on school children's health for different transportation modes.

In this study, we were also interested in finding out the impact of air pollution on children and differences in the respiratory health of children with different air quality management policies in the three selected Asian cities.

1.2 Objective of study

This project aims to identify the health impact of poor air quality on children by performing the lung function test, parent-completed questionnaires, student-completed log books and exposure assessments of outdoor air pollutants. It is difficult to separate the effects of individual pollutants upon health, but we believe that most children react with significant symptoms to different levels of ambient air pollution. Moreover, if respiratory health is compromised in childhood, the effects have been shown to continue into adulthood. Therefore, it is important to examine how air quality has a direct effect on pulmonary function and respiratory symptoms in children.

Most of the studies on air pollution in European countries have found that there is an association between the concentration of air pollutants and a decrease of pulmonary function in children. We intended to confirm the findings of these earlier studies

The main objectives of this research were:

i. To determine if there are any differences in the respiratory health of children under different environmental risk factors.

ii. To determine whether there are any measurable differences in the pulmonary function of children exposed to different indoor conditions.

iii. To determine if there are any differences in the respiratory health of children in other Asian cities with different air quality management policies.

iv. To identify the relationship between air quality in public transportation and the pulmonary function of school children.

2. Literature review

2.1 Review of questionnaire surveys

The respiratory health questionnaire is very commonly used in children's health surveys. Chen et al. (1998) evaluated children's respiratory symptoms and diseases using a parent-completed questionnaire in six communities in Taiwan. They found that children in the urban communities had higher risks of having respiratory symptoms (day or night-time cough, chronic cough, shortness of breath, nasal symptoms) or diseases compared to those living in rural communities. Furthermore, children in the petrochemical industrial communities had a higher risk of having nasal symptoms compared to children in the rural communities. Therefore, the prevalence of respiratory symptoms were included in our questionnaire. The study covered primary schools with a geographical distribution that included schools on both major and minor roads with different levels of air pollution, which helped to determine measurable differences in the respiratory health of children with various levels of air pollutants.

The questionnaire survey was carried out by Tsai et al. (2010) among fifth grade school children in Taipei, Taiwan. The questionnaire consisted of two parts, one for the school children and the other for their parents. The questionnaire for children was composed of four sections: anthropometric data, screening for respiratory symptoms, screening for exposure to residential risk factors, and questions on dietary habits and nutritional knowledge. They found an association between residential environmental factors and respiratory health in school children. The results showed that the residential environment plays a significant role in increasing the risk of respiratory diseases in primary school children in Taipei. Odoriferous chemical vapour contributes one of the major risk factors in residential settings. Other risk factors include gas leaks, damp and cockroaches at home. In terms of public health, the information is important for asthma intervention and management. With reference to their studies, apart from investigating the household environment in different Asian countries, we measured the indoor air quality of schools. Exposure to indoor air pollutants is believed to have consequences such as reducing the performance of teachers and students because of discomfort or absenteeism.

Tabaku et al. (2011) conducted a survey to compare the pulmonary function of children living in an urban area of Tirana, Albania with children living in a suburban area of the city. The survey was conducted between 2004 and 2005. They measured the dynamic pulmonary function and distributed the questionnaire to collect data on gender, current respiratory symptoms, allergy diagnosed by the physician, parents' education, smoking habits, and the presence of animals, synthetic carpets and mould in their houses. The results of the survey suggested that air pollution is associated with the respiratory health of children. A slight decrease in the values for pulmonary function of children from the urban area compared to the suburban area was observed.

He et al. (2011) conducted a study to evaluate the adverse effects of exposure to air pollution on growth of lung function in school-aged children in China. In their study, 1718 children were selected from three districts in Guangzhou to perform two pulmonary function tests with a time interval of six months between them. Children's respiratory symptoms were reported by parents who completed a self-administered questionnaire at both surveys. The air pollutants level data measured by municipal monitoring stations in Guangzhou was used as reference data; the study concluded that exposure to air pollution had adverse effects on growth of lung function of school children.

2.2 Review of children pulmonary function test

Public concern over the health effects of the indoor environment has risen. Interest has mainly been focused on the potential hazards of tobacco smoke, home dampness, keeping pets and nitrogen dioxide (NO_2). Belanger, Gent, Triche, Bracken and Leaderer (2006) conducted a research study to examine the associations of indoor NO_2 exposure with respiratory symptoms among children with asthma. In their survey, NO_2 was measured by using Palmes tubes. Information on respiratory symptoms during the month before the sampling was collected during home interviews with mothers of 728 children with active asthma. The sample comprised children younger than 12 years old who had lived at that home for at least 2 months and had asthmatic symptoms or who had used maintenance medication within the previous year. The results showed that exposure to indoor NO_2 was associated with increased respiratory symptoms among asthmatic children.

An increased exposure to vehicle exhaust emissions is likely to occur in those children who live near busy roads. Brunekreff et al. (1997) found that the association of lung function was strong in children living closest (<300 m) to the motorways. The result was further confirmed by Venn, Lewis, Copper, Hubbard and Britton (2001) who found that living within 90 m of a main road was associated with an increased risk of wheezing illness in children. Therefore, residential location questions were included in our questionnaire to identify this risk factor.

Yu et al. (2001) studied the association between air pollution and cardiopulmonary fitness among schoolchildren aged 8 to 12 in Hong Kong. The results showed that both boy and girl in the more polluted district had significantly poorer lung function, and the differences among girls were more marked. Yu et al. (2004) carried out similar research in Hong Kong again, and found that air pollution adversely affected the CO_2 max in children, and physical exercise in a polluted environment might not have beneficial effect of cardiopulmonary fitness.

Exposure to indoor air pollutants is believed to result in poorer performance by teachers and students because of discomfort or absenteeism (Mehta et al., 2013). Similar studies had been conducted outdoors: Anderson, Favarato and Atkinson (2011) evaluated an association between community levels of air pollution and asthma prevalence. However, statistical analysis revealed no evidence of an association between community levels of outdoor air pollution and asthma prevalence.

2.3 Reviews of the relationship between air pollution exposure and health

Air pollution exposure is commonly associated with asthma morbidity. O'Connor et al. (2008) conducted a study to investigate the association between fluctuations in outdoor air pollution and asthma morbidity among asthmatic children in the inner city. They analysed data from 861 children with persistent asthma in seven different US urban communities, who performed pulmonary function testing twice daily for a 2-week period in every 6 months over 2 years. They obtained daily pollution measurements from the Aerometric Information Retrieval System, a computer-based repository for information about air pollution in the United States. They examined the relationship between lung function and symptoms and fluctuations in pollutant concentrations by using mixed models. Single pollutant models were used to examine the relationship of lung function to each pollutant, one at a time, and mixed effects models were used to assess the relationship between lung function and pollutant concentrations. They found that higher 5-day average concentrations of NO_2, SO_2 and particles smaller than 2.5μm were associated with significantly lower pulmonary function in single pollutant models. Higher concentrations of NO_2 and particles smaller than 2.5 μm were associated with asthma-related missed school days, and higher NO_2 concentrations were associated with asthmatic symptoms. Based upon the research, they concluded that among asthmatic children in the inner city, short-term increases in air pollutant concentrations above the

National Ambient Air Quality Standards were associated with adverse respiratory health effects.

Oftedal et al. (2008) performed a survey of 2,307 on nine to ten-year-old children who lived in Norway. The outdoor air pollution exposure for each child was assessed by the EPISODE dispersion model, calculating hourly concentrations of nitrogen dioxide (NO_2) and particulate matter (PM_{10}, $PM_{2.5}$). Linear regression was further applied, stratified by gender. The results showed that early and lifetime exposure to outdoor air pollution were associated with a reduced peak expiratory flow and reduced forced expiratory flow at 25% and 50% of forced vital capacity, respectively, especially for girls. An inter-quartile increase of lifetime exposure to NO_2, PM_{10} and $PM_{2.5}$ was associated with changes in adjusted peak respiratory flow. They also found that there was a short-term effect of NO_2 that became stronger with increased time lags, but not of PM. However, in their study, air pollution exposure was calculated independently from the average modelling. This clearly leads to random error that dilutes the association between exposure and outcome.

Chen, et al. (1998) conducted a study to evaluate the effects of ambient air pollution on respiratory symptoms and the diseases of school children from an urban area in Taiwan. Respiratory health was assessed by an evaluation of children's respiratory symptoms and diseases using a parent-completed questionnaire. Data were analysed by using logistic regression analysis to compute odds ratio of adverse effects. Although the association with ambient air pollutants was suggested, the study could not confirm a causal relationship.

Due to the rapid development of China over last two decades, many researches have been carried out on Chinese sample populations to identify the correlations between ambient air pollutants (SO_2, TSP [total suspended particulates], NO_2) and the level of children's lung function (FVC, FEV1) in China (Wang, 2004; Wang et al., 2003; Peng et al., 2001; Zhang et al., 1996; Dong et al., 1999; Chen et al., 1996; Yin et al., 2005; Liu and Zhang, 2009). Their results showed that children living in seriously air-polluted areas have lower lung function indices than those in lightly air-polluted areas. However, in these researches there are no concrete data about the factors such as children's age, sex, growth and development, family economic status, smoking family members and household fuels. Furthermore, Neuberger et al. (2002) found that SO_2 and TSP do not seem to play a role as confounders for NO2. Therefore, further investigations into the features of lung function damage due to other ambient air pollution in China are needed.

Air pollution such as NO_2 and PM inside vehicles are well known pollutants that damage children's lung function. Rosenlund et al. (2009) found that traffic-related air pollution exposure is associated with reduced expiratory flows in school-aged children; however, only a few researches have been carried out to identify the relationship between the mode of transportation and children's pulmonary function. In order to fill the knowledge gap, an air quality survey along the children's typical travelling routes and in the transportation was conducted for similar analysis.

3. Methodology

Based on the literature review, we have designed our research methodology. Respiratory health questionnaires and log books were distributed through the schools to students. Information was collected through the parent-completed questionnaires and the student-completed log books. The questionnaire used in this study was mainly adapted and modified from the American Thoracic Society's recommended respiratory disease questionnaire and the International Study of Asthma and Allergies in Childhood (ISAAC II) questionnaire as shown in the appendix. This standardized questionnaire is divided into 2 sections. Section A is to obtain information on indoor environmental conditions such as home dampness, pet keeping, and family member smoking inside the home. Section B is to ascertain lifetime prevalence of asthma, wheezing and children's respiratory health for the past 12 months. The log books required the students to enter their route to school and activity after school over a week. Both the questionnaires and the log books were in similar format for all the Asian cities in this study. A lung function test using a digital spirometer was then performed on children of sampled classes. And, air quality along the travelling routes as reported in the log books was measured using portable air monitoring equipment.

3.1 Sampling

The study was performed on children who attended primary schools in three Asia cities (Hong Kong, Kathmandu, Hanoi). Third- to sixth grade students of 10-12 schools from each city were invited to participate in the survey. All primary schools that located in each city were considered as target, and a unique ID was assigned to each primary school. Simple random samples were applied for sampling, twenty primary schools were draw by random number sampling method. In Hong Kong, twenty schools by total were approached, twelve were successfully interviewed. In Kathmandu and Hanoi, ten schools by total were approached, and all ten schools were successfully interviewed.

Cluster sampling was further applied on selecting interviewees. Only children between 8 and 13 years old from selected primary school were included. We simply divided each class of 20-40 school children as an individual cluster, one cluster was randomly selected in each school. For each selected cluster, all students in that cluster were invited as targeted interviewees.

Respiratory health questionnaires and log books were distributed via the schools to the children. The parent-completed questionnaires and the pupil-completed log books were then collected within one month of distribution.

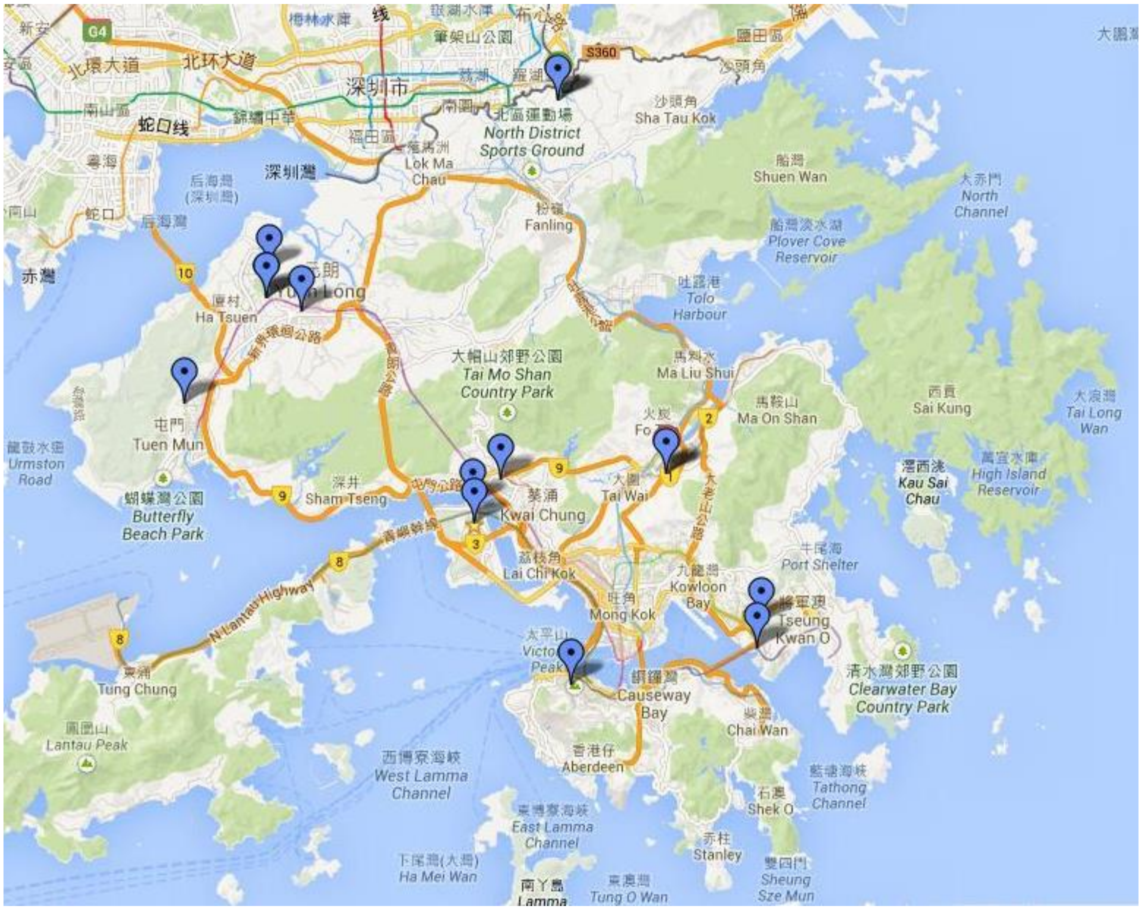
3.1.1 Hong Kong sampling

Twelve schools in various geographical locations in Hong Kong participated in this study from September 2011 to September 2013. The pulmonary function testing was carried out in the morning at each sampling. The locations of these schools are plotted on the map in Figure 1. All 12 schools were located in residential areas with traffic roads nearby. Table 1 provides details of the location of the sampled schools and also the date of the lung function and air quality sampling.

Table 1: List of the twelve schools in the study in Hong Kong

	School	Type of locality	Lung function sampling date	Air quality sampling date
1	TWTA	Located in residential area with car park nearby	January 2011	March 2011
2	HKCY	Located in residential area	March 2011	June 2012
3	CYPY	Located in residential area	April 2011	July 2011
4	LTSK	Located in residential area with light traffic roads nearby	April 2011	June 2011
5	LMCP	Located in residential area with light traffic roads nearby	May 2011	June 2012
6	LOPS	Located at roadside in city core area with heavy traffic roads nearby	Nov 2011	June 2012
7	YWPS	Located in residential area	December 2011	October 2011
8	HSKP	Located in residential area with light traffic roads nearby	February 2012	May 2012
9	TKLS	Located in rural area	March 2012	June 2012
10	YTKH	Located in residential area	January 2013	March 2013
11	HCLS	Located in residential area with car park nearby	March 2013	March 2013
12	TKP	Located in residential area	March 2013	March 2013

Figure 1: Locations of the twelve schools in the study area in Hong Kong



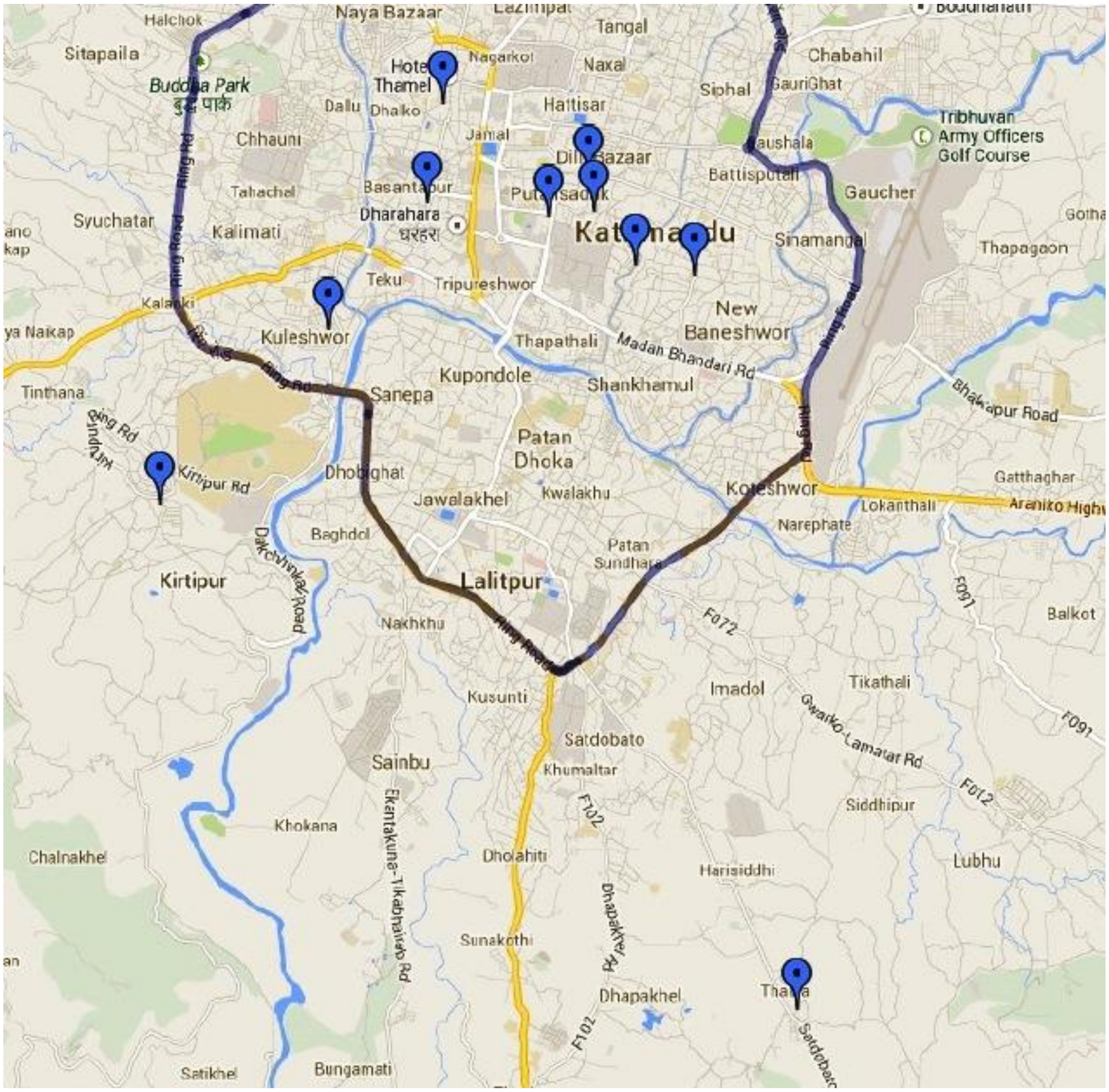
3.1.2 Kathmandu, Nepal sampling

Ten schools were selected purposively for the study from different parts of the Kathmandu valley, based on types of locality and basic assumptions about air pollution levels. The sampling took place from February 2013 to March 2013. The locations of these schools are plotted on the map in Figure 2. Table 2 provides details of the locations of the sampled schools and also the date of the lung function and air quality sampling.

Table 2: The twelve schools in the study in Nepal

	School	Type of locality	Lung function sampling date	Air quality sampling date
1	Ashpodel	Located in residential area	February 2013	February 2013
2	Occidental	Located in residential area, but school located near recently developed unpaved road near Dhobi Khola corridor	March 2013	March 2013
3	Padmodaya	Located at roadside in city core area	February 2013	February 2013
4	Padmakanya	Located at roadside in city core area	February 2013	February 2013
5	New horizon	Located in residential area	February 2013	February 2013
6	Juddodaya	Located at roadside in tourist market area of Thamel	March 2013	March 2013
7	Balsewa school	Located at roadside (small unpaved feeder road) in commercial area	March 2013	March 2013
8	Ratnarajya	Located at roadside in commercial area	March 2013	March 2013
9	Bluebird school	Located at Thabiba VDC about 4.5 km away from ring road	March 2013	March 2013
10	Bagbhairav	Located at roadside in Kirtipur municipality	March 2013	March 2013

Figure 2: Locations of the ten schools in the study area in Nepal



3.1.3 Hanoi, Viet Nam sampling

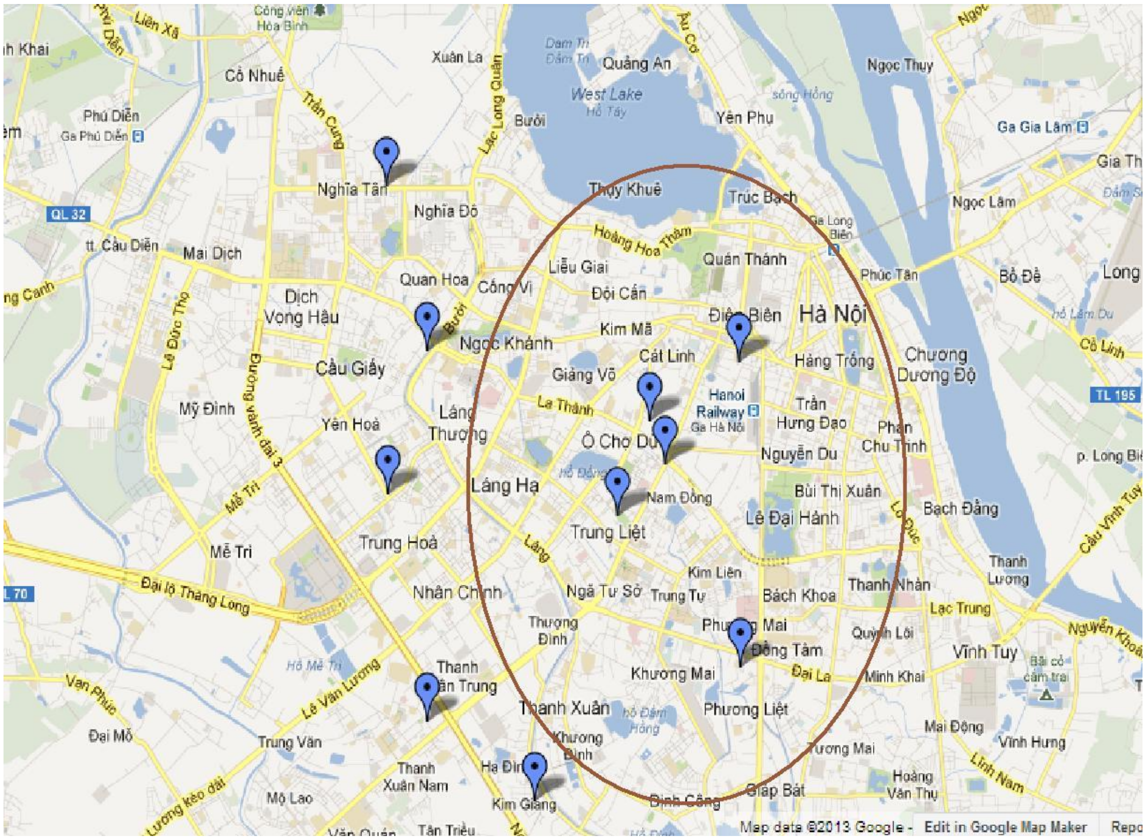
The 10 schools were selected for the study have different location features, and the sampling was conducted from March 2013 to April 2013. The schools were selected with the approval of the Hanoi Department of Education and were located in three different districts. Of these, one district was not in the central area but had some construction in process. The locations of these schools are plotted on the map in Figure 3. Table 3 provides the details of the location of the sampled schools and also of the dates of the lung function and air quality sampling.

Table 3: The twelve schools in the study in Vietnam

	School	Type of locality	Lung function sampling date	Air quality sampling date
1	Quan Hoa	Near road with low traffic flow in city centre	March 2013	March 2013
2	To Vinh Dien	Near narrow road with heavy traffic flow in city centre	March 2013	March 2013
3	Ly Thuong Kiet	Near main road with heavy traffic flow in city centre	March 2013	March 2013
4	Quang Trung	Near narrow road with medium traffic flow in city centre	March 2013	March 2013
5	Thinh Hao	Near narrow road with heavy traffic flow in city centre	April 2013	April 2013
6	Trung Hoa	Residential area in city centre, near small street with medium traffic flow	April 2013	April 2013
7	Nghia Do	Residential area far away from city centre	April 2013	April 2013

8	Phuong Liet	Residential area in city centre	April 2013	April 2013
9	Dang Tran Con A	Near construction area	April 2013	April 2013
10	Kim Giang	Near road with low traffic flow far away from city centre	April 2013	April 2013

Figure 3: Locations of the twelve schools in the study area in Viet Nam



3.2 Questionnaire survey

A letter was sent to each school head explaining the purpose of the study. A meeting was then arranged with the responsible teachers to discuss the practical aspects of this study. A briefing session was given to the chosen classes to explain the questionnaire design and provide instructions for filling in the questionnaire and log book.

Our study targeted at school children aged from 8 to 13. Most of the children stayed at the same school during their primary education. In other words, they have studied in the school for the last 5 or 6 years. The survey was conducted in three cities in Asia; the selected schools were situated in both the urban and rural areas of each of the cities. The log books aimed to find out the children's travelling patterns and the duration of their stay in different kinds of transportation modes. After collecting the questionnaires and log books from the schools, we checked their completeness and excluded the incomplete ones.

3.3 Pulmonary function test sampling

Pulmonary function tests are noninvasive diagnostic tests that provide measurable feedback on lung function. Spirometry is the most commonly used equipment for pulmonary function tests, measuring specifically the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled. Spirometry is an important tool used for generating pneumotachographs, which are helpful in assessing conditions such as asthma, pulmonary fibrosis and cystic fibrosis. The pulmonary function tests of this study were conducted by using spirometers (Model: MIR spirobank G). Disposable mouthpieces were used in spirometer to conduct a lung function test for each student. Prior to performing the test, students were fully briefed on how to blow into the mouth piece. Based on the American Thoracic Society recommendations, each student was asked to perform at least three satisfactory blows, with forced expiratory times exceeding 6 seconds. Pulmonary function tests were performed with two identical spirometers by fully trained technicians. Apart from operating the spirometers, trained technicians also measured the height and the weight of each sampled child. The heights and weights were further used to calculate the reference forced vital capacity (FVC) and 1 second forced expiratory volume (FEV1) value for each sampled students.

3.4 Air quality monitoring

To ascertain the interrelationships between health and air pollution for public transportation in Hong Kong, we decided to obtain health and environmental data directly. An activity log provided information on school-aged children's travelling routes and the modes of transportation. A lung function test on the children confirmed the self-administered health records, and an air quality survey provided on-site air quality exposure data on different transportations.

Three sets of air pollutant samples were collected, the first set of data was measured inside the classroom of each sampled school. The air sampling started from 0830 to 1030 for every indoor sampling. The second set of data was measured in outdoor at each sampled school. The outdoor air sampling carried out at the same time and duration as the indoor sampling. As mentioned in the previous section, sampled students were required to fill in a log book for their weekly travelling pattern. The last set of air pollutant sampling was monitored the pollutant along the routes to and from school of the sampled students.

Pollutants such as PM_{10}, CO_2 and total volatile organic compounds (TVOCs) were monitored in both three set of air sampling. The equipment was maintained at the respiratory level (i.e. 1.5 m above the ground), and was also free from any direct obstructions during monitoring. The following equipment was used for monitoring different pollutants:

a. PM monitor

TSI DUSTTRAK™ Aerosol Monitor Model 8520 was used for real time monitoring of PM_{10} and $PM_{2.5}$. The logging interval was set at 1 minute during monitoring time.

External Dimensions	8.7 in × 5.9 in × 3.4 in (221 mm × 150 mm × 87 mm)
Instrument Weight	3.3 pounds with batteries (1.5 kg)
Sensor Type	90° light scattering
Range	0.001 to 100 mg/m^3 (calibrated to ISO12103-1, A1 test dust)
Resolution	±0.1% of reading or ±0.001 mg/m^3, whichever is greater
Flow Rate	Adjustable 1.4 to 2.4 l/min (1.7 nominally)
Temperature Coefficient	+0.001 mg/m^3 per 1 °C (for variations from the temperature at

	which the DUSTTRAK was zeroed)
Operating Temperature	32 °F to 120 °F (0 °C to 50 °C)
Storage Temperature	−4 °F to 140 °F (−20 °C to 60 °C)
Operating Humidity	0 to 95% rh (non-condensing)
Time constant	Adjustable from 1 to 60 seconds
Data Logging	31,000 data points (21 days of logging once/minute)

b. CO_2 monitors

The portable TSI Q-TRAK (Model 8552/8554 Q-TRAK™ Plus IAQ Monitor) was used for real time monitoring of CO_2. The logging interval was set at 1 minute during monitoring time.

Range	CO_2 0–5000 ppm
Resolution	±3% of reading
Temperature	32 to 122 °F, resolution ±1.0 °F.
Humidity	5–95%, ±3% rh.

c. Total Volatile Organic Compound (TVOC) monitors

The ppbRAE parts per billion (ppb) total volatile organic compound (TVOC) monitor (Model PGM-7240) was used for real time monitoring of the total volatile organic compounds at ppb levels. The logging interval was set at 1 minute during monitoring time.

Specifications:

Size	8.2" L × 3.0" W × 2.0" H or 21.8 cm L × 7.62 cm W × 5.08 cm H
Weight	19.5 oz with battery pack
Detector	Photo-ionization sensor with standard 10.6 eV or optional 9.8 eV UV lamp
Range, Resolution and Response time	Isobutylene (calibration gas) 0–9999 ppb 1 ppb <5 sec 10.0–99.9 ppm 0.1 ppm <5 sec 100–199 ppm 1 ppm <5 sec
Datalogging	15,000 points with time/date
Temperature	14 °F to 113 °F(−10 °C to 40 °C)
Humidity	0 to 95% relative humidity (non-condensing)

A batch of pre-cleaned 2 litre stainless steel SUMMA canisters was used to collect air samples to analyse VOC in the lab. Integrated VOC air samples were obtained by using mass flow controllers (Model No. FC4104CV-G, Auto flow Inc.) at flow rates of 30 ml/min. After sampling, the canisters were shipped back to the Hong Kong Polytechnic University for the analysis of VOC. The analysis was performed with a Nutech 3550A Cryogenic concentrator using the TO-14ACOOL method.

3.5 Analysis and Modelling methodology

Many researchers have suggested that air pollution has a major impact on children's pulmonary function. In order to identify which air pollutants and to quantify the impacts on children's pulmonary function, air pollutant sampling was carried at each sampled school. The correlation between the different pollutants and the pulmonary function of the sampled students was investigated in this study.

A statistical analysis of covariance, ANCOVA, was carried out to identify if there were significant differences between the factors for each of the cities. ANCOVA is a general linear model which blends ANOVA and regression. ANCOVA evaluates whether population means of a dependent variable are equal across levels of a categorical independent variable, while statistically controlling the effects of other continuous variables that are not of primary interest, known as covariates. Therefore, when performing ANCOVA, the dependent variable means are adjusted to what they would be if all groups were equal on the covariates. For performing ANCOVA analysis, we need to define covariates. Principal component analysis was carried out on interested confounding factors and the scores from principal component analysis will apply for covariate.

As revealed in the literature review, the observed lung function is mostly affected by gender, weight and height. In order to isolate the bias from these three factors, they were included for principal factor analysis. Furthermore, there were some risk factors, such as passive smoking, transportation mode, and medical history of asthma. Therefore, these three factors were also included in the principal factor analysis.

A statistical model was applied to the data to quantify the impact of air pollutants on children's pulmonary function. Logistic model was further developed accordingly for respiratory illnesses.

4. Sampling results

4.1 Hong Kong sampling results

The selected schools were situated in both urban and rural areas in Hong Kong. A total of 12 schools were recruited for this study. Copies of the questionnaire were distributed via the schools and completed by students and their parents. The questionnaire aimed to explore the relationship between health and the micro-environments to which students are exposed. The total number of questionnaires collected was 310 from all the schools, the response rate is 99.04%. After collecting the questionnaire, reliability analysis was performed. Cronbach's Alpha was calculated and equaled to 0.783, which represents the questionnaire is acceptable (George and Mallery, 2003; Kline, 1999). The study targeted children at primary levels 5 or 6 in the primary schools. Therefore, most of the children in the 12 schools were at the ages of 11 and 12. The highest mean weight of school students was for those at School TWTA, and the lowest mean weight was for School LOPS. The mean weight of children among the 12 schools was not significantly different. Similarly, the mean height of school children was nearly the same across the 12 schools (1.39–1.58 m). The details of average height and weight, and gender at each school are presented in Table 4.

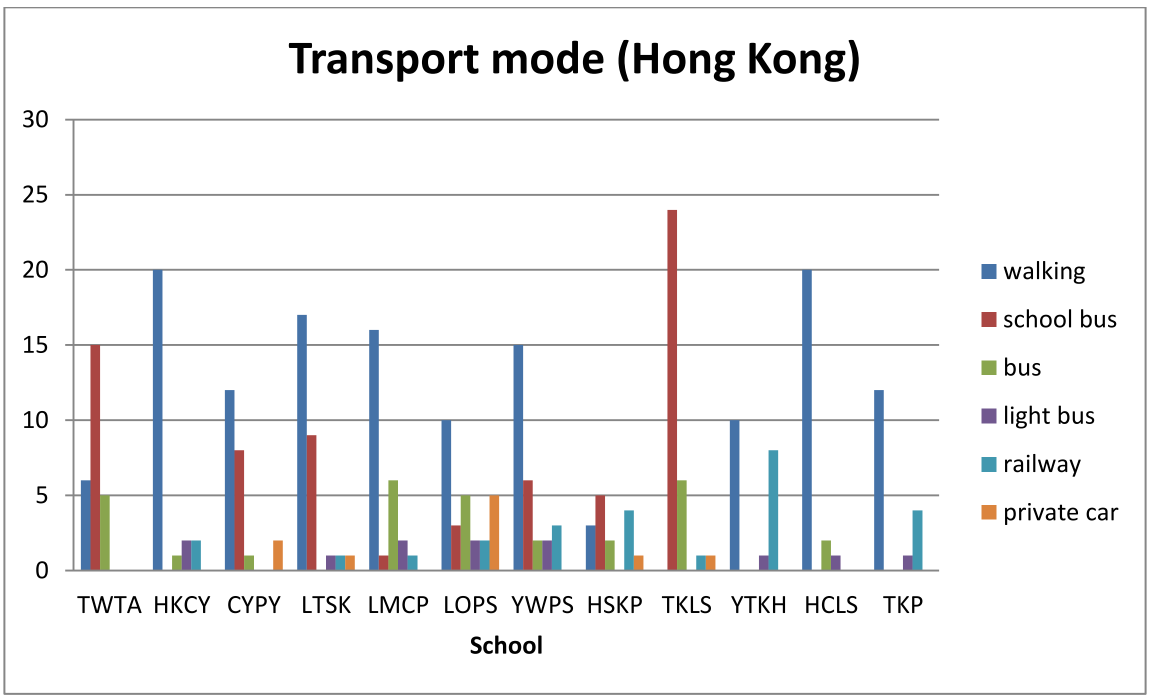
Table 4: Average height and weight, and the gender of sampled children

School	Height (m)		*Weight (kg)*		Female	Male	Grand Total
	Mean	***SD***	***Mean***	***SD***			
TWTA	1.56	10.04	47.04	10.63	10	16	26
HKCY	1.44	6.92	39.20	9.94	18	12	30
CYPY	1.44	6.95	37.88	7.97	12	12	24
LTSK	1.48	8.28	41.00	8.65	15	14	29
LMCP	1.51	8.30	42.81	8.44	13	14	27
LOPS	1.39	6.60	31.66	7.33	13	14	27
YWPS	1.41	6.12	34.06	5.51	10	18	28
HSKP	1.40	8.63	40.11	7.47	6	11	17
TKLS	1.49	8.20	44.63	9.67	13	19	32
YTKH	1.49	7.14	37.19	5.05	16	11	27
HCLS	1.50	9.67	39.57	7.44	7	16	23
TKP	1.48	7.87	39.45	8.08	10	10	20

4.1.1 Transport modes

The completed questionnaires which included information about the transport mode that children used to go to school, were collected from the children's parents. The transport mode distribution of the 12 schools is shown in Figure 4. It shows that the largest share of children went to school on foot (about 48%). This can be explained by the education policy of Hong Kong whereby most students study in the same district that they live; therefore, many students in Hong Kong are within walking distance of their school. The second highest mode used was the school bus with 24%.

Figure 4: Transport mode that children used to travel to school



4.1.2 Type of pets inside the home

Yarnell et al. (2003) performed a questionnaire survey of 2364 children from Northern Ireland and 2671 children from the Republic of Ireland with the aim of examining the prevalence of respiratory symptoms and the level of diagnosis. They found that pet ownership was common in the households of the sampled children. Cross-reactivity between different animal antigens is common in subjects with atopy, but furry animals are either more potently allergic than dogs or cats, or children come into closer contact with such animals. Statistical regression was further applied and found that keeping a furry pet at home has a statistically significant effect on children's respiratory systems. Although the relative odds of these outcomes are not large, they are nevertheless equivalent to the risk for occasional smokers and those with hay fever.

The data for the pet type inside children's household is shown in Table 5. Among 12 schools, TKLS had the highest number of families who raised different kinds of pets. More precisely, at TKLS 18.8% of student's families kept dogs, 6.2% kept cats and 12.5% kept other furry pets, like rabbits or hamsters.

Table 5: Results for percentages of pets inside the home

School	Dog	Cat	Bird	Other furry pet	None
TWTA	3.1%	0.0%	0.0%	3.8%	93.1%
HKCY	3.3%	0.0%	0.0%	6.7%	90.0%
CYPY	4.2%	0.0%	0.0%	0.0%	95.8%
LTSK	0.0%	0.0%	3.4%	3.4%	93.2%
LMCP	11.1%	3.7%	3.4%	7.4%	81.8%
LOPS	7.4%	14.8%	0.0%	7.4%	70.4%
YWPS	0.0%	0%	0.0%	0.0%	100.0%
HSKP	23.5%	5.9%	0.0%	0.0%	70.6%
TKLS	18.8%	6.2%	0.0%	12.5%	59.4%
YTKH	3.7%	0.0%	0.0%	0.0%	96.3%
HCLS	0.0%	0.0%	0.0%	0.0%	100.0%
TKP	5.0%	0.0%	0.0%	0.0%	95.0%

4.1.3 Status of smoking inside the home

The United States Environmental Protection Agency (USEPA) has concluded that exposure to secondhand smoke can cause lung cancer in children who do not smoke even more than in people who smoke. Since children are in a physical development phase, they may more easily be affected than adults. The high volume of secondhand smoke, especially inside the house, will damage children's health and lead to respiratory diseases, such as asthma, pneumonia, bronchitis and lung cancer.

Of 310 respondents to the questionnaire about the smoking status inside the home, 44% of children's families had people who smoked at home. In some schools, such as HSKP and HCLS, more than half of the children lived in a household environment that had a family member who smoked. The questionnaire data collected also shows that the number of cigarettes smoked per day was from 10 to less than 20 in most of the smokers' families; details are shown in Table 6.

Table 6: Status of smoking inside the home

School	Smoking	Non-smoking
TWTA	50.0%	50.0%
HKCY	40.0%	60.0%
CYPY	29.2%	70.8%
LTSK	48.3%	51.7%
LMCP	29.6%	66.7%
LOPS	33.3%	63.0%
YWPS	25.0%	75.0%
HSKP	58.8%	41.2%
TKLS	50.0%	46.9%
YTKH	25.9%	74.1%
HCLS	69.6%	30.4%
TKP	30.0%	70.0%

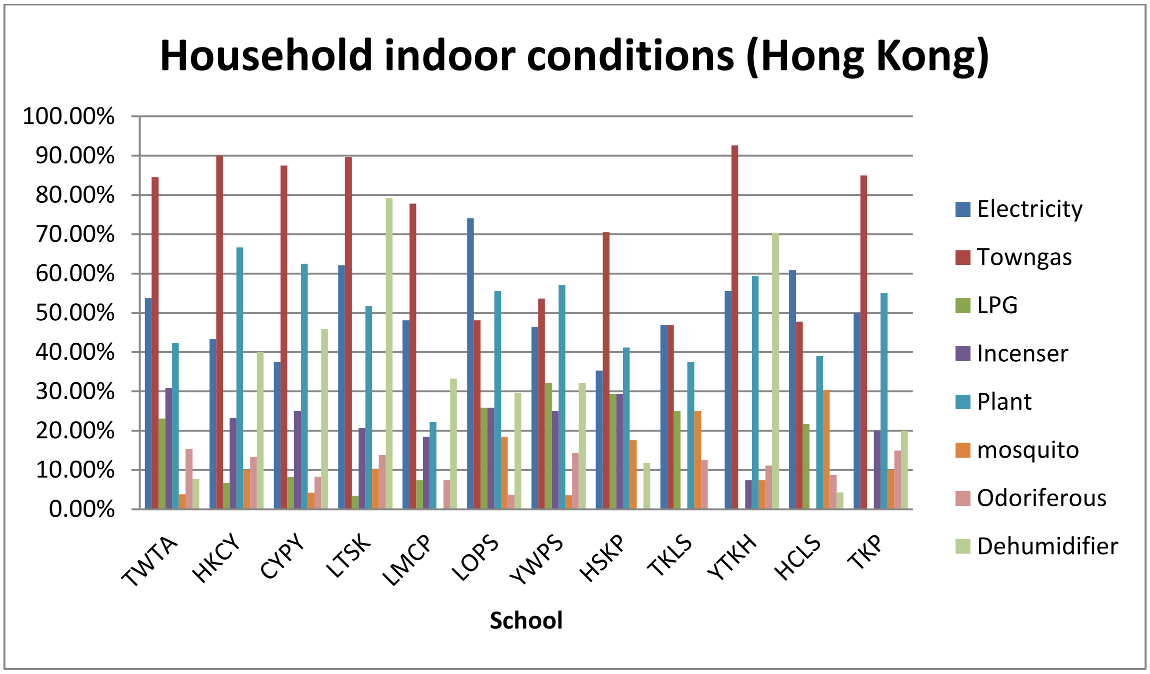
4.1.4 Cooking fuel

Of the 310 respondents to this question, 52.09% of families used town gas to cook in their daily lives. Some families (37.04%) used electricity, but most still used both gas and electricity. Only a very small proportion of families used liquid petroleum gas (LPG) to cook (10.87%).

4.1.5 Household indoor condition

There are various sources on the adverse health impact of indoor air pollution. Incense burning, odoriferous chemical vapours and possession of indoor plants are the most common activities in children's homes that affect the indoor air quality. However, mosquito repellent burning is not common in Hong Kong (see Figure 5).

Figure 5: Household indoor conditions



4.1.6 Moulds/mildew in the household

Indoor air pollution can be caused by hundreds of species of bacteria and fungi; in particular, by mould/mildew that can grow indoors if there is sufficient moisture. People who live and work in houses or public buildings with mould are at risk of respiratory symptoms and respiratory infections that can exacerbate asthma or rare conditions such as hypersensitivity pneumonitis, allergic alveolitis, chronic rhinosinusitis and allergic fungal sinusitis. The questionnaire data revealed that 43.88% of all children's houses across the 12 schools had mould or mildew, due to high humidity or rainy weather – CYPY had the highest percentage, and LTSK the second highest (see Table 7 for full results).

Table 7: Moulds/mildew in the household

School	Mould	No mould
TWTA	34.6%	65.4%
HKCY	50.0%	40.0%
CYPY	62.5%	37.5%
LTSK	62.1%	37.9%
LMCP	40.7%	55.6%
LOPS	25.9%	70.4%
YWPS	28.6%	71.4%
HSKP	41.2%	52.9%
TKLS	37.5%	53.1%
YTKH	51.9%	48.1%
HCLS	34.8%	65.2%
TKP	60.0%	40.0%

4.1.7 Respiratory diseases

Asthma

Asthma is a common disease in Hong Kong: it is estimated that around 10% of children and 5% of adults have experienced symptoms of asthma. The average percentage of sampled students who suffered from asthma was 8.71% (see Table 8 for a summary of the data by school).

Table 8: Number and percentage of children suffering from asthma by school

School	Number	Percentage
TWTA	2	7.7%
HKCY	1	3.3%
CYPY	6	25%
LTSK	4	13.8%
LMCP	3	11.1%
LOPS	4	14.8%
YWPS	2	7.1%
HSKP	1	5.9%
TKLS	1	3.1%
YTKH	2	7.4%
HCLS	1	4.3%
TKP	0	0.0%

Other respiratory diseases in recent 12 months

Table 9: Incidence of some respiratory diseases in recent 12 months

School	Sinusitis	Allergic rhinitis	Bronchitis	Pneumonia	Asthma
TWTA	0.0%	19.2%	0.0%	0.0%	7.7%
HKCY	3.3%	40.0%	3.3%	6.7%	3.3%
CYPY	0.0%	45.8%	0.0%	0.0%	25.0%
LTSK	0.0%	37.9%	6.9%	0.0%	13.8%
LMCP	3.7%	18.5%	0.0%	0.0%	11.1%
LOPS	0.0%	51.9%	3.7%	0.0%	14.8%
YWPS	7.1%	50.0%	3.6%	0.0%	7.1%
HSKP	5.9%	23.5%	0.0%	0.0%	5.9%
TKLS	0.0%	18.8%	0.0%	0.0%	3.1%
YTKH	0.0%	59.3%	0.0%	0.0%	7.4%
HCLS	0.0%	13.0%	0.0%	0.0%	4.3%
TKP	5.0%	25.0%	5.0%	0.0%	0.0%

Table 9 shows some of other respiratory diseases that children may suffer from. Among 12 schools with 310 respondents, allergic rhinitis is shown to be a disease that many children suffer from (34.2%), school YWPS had the highest percentage occurrence of this at 59.3%. The lowest incidence of this disease was 13.0% at school HCLS. Another common disease is asthma, which 8.7% children suffered from according to this survey.

4.1.8 Pulmonary function results

The average pulmonary function results of the 12 schools in Hong Kong is depicted in Figure 6. It shows all of the parameters representing the pulmonary function (functional vital capacity [FVC] and forced expiratory volume in 1 s [FEV1]). However, due to the height and weight differences of each sampled child, the FVC and FEV1 value cannot be applied directly for comparison. The predicted values from the Global Lung Function Initiative (2014) were further calculated according to the weight and height of each student, and the percentage difference between the sampled value and the predicted value (sampled/predicted) was further analysed for comparison.

The Global Lung Function Initiative (2014) equations are the first global multi-ethnic reference equations for spirometry that span all-ages. These are the result of unprecedented, unselfish and professional international cooperation endorsed by six international societies. Briefly, data from 74,187 healthy non-smokers (57.1% females) aged 3-95 years were used to derive multi-ethnic reference equations using modern statistical methods, including development of age dependent lower limits of normal. These all-age reference equations are generalisable across many populations and are available for the following four ethnic groups: Caucasians, which includes Europe, Israel, Australia, USA, Canada, Mexican Americans, Brazil, Chile, Mexico, Uruguay, Venezuela, Algeria, Tunisia; African Americans; South East Asians, which includes Thailand, Taiwan and China (including Hong Kong) south of the Huaihe River and

Qinling Mountains; and North East Asians which includes Korea and China north of the Huaihe River and Qinling Mountains.

The average percentage for the pulmonary function results of these twelve schools in Hong Kong is shown in Figure 7, which reveals that School CYPY had the best performance in the pulmonary function test, with over 110%. In constrast, School TWTA had the worst performace.

Figure 6: FVC pulmonary function results (value)

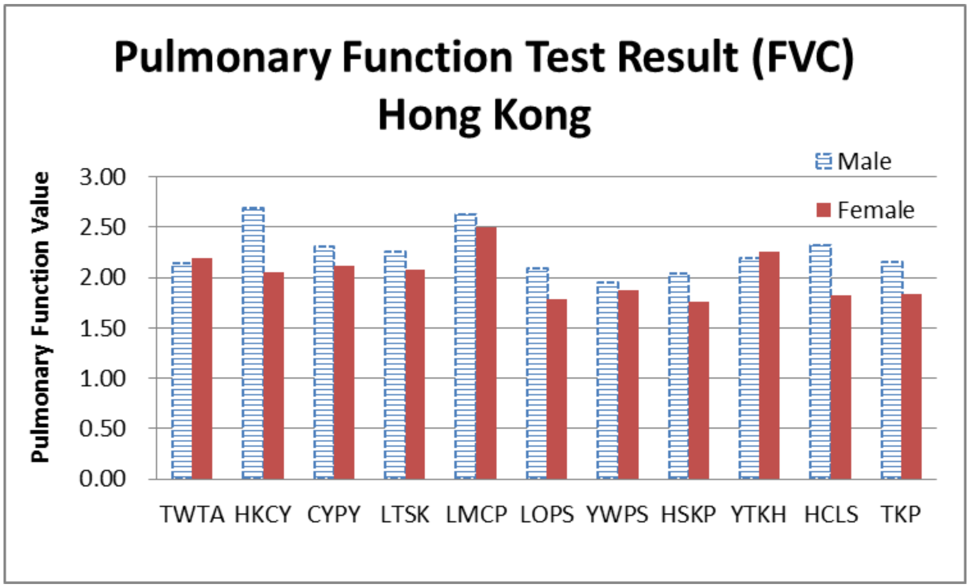


Figure 7: FEV1 pulmonary function results (value)

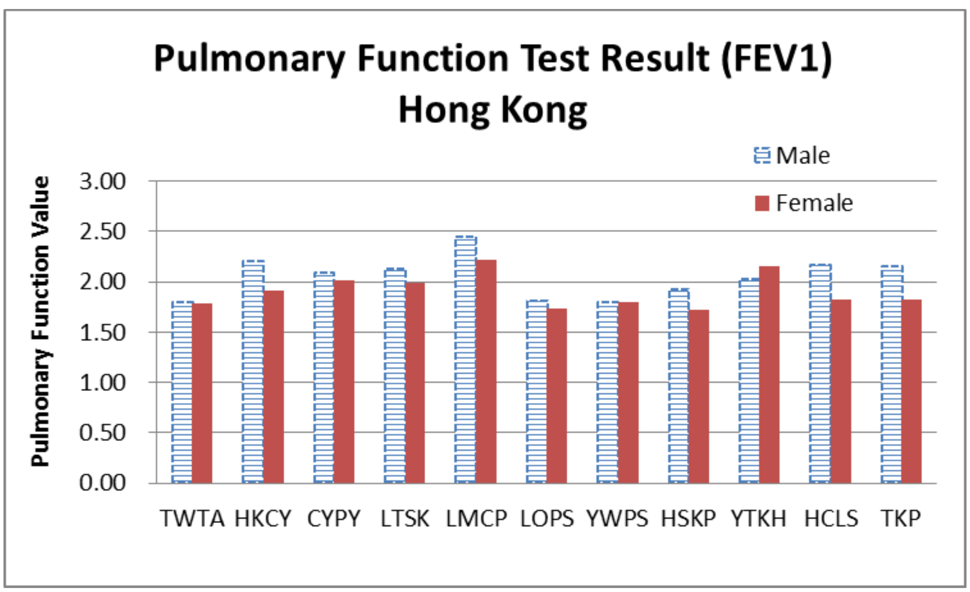


Figure 8: FVC pulmonary function results (percentage)

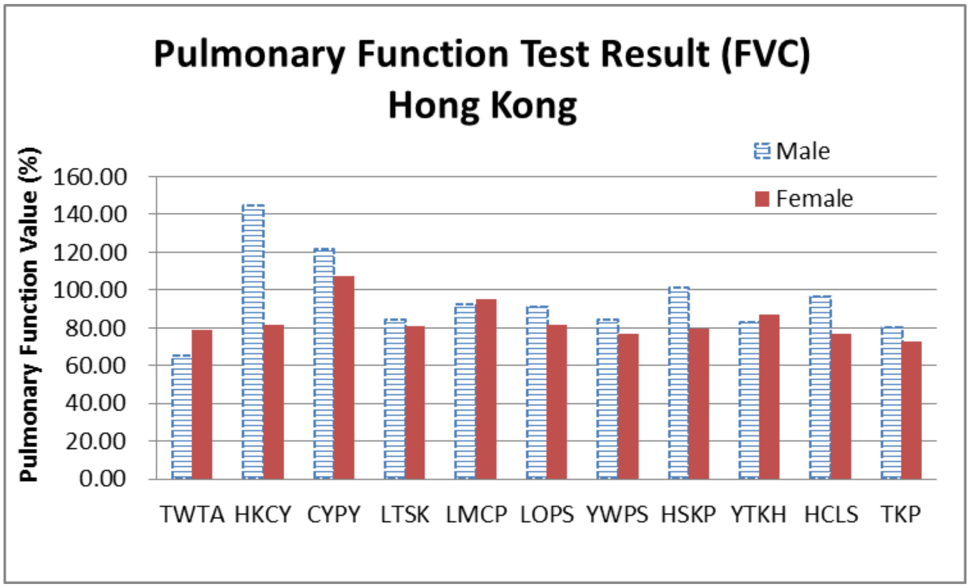
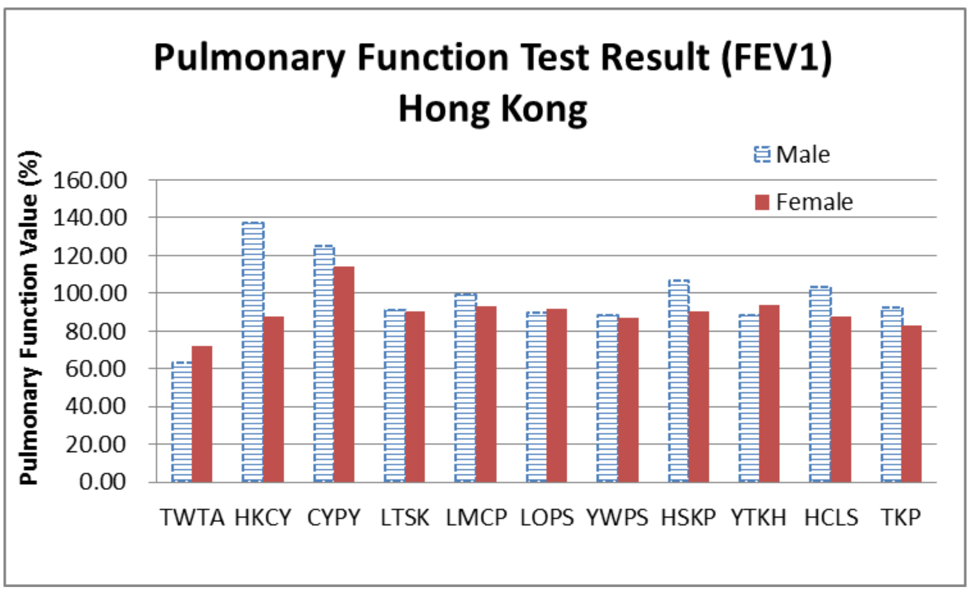


Figure 9: FEV1 pulmonary function results (percentage)

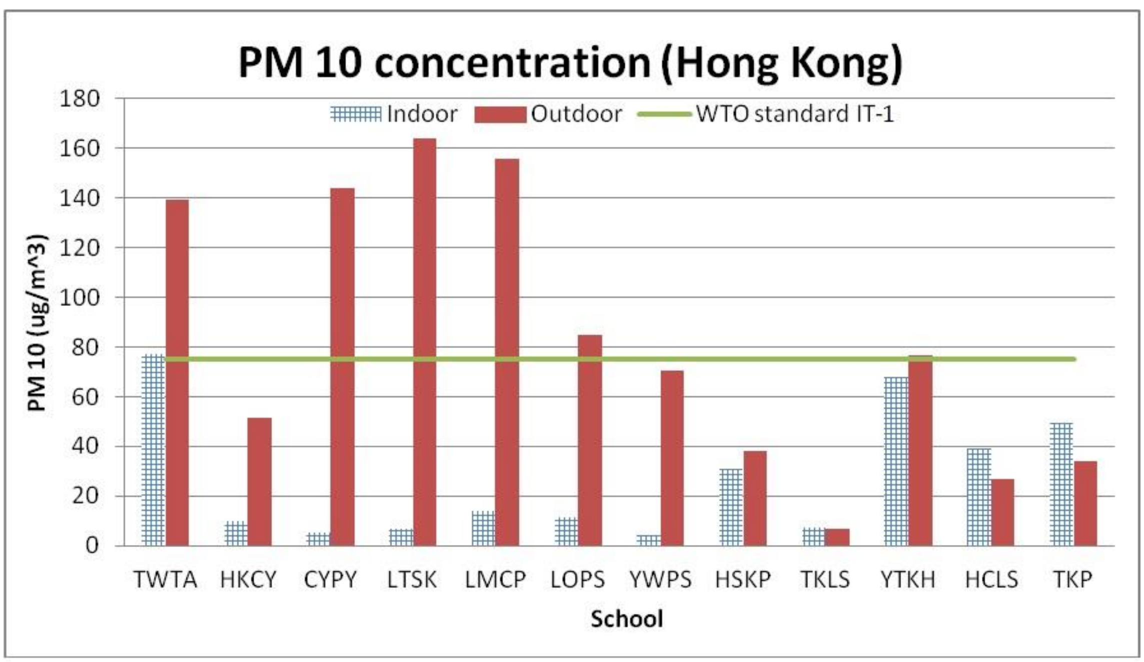


4.1.9 Air quality results

Concentration of PM

The PM_{10} concentration inside and outside school is shown in Figure 8. The PM_{10} concentration outside most schools exceeded the WHO standard IT-3 (24 hours average) (75 µg/m^3), except for school TKLS. The PM_{10} concentration inside the classroom of most schools was within WHO standard IT-1 (75 µg/m^3), except for four schools (TWTA, YTKH, HCLS, TKP). As shown in Figure 5, school TKLS recorded the lowest PM_{10} level both indoors and outdoors; this school is located in a restricted area with less traffic.

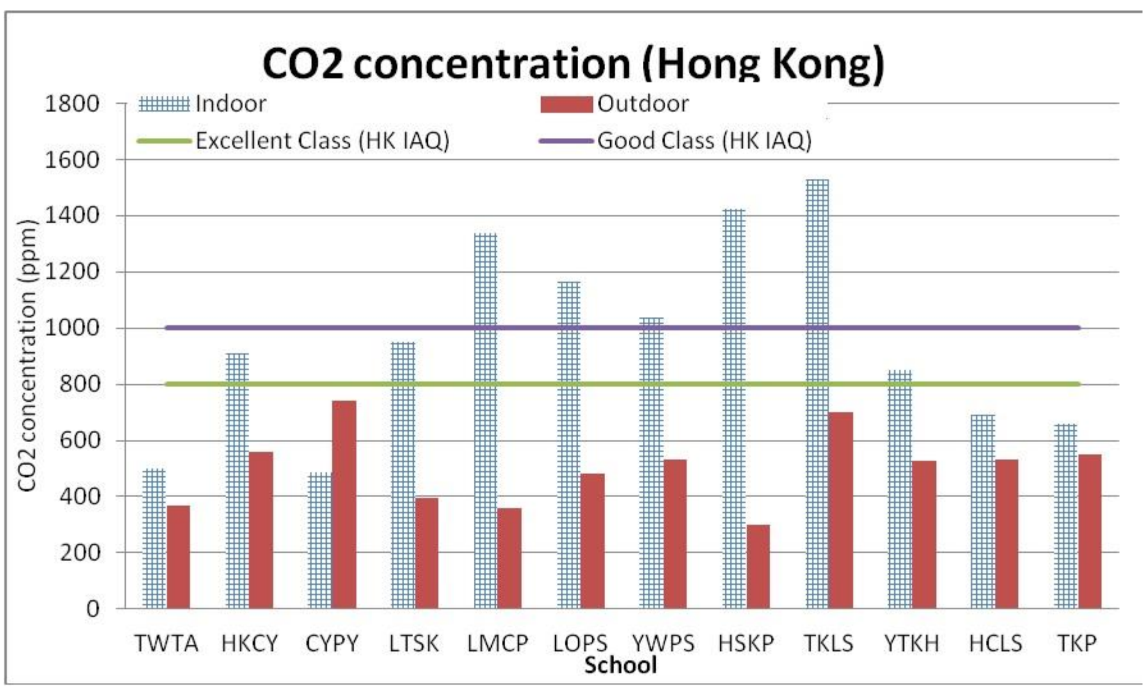
Figure 10: PM_{10} concentration inside and outside school



Concentration of CO_2

The CO_2 concentration inside and outside school is shown in Figure 9. Generally, the outdoor CO_2 concentration at all the schools was well below the standard of the Hong Kong Indoor Air Quality Objectives (HK IAQO). However, only 2 out of the 12 schools recorded below standard air quality indoors. The result shows that CO_2 levels indoors were higher than outdoors at most of schools and much higher at some of the schools. This is probably due to the high number of children inside during the monitoring time or in congested classrooms, as CO_2 comes also from a human source. Almost all classrooms were small in size with many children, and the effect of a high occupancy on CO_2 concentration becomes more significant in a restricted environment.

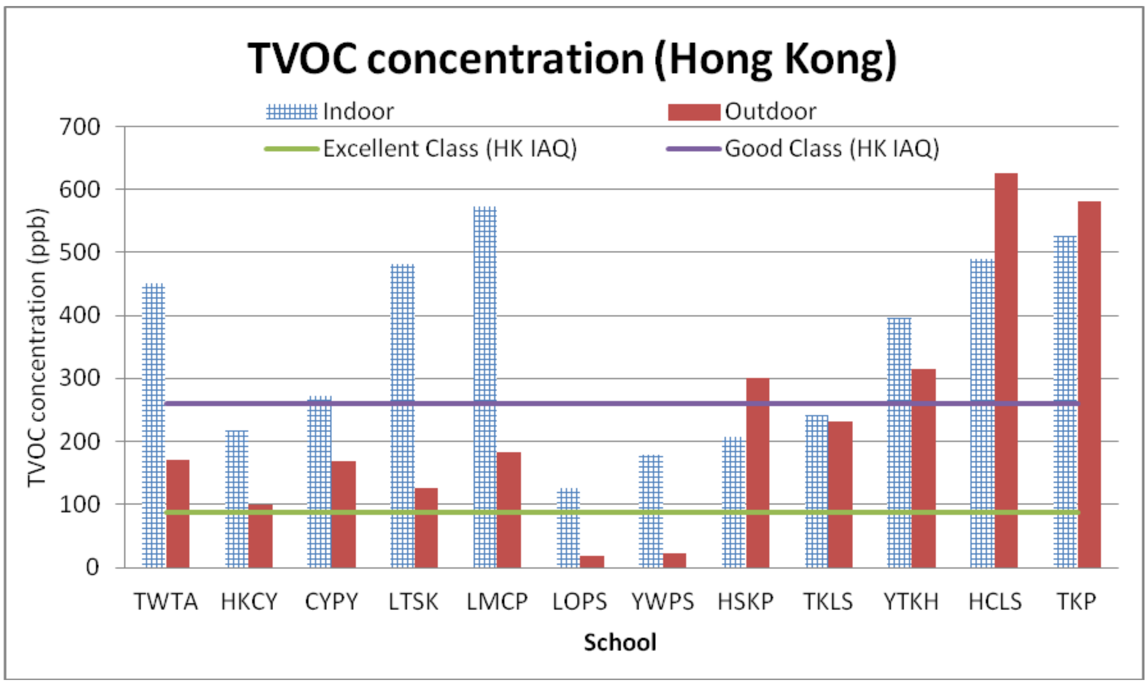
Figure 11: CO_2 concentration inside and outside school



Concentration of VOCs

The total VOC concentration for each school is presented in Figure 10 below. Generally, the VOC concentration outdoors at 8 out of 12 schools achieved a “good class” (using HK IAQO). School LOPS and YWPS achieved “excellent class” for outdoor VOC concentration. For indoor VOC concentration, 6 schools achieved a “good class” in the indoor condition out of 12.

Figure 12: TVOC concentration inside and outside school



4.1.9 Air sampling in different transportation mode

Air samples were collected and analysed on the various modes of transport reported by the 310 sampled pupils. The parameters of pollutants such as PM_{10}, $PM_{2.5}$, CO_2, CO and volatile organic compounds (VOCs) were monitored on-board the different transport modes. The average pollutant concentrations are shown in Figures 11 to 15. In terms of PM_{10}, the school bus and railway both exceeded the HKAQO of 180 µg/m^3 level. For $PM_{2.5}$, all transport modes far exceeded the WHO AQG Interim Target-1 of 75 µg/m^3 (24 hr), which the Government is trying to comply with; it is not doubted that this is a health concern. The CO_2 levels in school buses exceeded the HK IAQ good class level of 1000 ppmv (8 hr), which is probably due to the many children crowded inside the school bus. The TVOC levels of all transport modes far exceeded the HKIAQ good class level of 261 ppbv (8 Hr), with the school bus having the worst condition.

Figure 13: PM_{10} concentration in different transportation modes

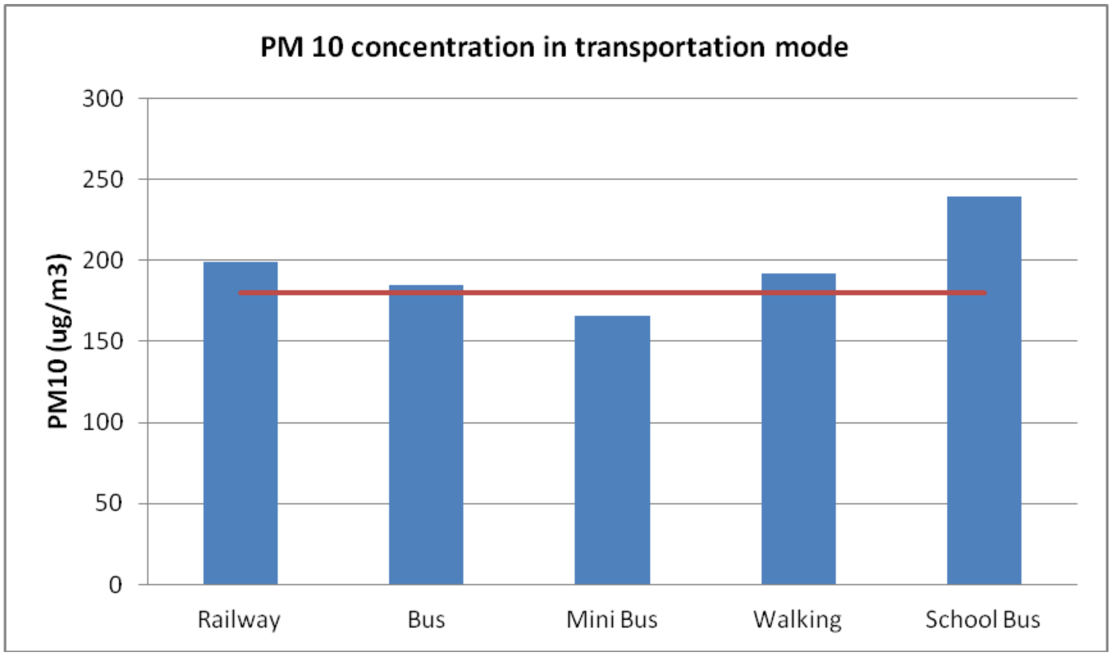


Figure 14: $PM_{2.5}$ concentration in different transportation modes

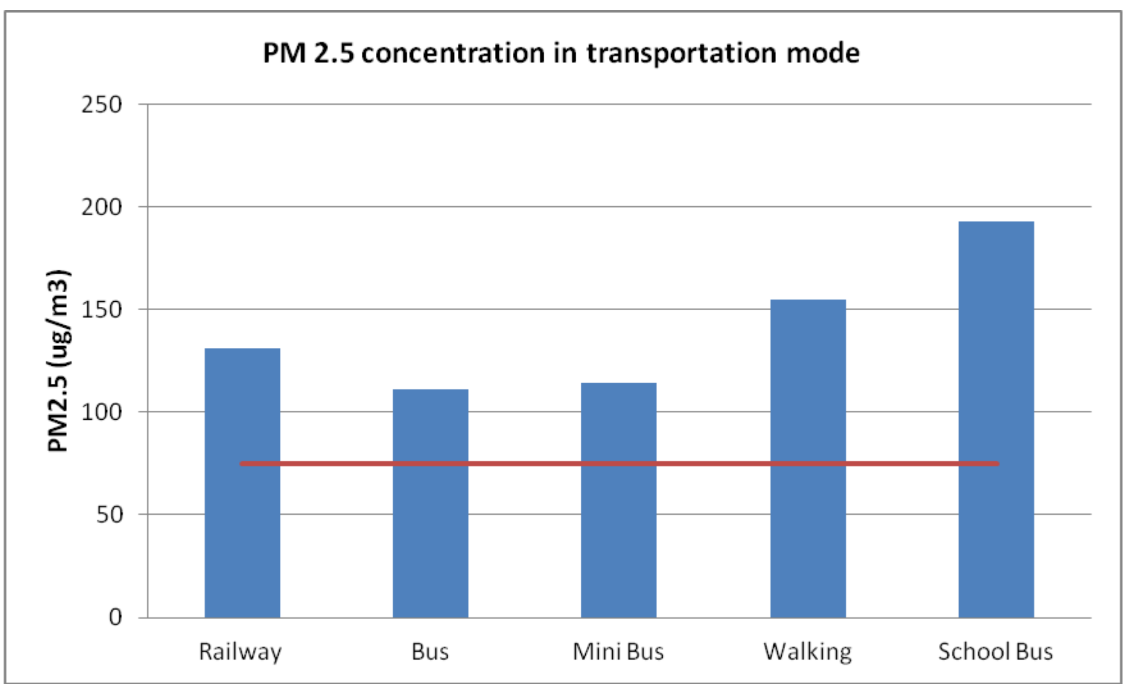


Figure 15: CO_2 concentration in different transportation modes

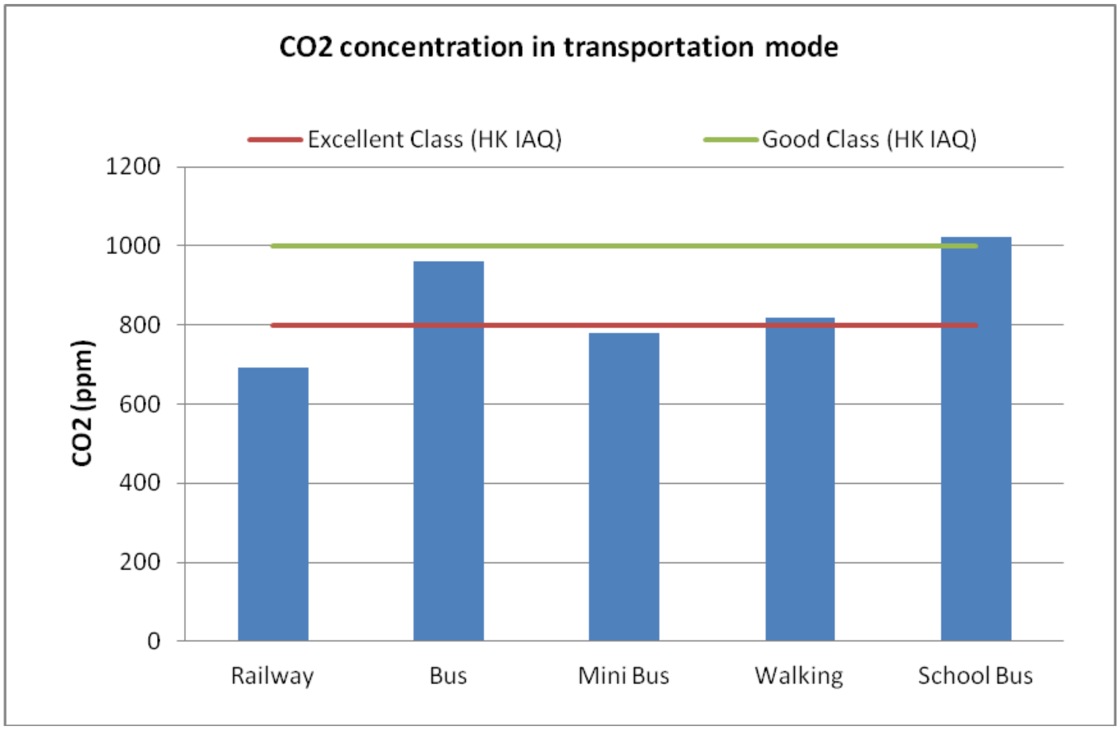


Figure 16: CO concentration in different transportation modes

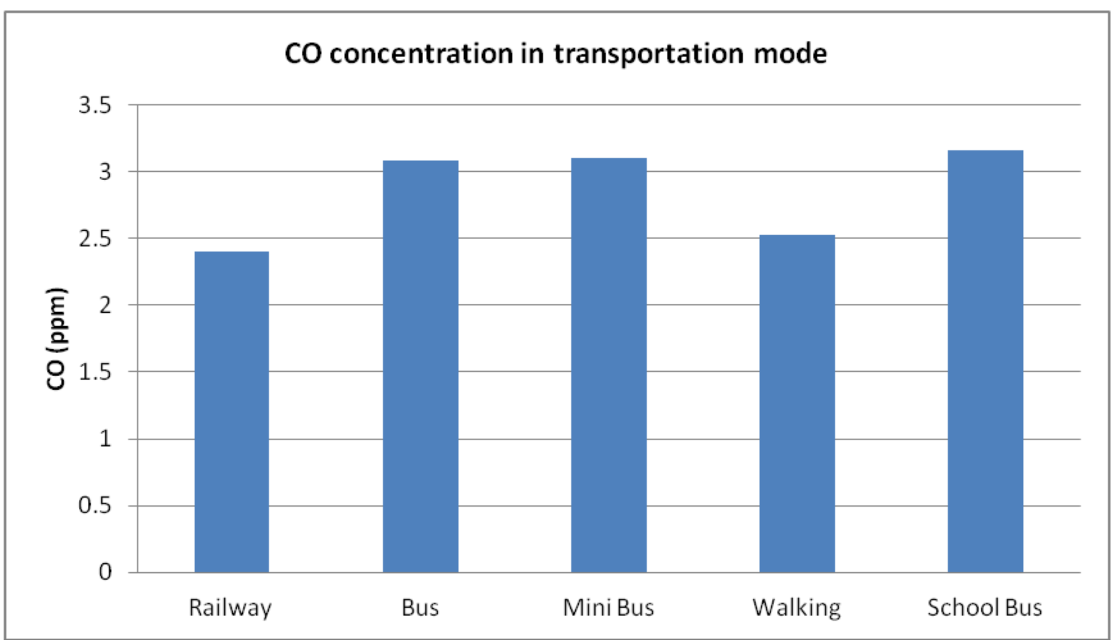
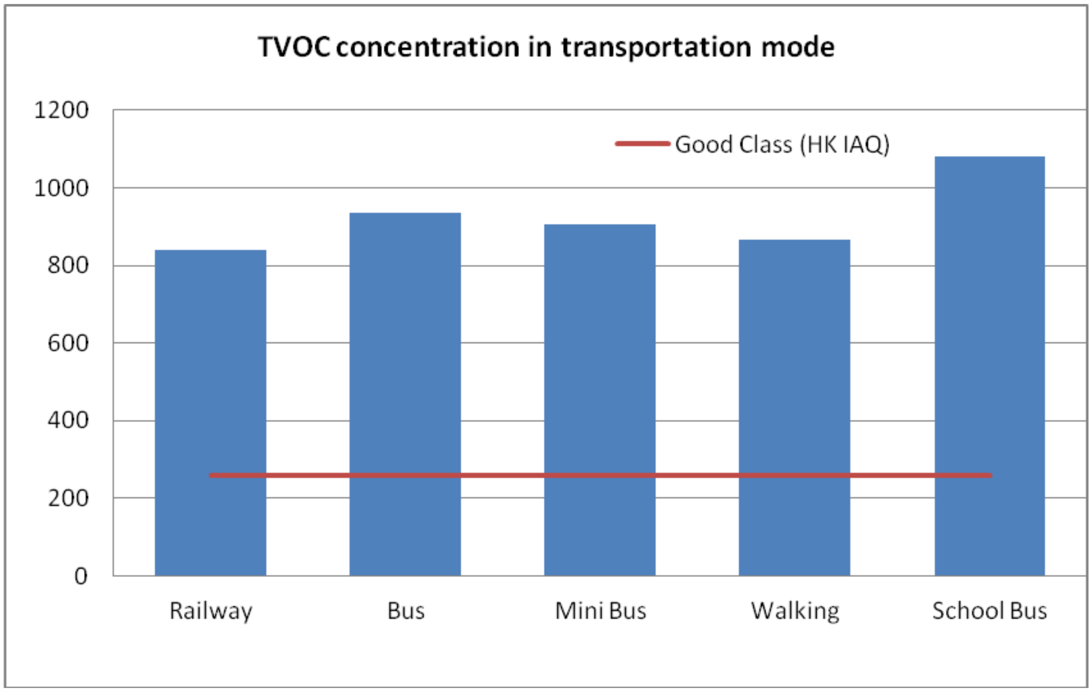


Figure 17: TVOC concentration in different transportation modes



4.2 Nepal sampling results

The baseline survey to collect data was conducted at 10 schools. Students studying at Grades 4 or 5 were targeted for the baseline survey in all the schools as they have been exposed to their surrounding micro-environment for a longer period. The questionnaire survey focused on the micro-environment the students were exposed to, their travel patterns to and from the school, and their health records. The questionnaires were distributed to parents for completion. About 35 students studying at Grades 4 and 5 from each school were targeted for the study. However, while a total of 350 students were targeted for the study, only 326 questionnaires were completed and returned. The response rate is 93.14%. The reliability analysis was performed in Nepal sampling, the Cronbach's Alpha was equaled to 0.826.

The details of the average height and weight, and gender of students at each school is presented below in the Table 10.

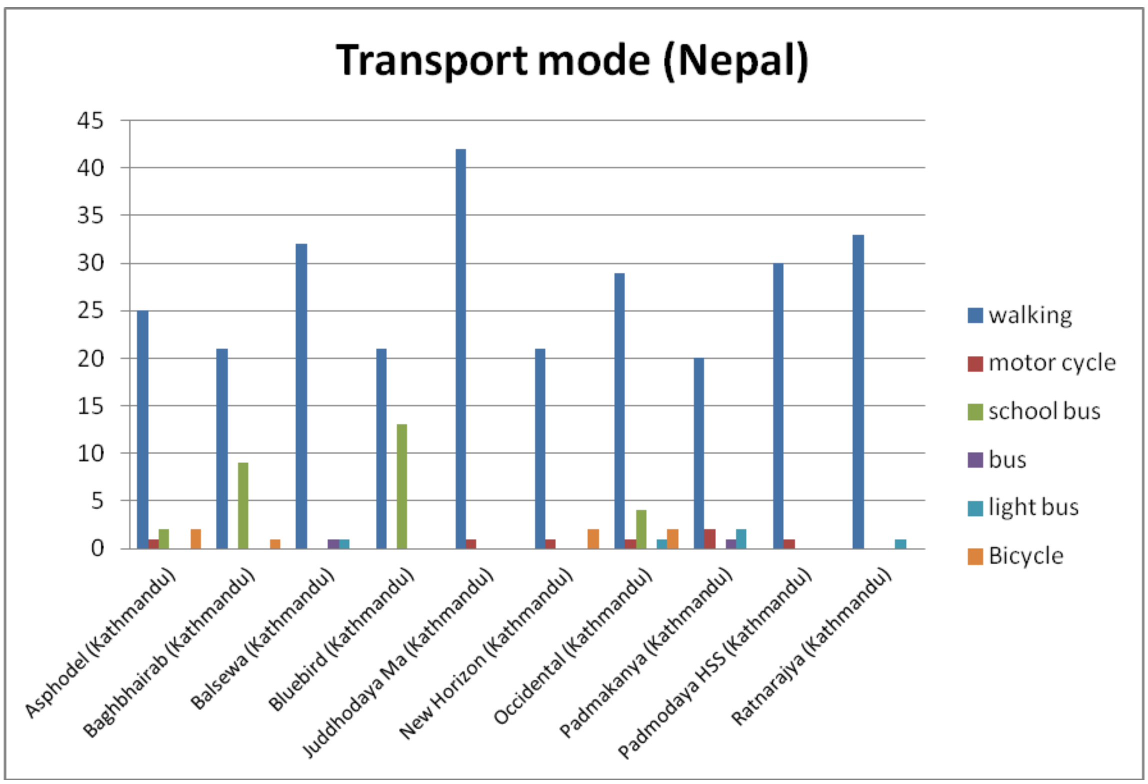
Table 10: Average height and weight, and gender of sampled children

School	Height (m)		*Weight (kg)*		Female	Male	Grand Total
	Mean	*SD*	*Mean*	*SD*			
Ashpodel	1.34	8.53	3.17	7.23	18	13	31
Bagbhairav	1.37	8.01	3.00	4.86	16	15	31
Balsewa	1.38	10.79	3.04	6.36	18	16	34
Bluebird	1.32	6.08	2.73	4.36	17	17	34
Juddodaya	1.44	7.67	3.47	6.25	21	23	44
New Horizon	1.35	5.88	2.63	4.78	10	14	24
Occidental	1.31	6.83	2.78	4.22	14	23	37
Padmakanya	1.44	9.40	3.21	8.35	25	0	25
Padmodaya	1.39	13.31	3.06	8.96	15	17	32
Ratnarajya	1.46	8.19	3.40	6.26	18	16	34

4.2.1 Transport modes

Most of school students at all the schools went to school on foot. From the 10 schools, almost 85.5% of students travelled by foot and 8.45% travelled by school bus. The highest percentage of school bus use was at Bluebird school, where 38.2% of students travelled by bus (see breakdown in Figure 16).

Figure 18: Transport mode that children used to travel to school



4.2.2 Type of pets inside the home

Allergic reactions from indoor pets such as cats, dogs, and rodents can frequently be a health issue if proper care is not taken. About 32.2% of students had a dog as a household pet, 4.18% had a cat, 4.38% had a bird and 56.85% of students had no pet. The breakdown of data for the type of pets inside the children’s homes is shown in Table 11.

Table 11: Results for pets kept in the home

School	Dog	Cat	Bird	None
Ashpodel	35.5%	0.0%	3.2%	61.3%
Bagbhairav	38.7%	6.5%	3.2%	51.6%
Balsewa	32.4%	0.0%	0.0%	58.8%
Bluebird	50.0%	2.9%	5.9%	29.4%
Juddodaya	29.5%	11.4%	11.4%	61.4%
New Horizon	21.4%	7.1%	10.7%	53.6%
Occidental	16.2%	0.0%	5.4%	75.7%
Padmakanya	32.0%	8.0%	4.0%	52.0%
Padmodaya	28.1%	0.0%	0.0%	68.8%
Ratnarajya	38.2%	5.9%	0.0%	55.9%

4.2.3 Status of smoking inside the home

Overall for the 10 schools, 27.3% of family members smoked cigarettes inside the home. The highest percentage of student's houses where family members smoked at home was at Balsewa School (47.1%), and second highest percentage was at Bagbhairab (38.7%). The percentage smoking inside the home was quite significant at most schools and there is certainly a need for targeting the awareness of parents in these cases. Details are shown in Table 12.

Table 12: Status of smoking inside the home

School	Smoking	Non-smoking
Ashpodel	25.8%	74.2%
Bagbhairav	38.7%	61.3%
Balsewa	47.1%	52.9%
Bluebird	17.6%	82.4%
Juddodaya	22.2%	77.8%
New Horizon	20.8%	79.2%
Occidental	5.4%	94.6%
Padmakanya	48.0%	52.0%
Padmodaya	34.3%	65.7%
Ratnarajya	20.6%	79.4%

4.2.4 Cooking fuel

About 96.29% of student families used LPG as a cooking fuel, 2.06% used kerosene and 1.66% used firewood (see Table 13). The findings of a research study entitled, "Acute Lower Respiratory Infection in Childhood and Household Fuel Use in Bhaktapur, Nepal" provides support that the use of biomass as household fuel, along with kerosene, is one of the major risk factors for acute lower respiratory infection in young children (Bates et al., 2013). With rapid urbanization and modernization, most families commonly use LPG as a cooking fuel in the city area.

Table 13: Cooking fuel (Nepal)

School	Cooking fuel		
	Firewood	Kerosene	LPG
Ashpodel	0.0%	0.0%	100.0%
Bagbhairav	6.5%	0.0%	93.5%
Balsewa	0.0%	2.9%	97.1%
Bluebird	5.9%	0.0%	94.1%
Juddodaya	0.0%	4.7%	95.3%
New Horizon	0.0%	0.0%	100.0%
Occidental	0.0%	0.0%	100.0%
Padmakanya	4.2%	4.2%	91.7%
Padmodaya	0.0%	0.0%	100.0%
Ratnarajya	0.0%	8.8%	91.2%

4.2.5 Household indoor condition

There are various sources of indoor air pollution that are associated with adverse health impacts that people are rarely aware of; these include incense burning, mosquito repellent burning and odoriferous chemical vapours. Mosquito coils may represent a serious potential threat to children's health as prolonged use has been associated with an increased incidence of asthma and persistent wheezing in children. The smoke from the coils is found to be entirely composed of respirable-sized particles; some are quite small and the particles contain numerous polycyclic aromatic hydrocarbons (PAH) and carbonyl compounds, including formaldehyde. The burning of mosquito repellent coils is quite common in families in the Kathmandu Valley, especially during the hot season when mosquito numbers rise – 40.46% of households burned mosquito repellent coils in the house.

The burning of incense is quiet common as part of religious ceremonies and rituals in Hinduism, Buddhism and many other religions. The burning of incense as a daily ritual is quite common among families of the Kathmandu Valley, where the majority are Hindu or Buddhist. About 53.52% of households burn incense inside the house. Usually the use of odoriferous chemical vapours inside the home is not so common among the families of the Kathmandu valley: 4.11% of student families used odoriferous chemical vapour. For a breakdown of the sources of indoor air pollution see Table 14.

Table 14: Household condition (Nepal)

School	Incense burning	Indoor plants	Mosquito repellent burning	Odoriferous chemical vapour	None
Ashpodel	58.1%	16.1%	19.4%	3.2%	25.8%
Bagbhairav	51.6%	12.9%	25.8%	3.2%	25.8%
Balsewa	35.3%	8.8%	55.9%	0.0%	20.6%
Bluebird	35.3%	11.8%	50.0%	2.9%	26.5%
Juddodaya	61.4%	9.1%	50.0%	6.8%	18.2%
New Horizon	62.5%	54.5%	53.3%	13.3%	37.5%
Occidental	27.0%	10.8%	16.2%	2.7%	43.2%
Padmakanya	60.0%	24.0%	64.0%	0.0%	16.0%
Padmodaya	59.4%	3.1%	40.6%	3.1%	18.8%
Ratnarajya	47.1%	8.8%	29.4%	5.9%	38.2%

4.2.6 Moulds/mildew in the household

About 17.27% of houses had the presence of moulds/mildew in the walls and ceilings during the rainy season only, 2% had the presence of mould/mildew on most days of year, 5.36% had it when it rained continuously, while in 0.42% of houses mould/mildew grow only when the humidity was high. The relationships between dampness, microbial exposure and health effects cannot be quantified precisely, but it is recommended that dampness and mould-related problems be prevented and remediated as they increase the risk of hazardous exposure to microbes and chemicals.

Table 15: Moulds/mildew in the household

School	Mould	No mould
Ashpodel	24.1%	75.9%
Bagbhairav	16.1%	83.9%
Balsewa	30.3%	69.7%
Bluebird	13.8%	86.2%
Juddodaya	14.0%	86.0%
New Horizon	16.7%	83.3%
Occidental	27.8%	72.2%
Padmakanya	36.0%	64.0%
Padmodaya	50.0%	50.0%
Ratnarajya	21.9%	78.1%

4.2.7 Respiratory diseases

Asthma

Unlike Hong Kong, asthma is a not common in Nepal: only two cases were recorded in ten sampled schools (see Table 16).

Table 16: Number of children suffering from asthma

School	Number	Percentage
Ashpodel	0	0.0%
Bagbhairav	0	0.0%
Balsewa	0	0.0%
Bluebird	0	0.0%
Juddodaya	0	0.0%
New Horizon	0	0.0%
Occidental	0	0.0%
Padmakanya	0	0.0%
Padmodaya	2	6.3%
Ratnarajya	0	0.0%

Other respiratory diseases in previous 12 months

Of the 10 schools, only Padmodaya had respondents suffering from asthma (10%). During the previous 12 months, of the 326 responses from 10 schools about 0.62% suffered from asthma, 10.9% suffered from pneumonia, 0.31% suffered from bronchitis, 4.68% suffered from sinusitis and 4.0% suffered from allergic rhinitis. The percentage distribution of surveyed students suffering from different respiratory diseases in the 10 schools during the previous year is presented in Table 17.

Table 17: Incidence of some respiratory diseases in previous 12 months

School	Sinusitis	Allergic rhinitis	Bronchitis	Pneumonia	Asthma
Ashpodel	0.0%	6.5%	0.0%	0.0%	0.0%
Bagbhairav	0.0%	3.2%	0.0%	3.2%	0.0%
Balsewa	2.9%	2.9%	0.0%	8.8%	0.0%
Bluebird	5.9%	2.9%	0.0%	5.9%	0.0%
Juddodaya	6.8%	9.1%	0.0%	13.6%	0.0%
New Horizon	0.0%	4.2%	0.0%	16.7%	0.0%
Occidental	0.0%	8.1%	0.0%	5.4%	0.0%
Padmakanya	4.0%	0.0%	0.0%	16.0%	0.0%
Padmodaya	12.5%	3.1%	3.1%	21.9%	6.2%
Ratnarajya	14.7%	0.0%	0.0%	17.6%	0.0%

4.2.8 Pulmonary function results

The average pulmonary function results of the ten schools in Nepal is plotted by value and percentages in Figures 17 and 18, respectively.

Figure 19: FVC pulmonary function results (value)

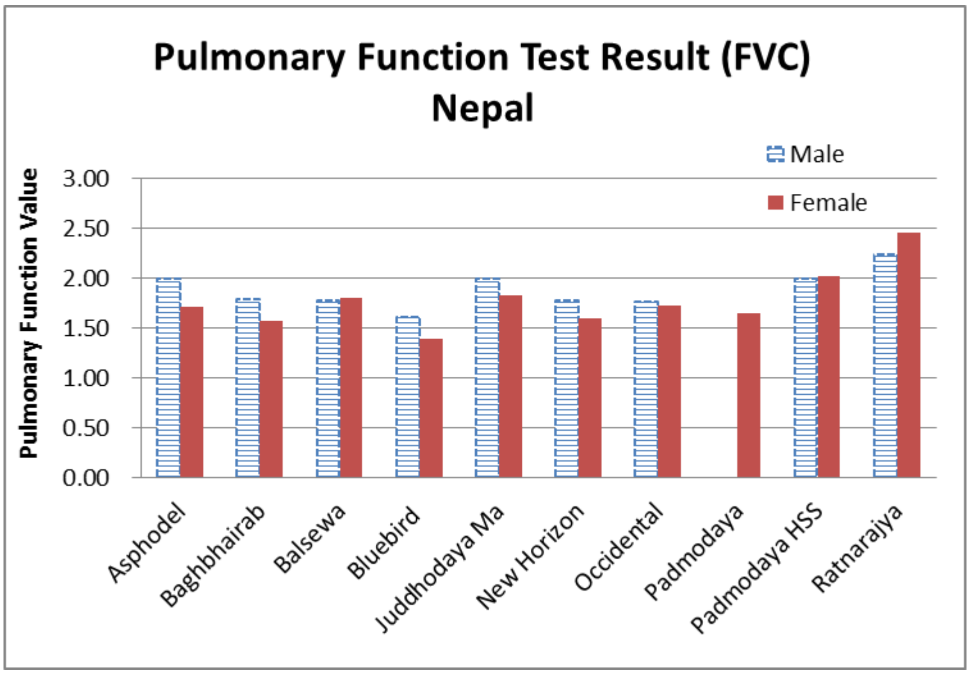


Figure 20: FEV1 pulmonary function results (value)

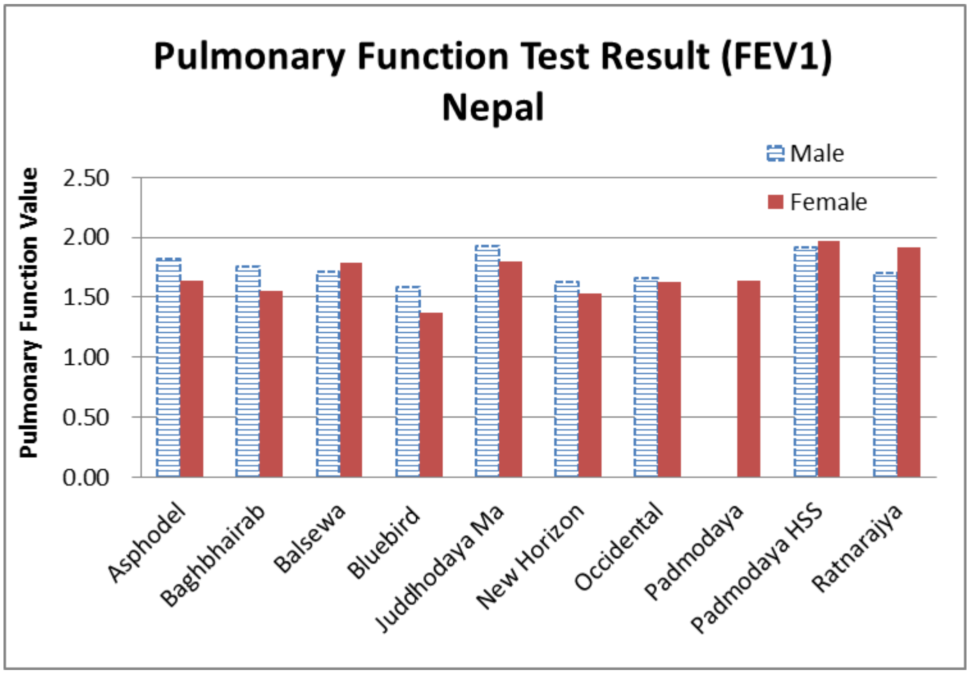


Figure 21: FVC pulmonary function results (percentage)

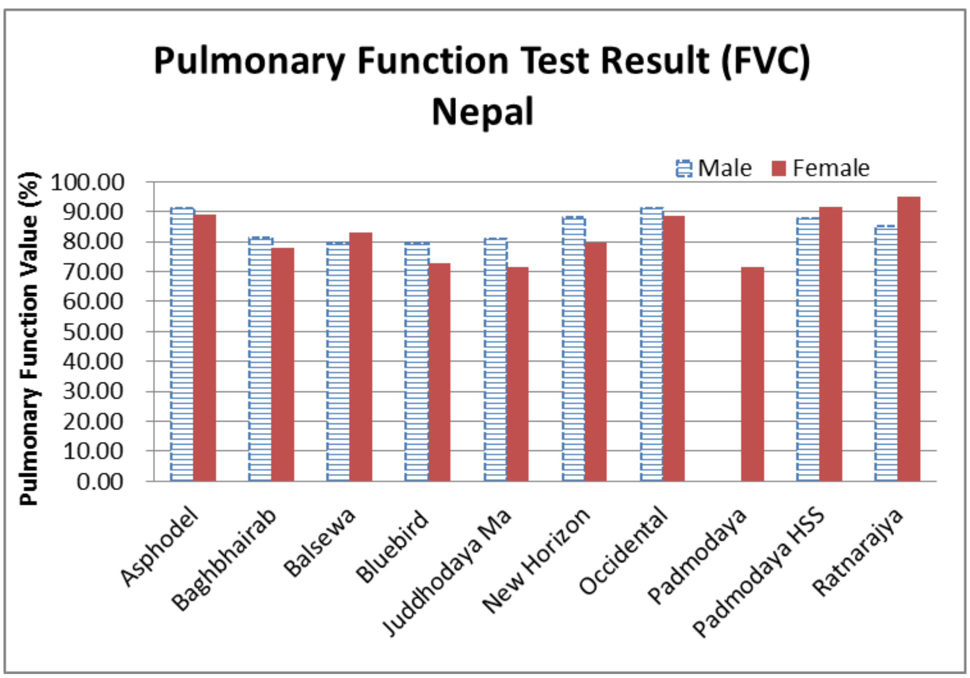
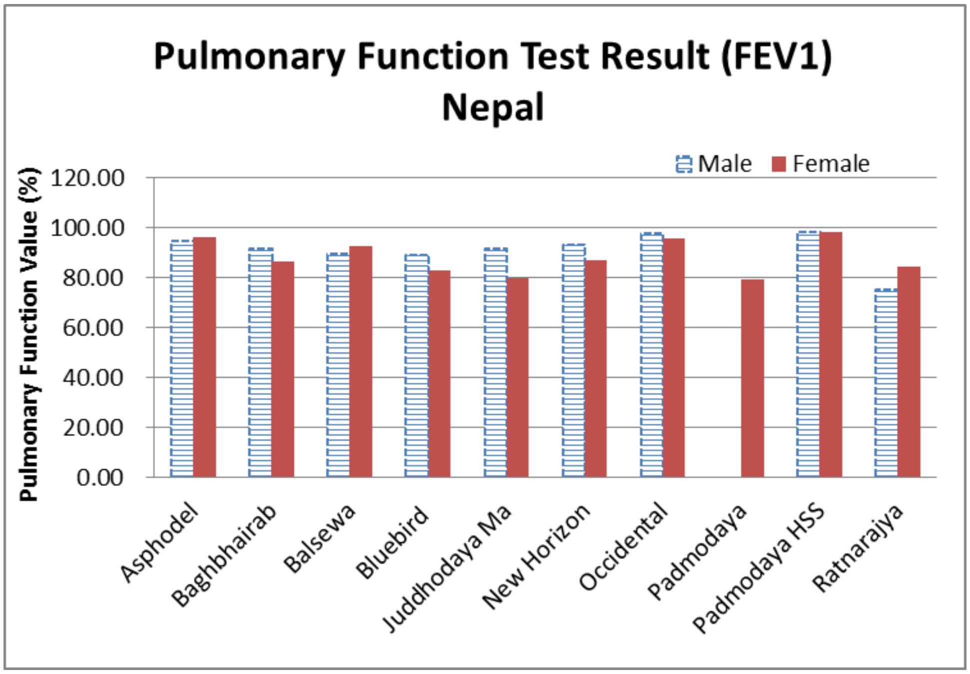


Figure 22: FEV1 pulmonary function results (percentage)

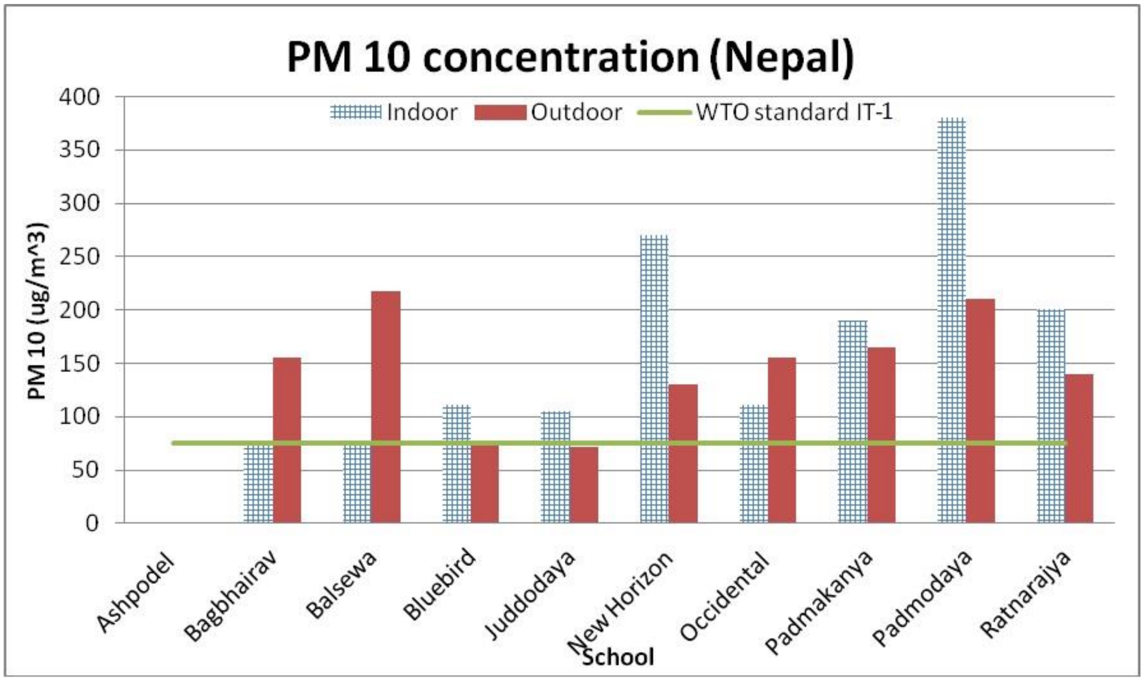


4.2.9 Air quality results

Concentration of PM

The PM_{10} concentration inside and outside school is shown in Figure 19. The concentration of PM_{10} outside the school exceeds the WHO ambient air quality standard at most school except for Bluebird and Juddodaya. Bluebird had the lowest concentration (71.2 µg/m3) among the 10 schools and was not found to exceed the WHO IT-1 standard. The concentration outside Bagbhairav School in Kirtipur was found to be 154.9 µg/m3. The concentration outside New Horizon, which lies in a residential area, seems comparatively lower than at schools in roadside and commercial areas. However, the concentration outside Occidental School, which also lies in the residential area, was found to match that of other schools in commercial and roadside areas. This can be attributed to the recent construction of a road in the Dhobikhola corridor, which is quite near to school.

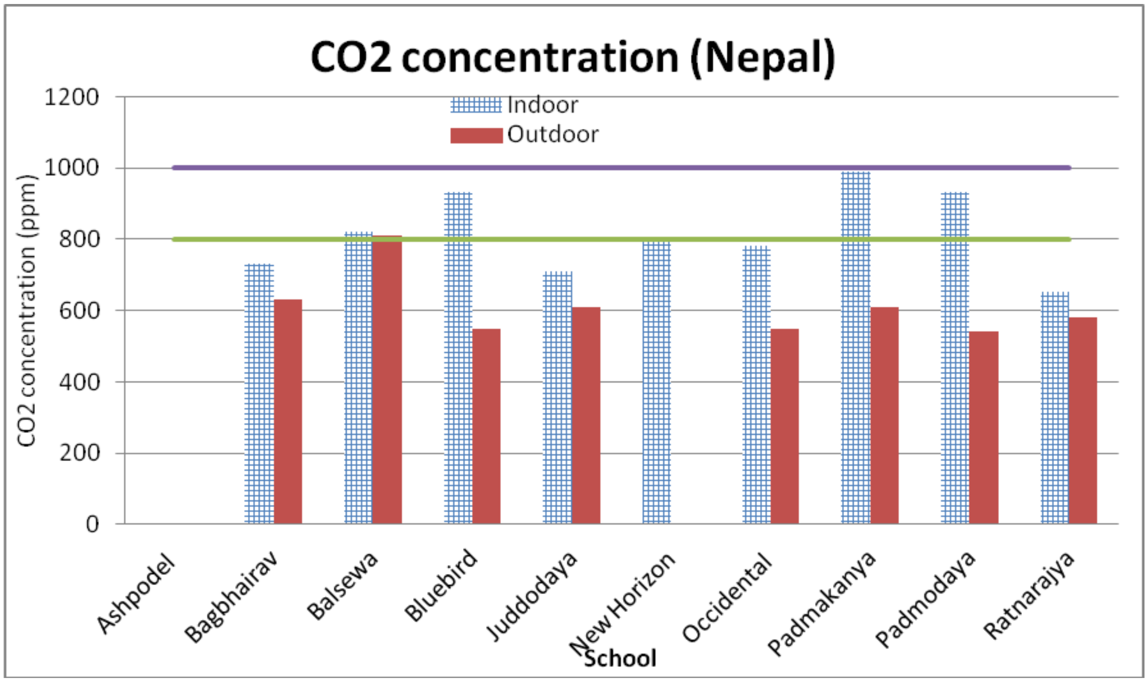
Figure 23: PM_{10} concentration inside and outside school



Concentration of CO_2

The CO_2 concentration inside and outside school is shown in Figure 20.

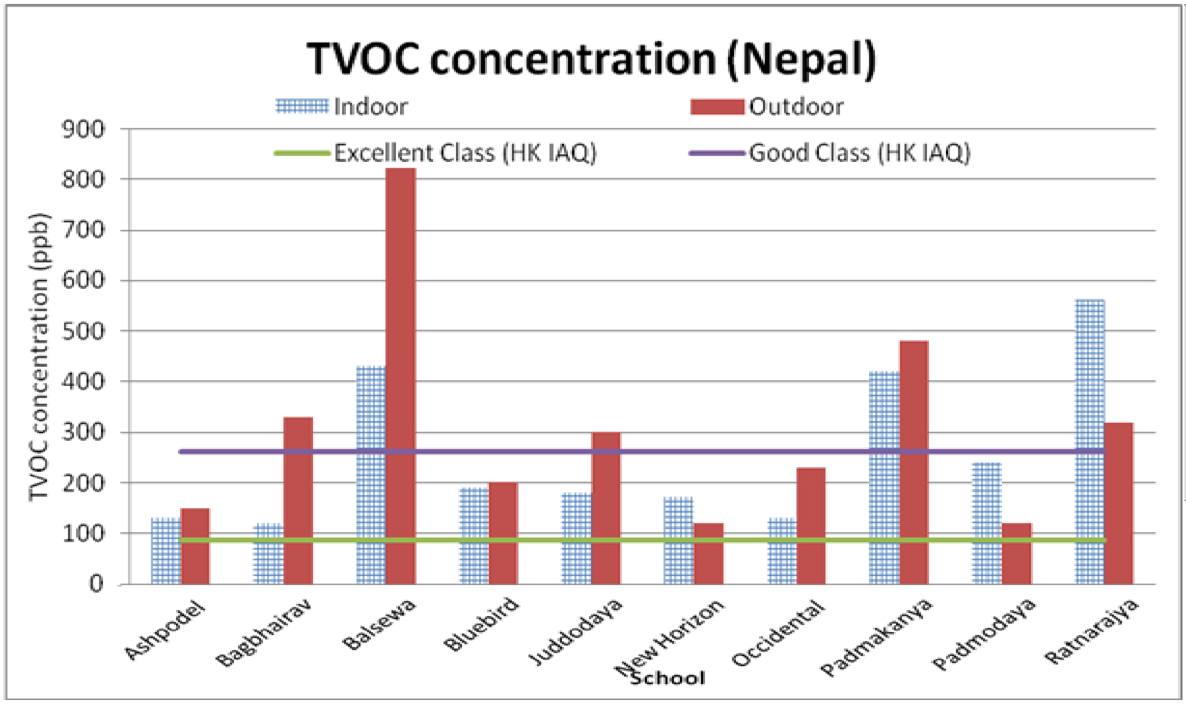
Figure 24: CO_2 concentration inside and outside school



Concentration of VOCs

The total VOC concentration at each school is presented in Figure 21. The concentration of TVOC inside the classroom was found to be within the “good class” except for three schools: Balsewa, Padmakanya and Ratnarajya. The concentration of TVOC outside the school was found to exceed “good class” in the case of five schools: Bagbhariav, Balsewa, Juddodaya, Padmakanya and Ratnarajya. TVOC concentration outside Balsewa School was found to be exceptionally high compared to other schools, with a concentration of 823.12 ppb. A major source in this case can be attributed to vehicular emissions as Balsewa School is located beside a narrow entry in Jhoche in the Basantapur area – many motorcycles pass through this narrow road to obtain access to the Basantapur area as the main Basantapur Durbar Square has been declared a vehicle free zone. The TVOC concentrations outside schools in the residential area (Ashpodel, New Horizon and Occidental) seem to be relatively lower than at schools in other areas as vehicular movement in these areas is lower.

Figure 25: TVOC concentration inside and outside school



4.3 Vietnam Study

Ten schools were selected with the approval of the Hanoi Department of Education, located in three different districts. The questionnaire survey focused on Grade 4 children in primary schools (about 10 years old) and the number of children selected was between 50 and 60 at each school. The questionnaire survey included the indoor environment that children are exposed to, which refers to the number of people who smoke, the kind of pet that is kept, the indoor conditions of mould/mildew inside the home, the mode of transportation, routes to and from school and the health record.

The study was targeted at Grade 4 children at primary school. The total number of completed questionnaires collected was 511, the response rate is 97.71%. The reliability analysis was performed and the Cronbach's Alpha was equaled to 0.851. The highest mean weight of school students was at Dang Tran Con A School and lowest mean weight was at Thinh Hao School. However, the mean weight of children among the 10 schools was not significantly different. Similarly, the mean height of the school children was almost the same for the 10 schools (1.36–1.39 m). The details of average height and weight of students and also gender for students at each school is presented below in Table 18.

Table 18: Average height and weight, and gender of sampled children

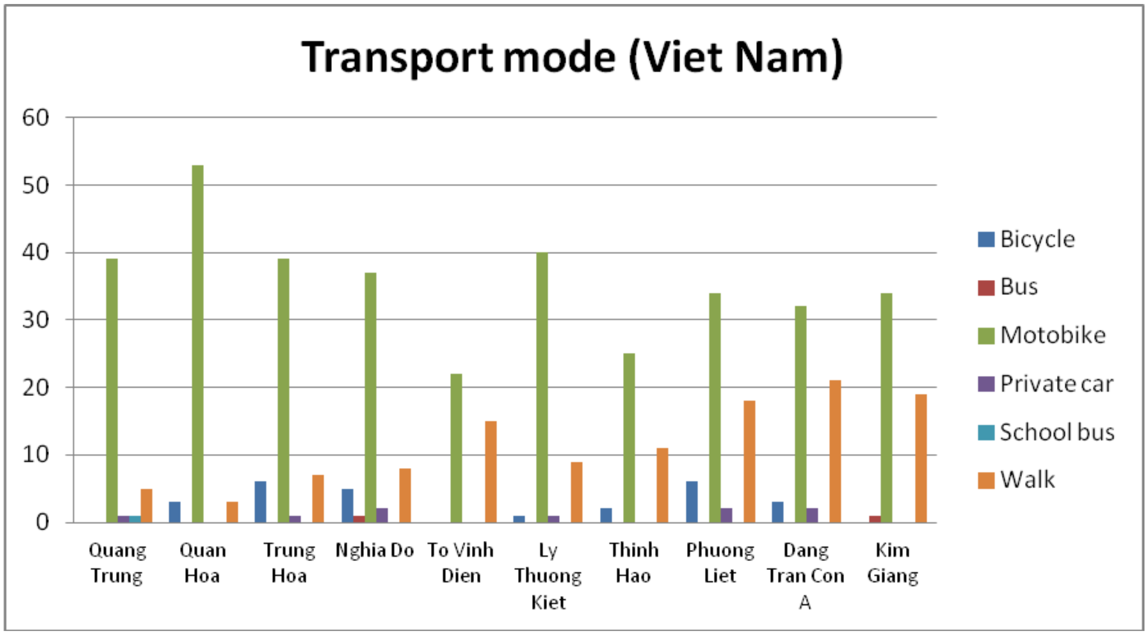
School	**Height (m)**		***Weight (kg)***		**Female**	**Male**	**Grand Total**
	Mean	***SD***	***Mean***	***SD***			
Dang Tran Con A	1.37	0.06	35.15	6.66	26	32	58
Kim Giang	1.37	0.06	34.94	6.14	28	26	54
Ly Thuong Kiet	1.36	0.07	33.45	6.37	25	26	51
Nghia Do	1.37	0.06	34.81	7.70	21	33	54
Phuong Liet	1.36	0.08	34.08	7.98	24	36	60
Quan Hoa	1.39	0.07	34.87	7.10	32	27	59
Quang Trung	1.36	0.05	33.23	5.41	26	20	46
Thinh Hao	1.36	0.08	32.15	5.84	16	23	39
To Vinh Dien	1.37	0.07	33.54	6.20	16	21	37
Trung Hoa	1.36	0.08	33.57	5.72	28	25	53

4.3.1 Transport modes

The questionnaires collected from the children's parents included information about the transportation mode that children used to go to and from school. The transportation mode results for all 10 schools are shown in Figure 22. The graph shows that in all 10 schools, most of children used motorcycles as the transportation mode. In total about 70% school children went to school by motorcycle. The second highest mode was walking (23%).

The number of students using public transport (including buses and school buses) was very low (only 1–2 at most). The reason for this is that most of the public schools in Vietnam still do not supply school buses for children. Public buses are always very crowded in the early morning and late afternoon and are not safe for children. The poor public transport system is the reason for the high rate of usage of private transport such as motorcycles.

Figure 26: Transport mode that children used to travel to school



4.3.2 Type of pets inside the home

Numerous studies have shown that keeping furry pets inside house will cause skin diseases, digestive diseases or respiratory diseases to children especially when they play too close to the pets.

The data for the type of pet inside the children's home is shown in Table 19. Generally, the percentage of families that had pets ranged from 10 to 20%. Others furry pets, mostly chickens or ducks, were found in some houses away from the city centre. Of the 10 schools, Kim Giang School had the highest number of families who kept pets. More precisely, at Kim Giang school 22% of families had dogs, 13% had birds, 13% had cats and 26% had other pets like chickens or ducks. This also means that many families had several kinds of pets inside the home.

Table 19: Results for pets kept inside the home

School	Dog	Cat	Bird	None
Dang Tran Con A	3.0%	10.0%	16.0%	71.0%
Kim Giang	22.0%	13.0%	13.0%	48.0%
Ly Thuong Kiet	8.0%	22.0%	18.0%	57.0%
Nghia Do	17.0%	9.0%	13.0%	65.0%
Phuong Liet	17.0%	17.0%	5.0%	60.0%
Quan Hoa	19.0%	19.0%	12.0%	63.0%
Quang Trung	13.0%	15.0%	15.0%	59.0%
Thinh Hao	10.0%	23.0%	10.0%	67.0%
To Vinh Dien	11.0%	16.0%	8.0%	70.0%
Trung Hoa	9.0%	4.0%	13.0%	68.0%

4.3.3 Status of smoking inside the home

Of the 495 who responded to the question about smoking status inside the home, 44% of children's families revealed they had people who smoked. In some schools such as Thinh Hao, Ly Thuong Kiet and Quang Trung, more than half of children have to live in household environment which had smokers. The questionnaire data collected also shows that in almost families that had smokers the number of cigarettes was from less than 10 to less than 20 per day. More detail is shown in Table 20 below.

Table 20: Status of smoking inside the home

School	Smoking	Non-smoking
Dang Tran Con A	19.0%	81.0%
Kim Giang	31.0%	69.0%
Ly Thuong Kiet	54.0%	46.0%
Nghia Do	40.0%	60.0%
Phuong Liet	53.0%	47.0%
Quan Hoa	47.0%	53.0%
Quang Trung	58.0%	42.0%
Thinh Hao	62.0%	38.0%
To Vinh Dien	49.0%	51.0%
Trung Hoa	40.0%	60.0%

4.3.4 Cooking fuel

Most of the households in the 10 surveyed schools (and in Hanoi more generally) used gas as the major cooking fuel. Of the 493 respondents to this question, 92% of families said they used gas to meet their daily cooking needs. Besides this, some families (28%) used electricity, but most of these still had both gas and electricity. The number of families using coal or wood to cook was very small, amounting to only 6%.

4.3.5 Household indoor condition

There are various sources of indoor air pollution that can have adverse health impacts, and which people are rarely aware of such as incense burning, indoor plants and odoriferous chemical vapours. Among these, incense burning and indoor plants were found most commonly in this survey. The use of mosquito repellent burning is not common in Hanoi because people have acknowledged the harm of having this inside the home.

Table 21: Household indoor condition

School	Incense burning	Indoor plants	Mosquito repellent burning	Air purifier	Odoriferous chemical vapour	Dehumidifier
Dang Tran Con A	53.0%	23.0%	4.0%	2.0%	9.0%	5.0%
Kim Giang	90.0%	47.0%	10.0%	12.0%	10.0%	10.0%
Ly Thuong Kiet	65.0%	39.0%	2.0%	8.0%	14.0%	6.0%
Nghia Do	54.0%	16.0%	8.0%	4.0%	12.0%	4.0%
Phuong Liet	37.0%	19.0%	5.0%	2.0%	11.0%	2.0%
Quan Hoa	52.0%	26.0%	5.0%	9.0%	24.0%	7.0%
Quang Trung	57.0%	23.0%	2.0%	5.0%	14.0%	5.0%
Thinh Hao	62.0%	18.0%	8.0%	5.0%	15.0%	0.0%
To Vinh Dien	59.0%	24.0%	8.0%	8.0%	16.0%	5.0%
Trung Hoa	54.0%	44.0%	8.0%	2.0%	17.0%	6.0%

4.3.6 Moulds/mildew in the household

Questionnaire data collected showed that 55% of homes of the children at all 10 schools had mould or mildew due to high humidity or rainy weather. Of the schools, Kim Giang School had the highest percentage, the second being Dang Tran Con A School. Both schools are located in a newly developed area, near to construction sites.

Table 22: Moulds/mildew in the household

School	Mould	No mould
Dang Tran Con A	40.0%	60.0%
Kim Giang	30.0%	70.0%
Ly Thuong Kiet	55.0%	45.0%
Nghia Do	45.0%	55.0%
Phuong Liet	45.0%	55.0%
Quan Hoa	46.0%	54.0%
Quang Trung	50.0%	50.0%
Thinh Hao	53.0%	47.0%
To Vinh Dien	47.0%	53.0%
Trung Hoa	41.0%	59.0%

4.3.7 Respiratory diseases

Asthma

The proportion of children who suffered from asthma was not particularly high (11%). However, To Vinh Dien School had the highest ratio (19%). There was no asthma reported at Thinh Hao School.

Table 23: Number of children suffering from asthma

School	Number	Percentage
Dang Tran Con A	9	16.0%
Kim Giang	7	14.0%
Ly Thuong Kiet	7	15.0%
Nghia Do	4	9.0%
Phuong Liet	7	12.0%
Quan Hoa	5	9.0%
Quang Trung	4	9.0%
Thinh Hao	0	0.0%
To Vinh Dien	7	19.0%
Trung Hoa	4	8.0%

Other respiratory diseases in previous 12 months

Table 24: Incidence of respiratory diseases in previous 12 months

School	Sinusitis	Allergic rhinitis	Bronchitis	Pneumonia	Asthma
Dang Tran Con A	2.0%	30.0%	12.0%	2.0%	7.0%
Kim Giang	4.0%	24.0%	32.0%	22.0%	6.0%
Ly Thuong Kiet	8.0%	25.0%	37.0%	0.0%	4.0%
Nghia Do	7.0%	24.0%	18.0%	2.0%	0.0%
Phuong Liet	2.0%	34.0%	26.0%	5.0%	5.0%
Quan Hoa	7.0%	33.0%	26.0%	2.0%	5.0%
Quang Trung	2.0%	43.0%	13.0%	0.0%	0.0%
Thinh Hao	3.0%	39.0%	12.0%	0.0%	0.0%
To Vinh Dien	3.0%	32.0%	32.0%	3.0%	0.0%
Trung Hoa	6.0%	27.0%	23.0%	0.0%	2.0%

Table 24 shows some of the other respiratory diseases that children may suffer from. Thirty-one percent of students from the 10 schools with 479 respondents suffered from allergic rhinitis, and Quang Trung School has the highest proportion at 43%. The lowest incidence of this condition was 24% at Nghia Do School. Another common condition was bronchitis, which 23% of children suffered from. There are also other diseases that people suffered from for many reasons including the weather, indoor conditions and air pollution. Other diseases that had a low incidence are listed as sinusitis, bronchitis and asthma; however, these are the more serious diseases. Dang Tran Con A, Ly Thuong Kiet and Kim Giang schools were some of the schools which had more children suffering from these conditions.

4.3.8 Pulmonary function results

As Figure 27 shows, Thinh Hao School recoded the lowest mean FVC (1.73) while Nghia Do School recorded the highest mean FVC (2.23). The second highest mean FVC was recorded at Trung Hoa and Dang Tran Con A Schools, with the result of 2.06. The percentages are shown in Figure 29.

Figure 27: FVC pulmonary function results (value)

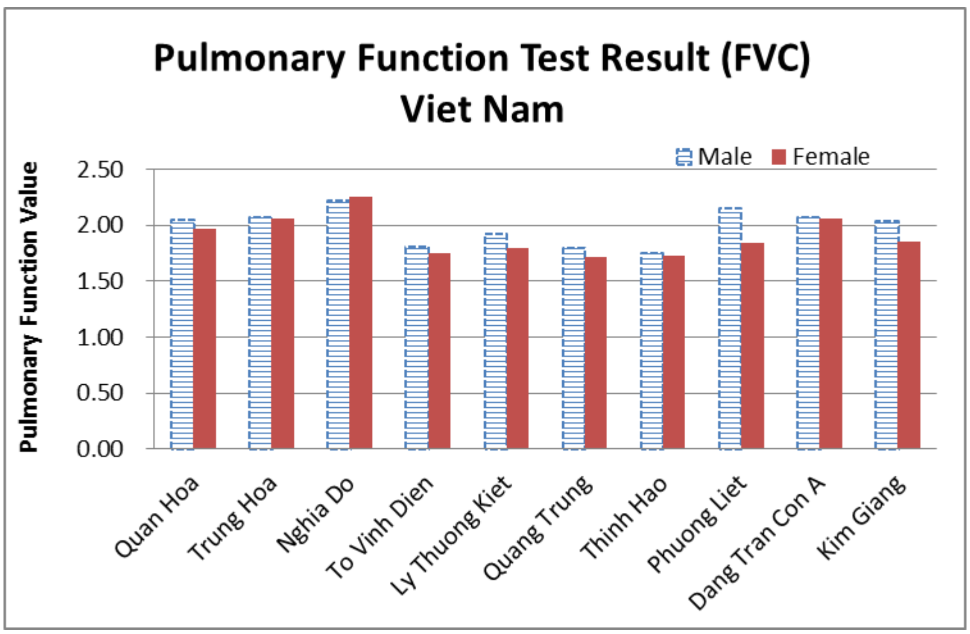


Figure 28: FEV1 pulmonary function results (value)

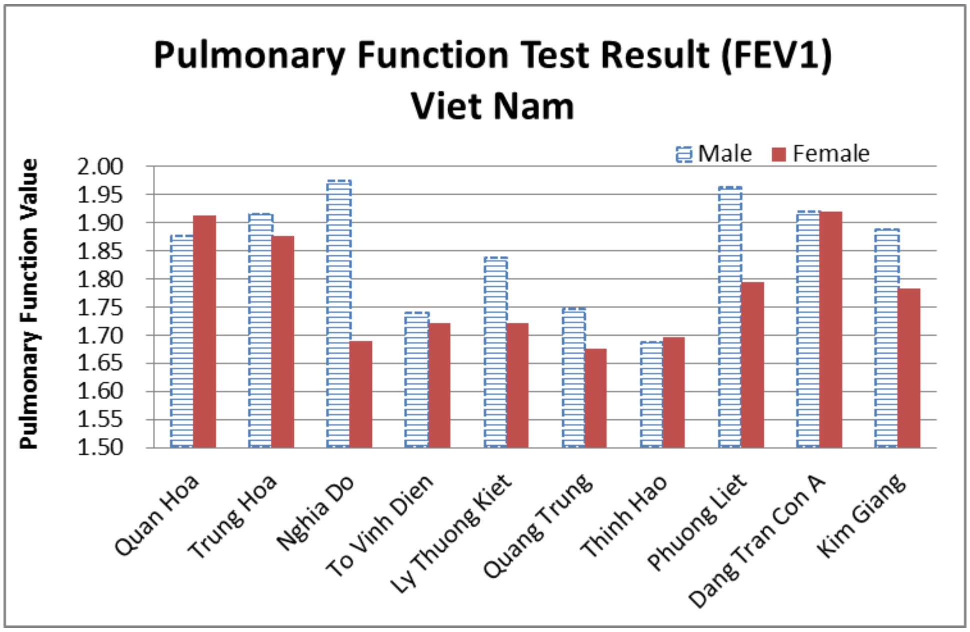


Figure 29: FVC Pulmonary function results (percentage)

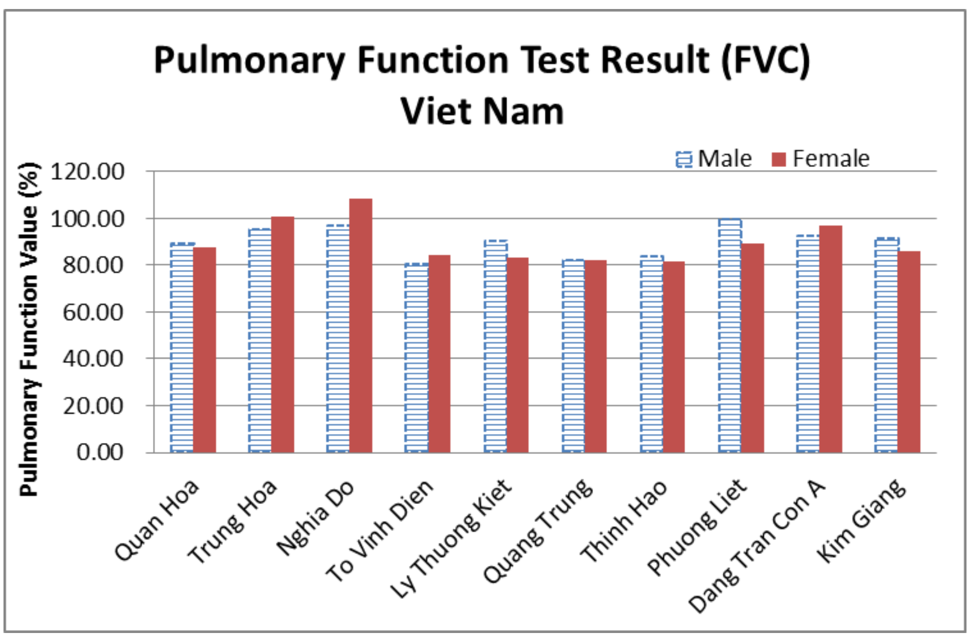
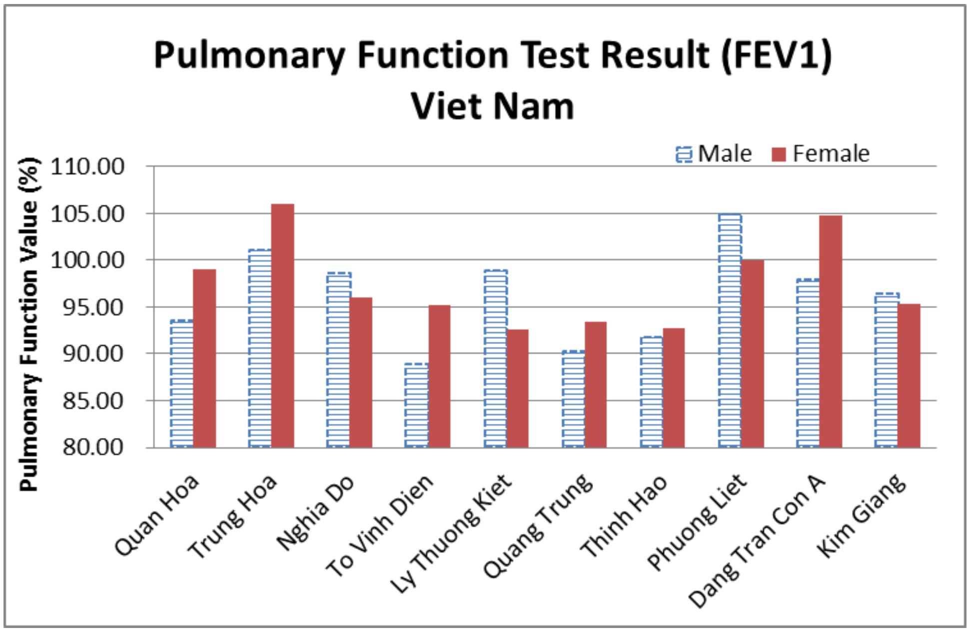


Figure 30: FEV1 Pulmonary function results (percentage)



As Figure 27 shows, Thinh Hao School had lowest mean FEV1 of 1.69 while Nghia Do School had the highest mean FEV1 of 1.97. The second highest mean FEV1 was that of Dang Tran Con A School with the result of 1.92. Figure 28 shows that Trung Hoa School had the highest mean of percentage FEV1. Furthermore, Thinh Hao School recorded the lowest value in both FVC and FEV1 percentages.

4.3.9 Air quality results

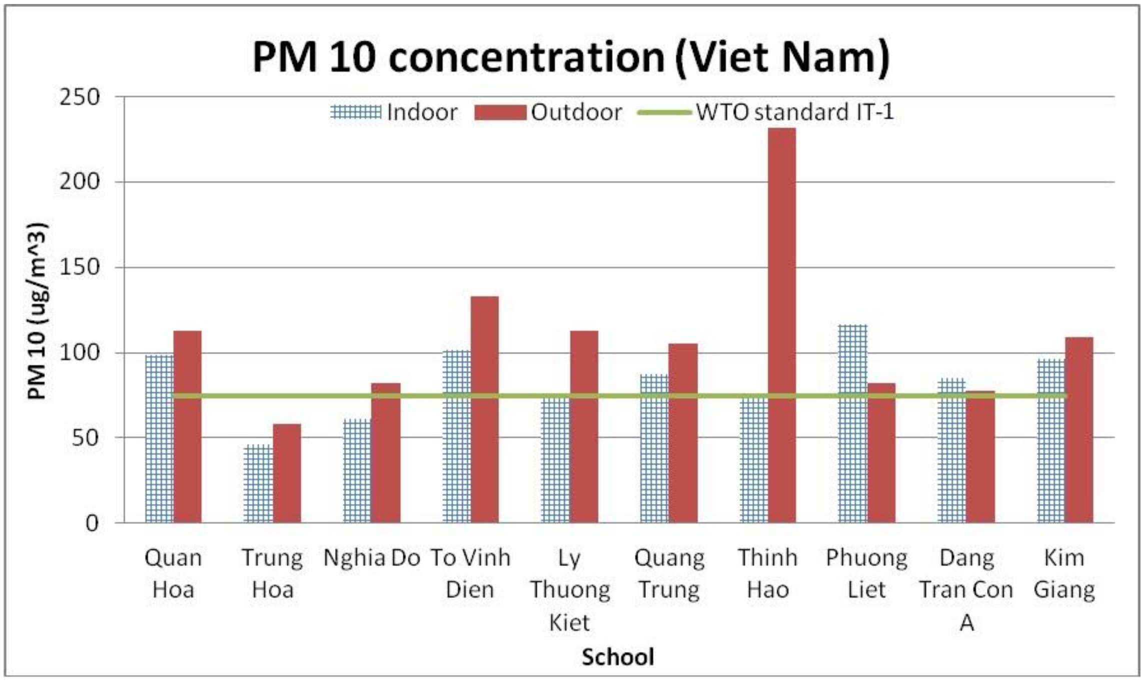
Concentration of PM

The PM_{10} concentration inside the classroom of most schools exceeded the acceptable WHO standard IT-3 (75 µg/m^3) at Trung Hoa and Nghia Do Schools. However, the PM_{10} concentration at none of the schools exceeded the Vietnam National Technical regulation (QCVN) of 150 µg/m^3. Trung Hoa School had the lowest PM_{10} level inside the classroom while Phuong Liet School had the highest.

The PM_{10} concentration outside most schools exceeded the WHO standard IT-3 (75 µg/m^3) except for Trung Hoa School. However, compared to the QCVN, only Thinh Hao School had a higher result, exceeding the PM_{10} level.

Figure 31 shows that the PM_{10} level outside the school was lower than that inside the classroom at Phuong Liet and Dang Tran Con A Schools.

Figure 31: PM_{10} concentration inside and outside school



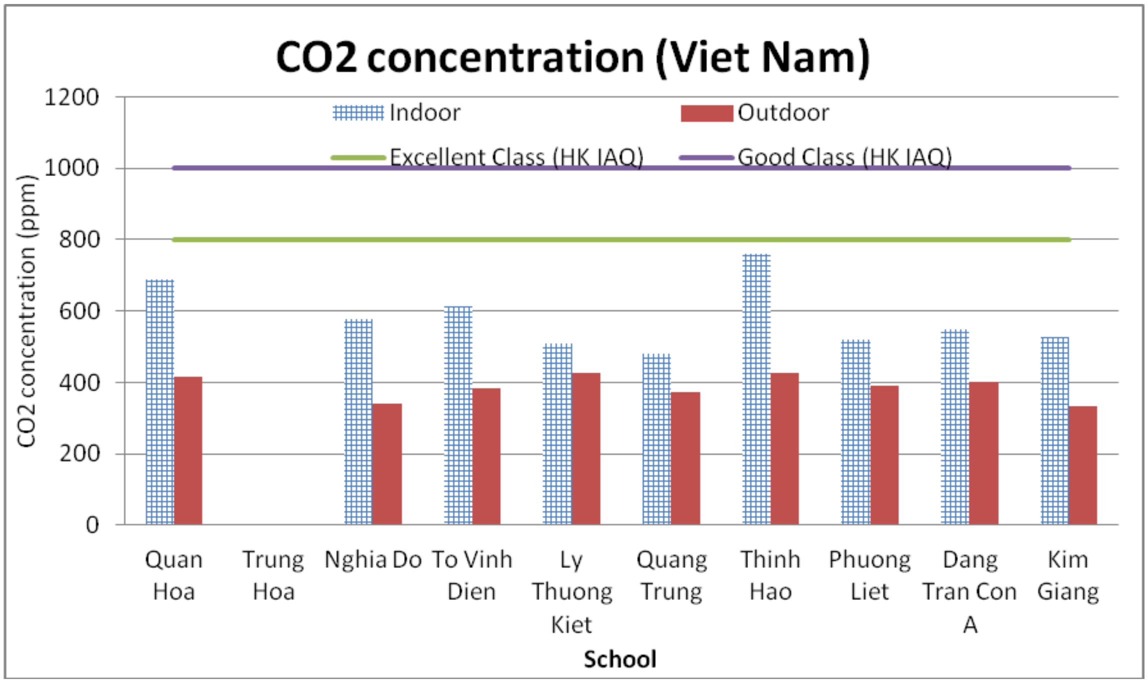
Generally, the concentration of PM was higher in most schools near the roadside, especially in the City Centre, such as at Thinh Hao, Quan Hoa, To Vinh Dien, Ly Thuong Kiet and Quang Trung Schools. The PM concentration at Thinh Hao School was much higher than the others because it is located near a small and congested road; another reason may be that the monitoring was conducted outside the school on another day that had different weather conditions (sunny, hotter, lower humidity). In addition, the inside level may be affected by condition and activities inside the classroom.

Concentration of CO_2

Generally, the CO_2 concentration at all of the schools was well below the Hong Kong Indoor Air Quality Object standard. Figure 32 shows that Thinh Hao School had the highest CO_2 level both inside and outside the school. Quang Trung School had the lowest inside CO_2 concentration, while Kim Giang School had the lowest outside CO_2 concentration.

The result shows that the CO_2 level indoors were higher than outdoors at most of the schools, and they were even much higher at some of the schools. This is probably due to the high number of children inside the congested classrooms during the monitoring time as CO_2 comes also from a human source. Since almost classrooms were small in size with many children in them, the effect of the high occupancy on CO_2 concentration becomes more significant in a restricted environment. However, the CO_2 level at most of schools was still well within the standard.

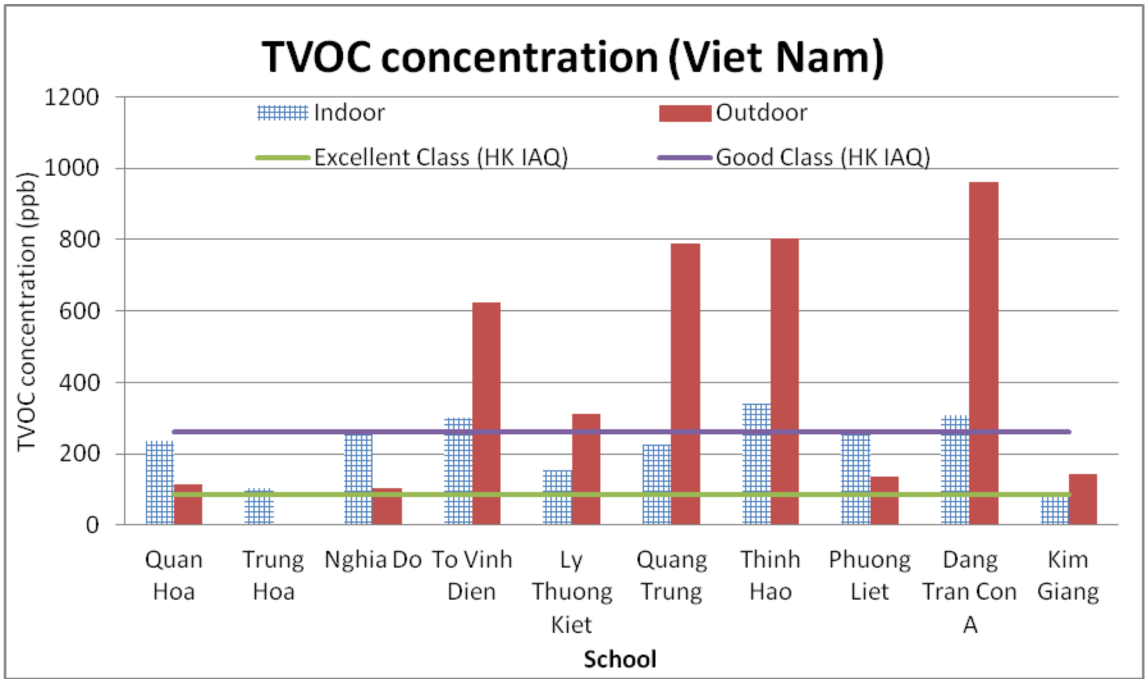
Figure 32: CO_2 concentration inside and outside school



Concentration of VOCs

The VOC concentrations at each of the schools is presented in Figure 33. Generally, almost all schools (except Thinh Hao, To Vinh Dien, Dang Tran Con A) had a VOC concentration indoors which achieved “good class” (compared to HK IAQO). Dang Tran Con A School had the highest concentration of VOC outside, while the lowest was at Nghia Do School. The second highest was at Thinh Hao School. The high VOC level outside Dang Tran Con A School can probably be attributed to the condition of the street, which is very narrow and near a small market and vehicle repair shop. As can be seen in Figure 33, the VOC concentration inside the classroom was relatively low and lower than the outside level (except for Quan Hoa and Nghia Do Schools). Thinh Hao had the highest VOC concentration inside the classroom. Trung Hoa and Kim Giang Schools had very low VOC concentrations, that were nearly equal to or within “excellent class” (compared to HK IAQO).

Figure 33: TVOC concentration inside and outside school



5. Analysis

ANCOVA was used for testing the significant difference between factors on pulmonary function in this survey. As mentioned in section 3, for performing ANCOVA analysis, we need to define covariates. For performing ANCOVA analysis, we need to define covariates. Principal component analysis was used on six interested confounding factors

a. Gender,

b. Weight,

c. Height,

d. Passive smoking,

e. Transportation mode,

f. Medical history of asthma

The scores from principal component analysis were applied for the covariate of ANCOVA.

The principal component analysis was carried out on the data set, and the eigenvalues and percentage of variance represented by corresponding components are shown in Table 25. The result showed that two components had eigenvalues greater than one, so these two components were selected as the principal factors in our data set. Varimax with Kaiser normalization was applied for rotation methods of extracting the principal components. The corresponding components are shown in Table 26.

Table 25: Eigenvalues and percentage of variance represented by corresponding components

Component	Eigenvalues	% of Variance
1	1.521	35.966
2	1.126	26.626
3	0.841	19.887
4	0.517	12.225
5	0.211	4.989
6	0.013	0.307

Table 26: Result of principal components analysis

	Component	
	1	2
Gender	-0.194	-0.519*
Weight	0.832*	-0.189
Height	0.768*	-0.381
Passive smoking	0.244	0.156
Transportation mode	0.414*	0.382
Medical history of asthma	0.224	0.682*

*. Coefficient is significant at the 0.05 level.

After Varimax rotation, three components were extracted by the principal component analysis. The first component was dominated by the factor weight, height and transportation mode. This means that these three factors can represent 35.966% of the overall variation. The second component had two significant factors, which were gender and medical history of asthma. The second component represented 26.626% of the overall variation.

Besides testing the significant difference between factors on pulmonary function, statistical logistic model was developed for respiratory illnesses. Finally a statistical regression model was developed by different factors. The regression model is important to quantify the effect of each factor to pulmonary function.

5.1 Hong Kong analysis

Significant differences were obtained for three factors: gender, mode of transportation and family member smoking inside home for both FVC and FEV1 by ANCOVA. Boys had a better performance than girls for both FVC and FEV1. Furthermore, family member smoking inside home had a significant relationship with poor lung function in children.

Table 27: ANCOVA results for different factors

Dependent variable	Factor	ANCOVA (Significant value)
FVC	Gender	0.002*
	School	0.809
	Mode of transportation	0.002*
	Keeping furry pet at home in last 12 months	0.538
	Family member smoking inside home	0.047*
	Incense burning at home	0.361
	Mosquito repellent burning	0.826
	Mould on wall	0.544
	Suffered asthma in the last 12 months	0.347
FEV1	Gender	0.032*
	School	0.797
	Mode of transportation	0.000*
	Keeping furry pet at home in last 12 months	0.186
	Family member smoking inside home	0.005*
	Incense burning at home	0.393
	Mosquito repellent burning	0.304
	Mould on wall	0.538
	Suffered asthma in the last 12 months	0.269

* Significant at the 0.05 level (2-tailed).

For children's lung function, significant differences between FVC and FEV1 are found in three situations: FVC and FEV1 are different between boys and girls (gender), different modes of transportation and tobacco smoking households. Boys had a better lung function than girls: at 9.11% and 6.57% boys performed better than girls for both FVC and FEV1, respectively. Furthermore, children in tobacco smoking households had a significantly poorer lung function. Children with smokers at home performed 4.94% and 4.86% worse than children with no smokers at home for FVC and FEV1, respectively.

The correlations between pulmonary function values and air pollutant concentrations are shown in Table 28. Negative correlations are observed between the lung function FVC and FEV1 and PM_{10} and TVOC concentrations for both indoor PM_{10} and TVOC concentrations at all the 12 schools.

Table 28: Correlation table between lung function and indoor air quality

	Indoor PM_{10}	Indoor CO	Indoor TVOC
FVC	−0.64	0.07	−0.44
FEV1	−0.53	0.11	−0.47

Figure 34: The mean plot of FVC of different transportation modes

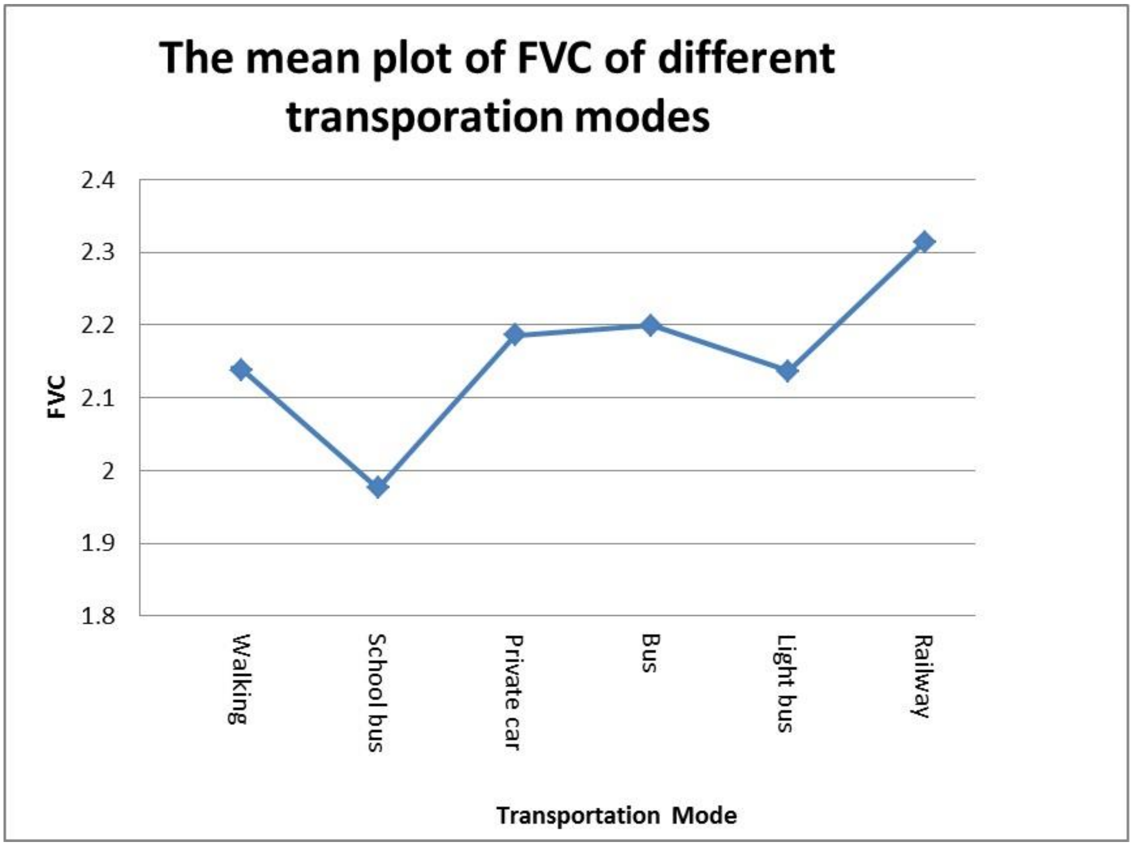
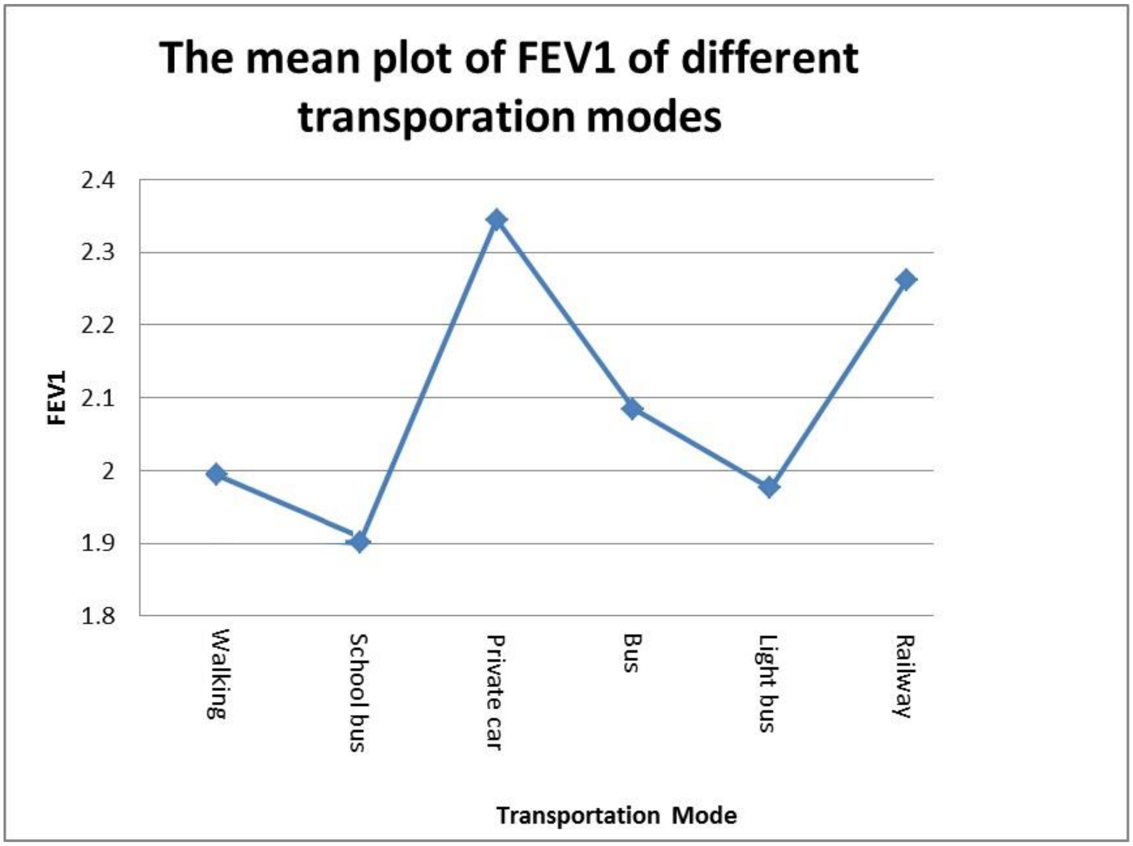


Figure 35: The mean plot of FEV1 of different transportation modes



Figures 34 and 35 show that students who went to school by school bus had the worst performance for both FVC and FEV1. Students who went to school by railway had the best performance in FVC and students who went to school by private car had the best performance in FEV1. Our sampling results show that the measured PM_{10} in school buses is nearly 20% higher than for any other modes of transport. Furthermore, school buses recorded the worst air quality, having the highest value of all the six pollutants.

We further separated the data set into two groups by gender, and tried to develop a regression model with the FVC and FEV1. The lung function value was considered as the dependent variable and the other ten parameters: age, height, weight, mode of transportation, kept furry pet at home in previous 12 months, family member smoking inside the home, incense burning at home, mosquito repellent burning, mould on wall, and whether a doctor has ever said that the child has asthma, which were considered as independent variables. The development of each statistical model together with the coefficient and R-square value of each model are shown in Table 29.

Table 29: Statistical model development and R-square change

Boy Data Set			
Dependent variable	Included variable	Partial regression coefficients	Standardized coefficients (Beta)
FVC	Constant	-0.184	
R-square: 0.490	Height	0.021	0.268
	Weight	0.023	0.101
	Family member smoking inside home	-0.157	-0.039
FEV1	Constant	-0.636	
R-square: 0.489	Height	0.011	0.257
	Weight	0.019	0.150
	Family member smoking inside home	-0.114	-0.109

Girl Data Set

Dependent variable	Included variable	Partial regression coefficients	Standardized coefficients (Beta)
FVC	Constant	-0.162	
R-square: 0.591	Height	0.018	0.355
	Weight	0.017	0.251
	Family member smoking inside home	-0.168	-0.071
FEV1	Constant	-0.546	
R-square: 0.562	Height	0.018	0.441
	Weight	0.127	0.469
	Family member smoking inside home	-0.136	-0.114

Note: Significant at the 0.05 level (2-tailed).

Five disease-related questions were included in the questionnaire. Logistic regression model was further applied for respiratory illnesses. Nine independent variables were included gender, weight, height, mode of transportation to school, keep furry pet at home in last 12 months, family member smoking inside home, incense burning at home, mosquito repellent burning, and mould on wall for logistic regression model development. The partial regression coefficient of each logistic models and also the odds ratio are shown in Table 30.

Odds ratio is used to a measure of association between an exposure and an outcome. It represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. When a logistic regression is calculated, the partial regression coefficient is the estimated increase in the log odds of the outcome per unit increase in the value of the exposure. In other words, the exponential function of the partial regression coefficient is the odds ratio associated with a one-unit increase in the exposure.

A significant impact was found for indoor living conditions on family member smoking inside home has the incidence of suffering from allergic rhinitis. Besides this, no significant impact was found for the other diseases.

Table 30: Logistic regression model for respiratory illnesses (Hong Kong)

Dependent variable	Significant independent variable	Partial regression coefficients	Odds ratio
Suffered asthma in the last 12 months	No significant variables were included in model		
Sinusitis	No significant variables were included in model		
Allergic rhinitis	Constant	3.436	31.062
	Age	-0.273	0.761
	Family member smoking inside home	0.741	2.098
Bronchitis	No significant variables were included in model		
Pneumonia	No significant variables were included in model		

Note: Significant at the 0.05 level (2-tailed).

5.2 Nepal analysis

A statistical analysis, ANCOVA, was carried out to identify if there were significant differences between factors for each of the cities, as shown in Table 31. Similar to Hong Kong, a significant difference was obtained in gender for both FVC and FEV1. Boys performed better than girls for both FVC and FEV1. Furthermore, a significant difference was obtained between schools. The mean plot of FVC) and FEV1 for different schools is shown in Figures 30 and 31. The correlation between lung function value and indoor air quality were further calculated, as shown in Table 32. A negative linear relationship was obtained between the lung function value and indoor air quality for CO and TVOC.

Table 31: ANCOVA results for different factors

Dependent variable	Factor	ANCOVA (Significant value)
FVC	Gender	0.038*
	School	0.001*
	Mode of transportation	0.884
	Keeping furry pet at home in last 12 months	0.083
	Family member smoking inside home	0.363
	Incense burning at home	0.514
	Mosquito repellent burning	0.916
	Mould on wall	0.751
	Suffered asthma in the last 12 months	0.624
FEV1	Gender	0.018*
	School	0.003*
	Mode of transportation	0.947
	Keeping furry pet at home in last 12 months	0.986
	Family member smoking inside home	0.544
	Incense burning at home	0.669
	Mosquito repellent burning	0.694
	Mould on wall	0.075
	Suffered asthma in the last 12 months	0.351

* Significant at the 0.05 level (2-tailed).

Figure 36: Mean plots of schools (FVC)

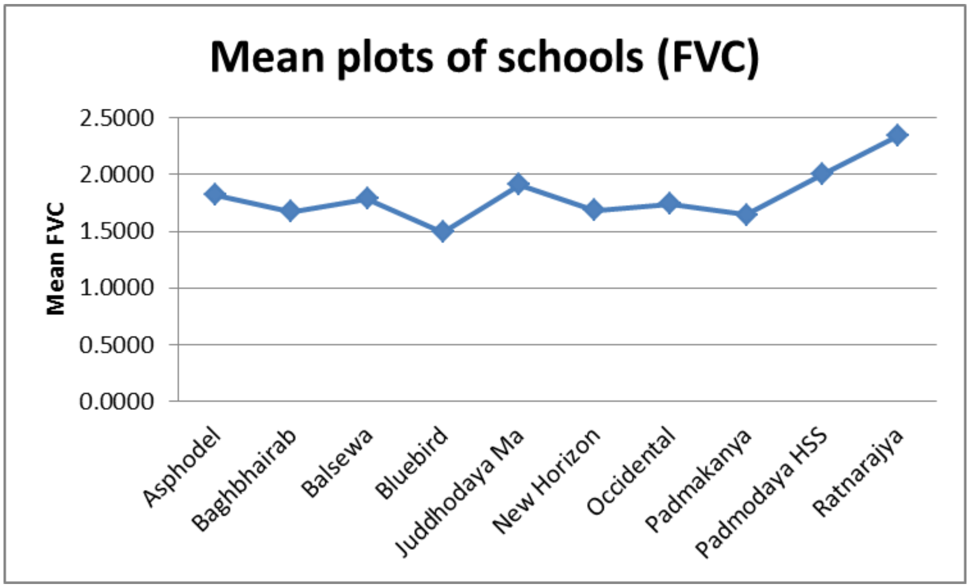


Figure 37: Mean plots for school (FEV1)

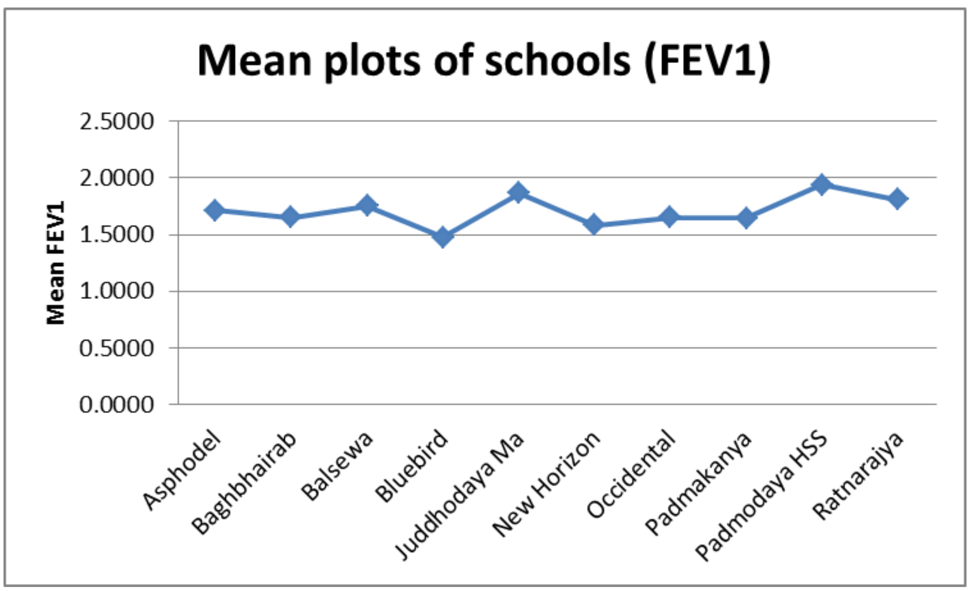


Table 32: Correlation table between lung function and indoor air quality

	Indoor PM_{10}	Indoor CO	Indoor TVOC
FVC (percentage)	0.3099	−0.4730	−0.0530
FEV1 (percentage)	0.1524	−0.0393	−0.6053

Similar to Hong Kong study, five disease-related questions were included in the questionnaire. Logistic regression model was further applied for respiratory illnesses. Nine independent variables were included gender, weight, height, mode of transportation to school, keep furry pet at home in last 12 months, family member smoking inside home, incense burning at home, mosquito repellent burning, and mould on wall for logistic regression model development. The coefficients of each logistic model are shown in Table 33.

A significant impact was found for indoor living conditions on keeping pet at home have the incidence of suffering from Sinusitis. Positive coefficient was found on the factor which implies keeping pet at home has higher chance to suffering from sinusitis. Besides this, no significant impact was found for the other diseases.

Table 33: Logistic regression model for respiratory illnesses (Nepal)

Dependent variable	Significant independent variable	Partial regression coefficients	Odds Ratio
Suffered asthma in the last 12 months	No significant variables were included in model		
Sinusitis	Constant	0.205	1.228
	Keeping furry pet at home in last 12 months	0.552	1.737
Allergic rhinitis	No significant variables were included in model		
Bronchitis	No significant variables were included in model		
Pneumonia	No significant variables were included in model		

Note: Significant at the 0.05 level (2-tailed).

5.3 Vietnam Analysis

Table 34 shows the ANCOVA result for the Vietnam sample. The results show that there is a significant difference between schools in the mean of FEV1. The mean plots between schools are shown in Figures 32 and 33. The correlation between the lung function value and indoor air quality were further calculated, and shown in Table 35. The results show that there was an inversely proportional relationship between the lung function value and indoor air quality. Furthermore, a significant difference in the mean of the FEV1 was also obtained for keeping furry pet at home. Children from keeping pet at home families had a relatively lower FEV1 than others.

Table 34: ANCOVA results for different factors

Dependent variable	Factor	ANCOVA (Significant value)
FVC	Gender	0.140
	School	0.119
	Mode of transportation	0.820
	Keeping furry pet at home in last 12 months	0.196
	Family member smoking inside home	0.254
	Incense burning at home	0.440
	Mosquito repellent burning	0.398
	Mould on wall	0.386
	Suffered asthma in the last 12 months	0.735
FEV1	Gender	0.098
	School	0.000*
	Mode of transportation	0.890
	Keeping furry pet at home in last 12 months	0.034*
	Family member smoking inside home	0.566
	Incense burning at home	0.356
	Mosquito repellent burning	0.308
	Mould on wall	0.350
	Suffered asthma in the last 12 months	0.795

* Significant at the 0.05 level (2-tailed).

Figure 38: Mean plot of schools (FVC)

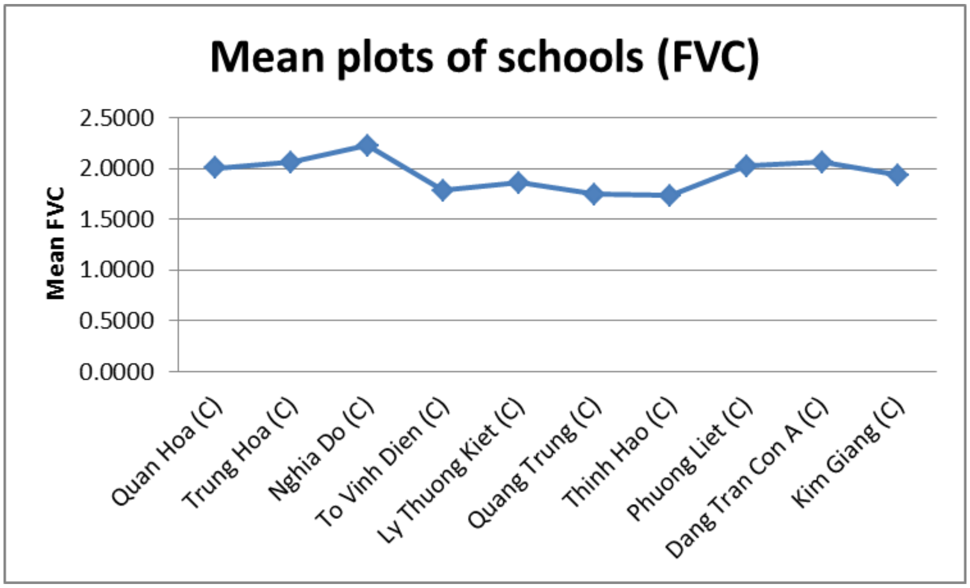


Figure 39: Mean plot of schools (FEV1)

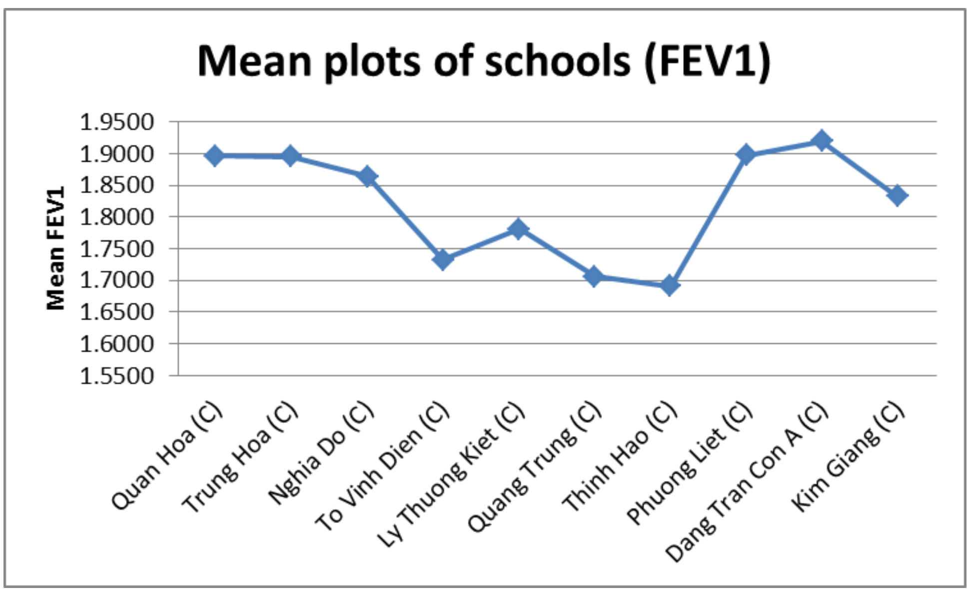


Table 35: Correlation table between lung function and indoor air quality

	Indoor PM_{10}	Indoor CO	Indoor TVOC
FVC (Percentage)	−0.3999	−0.2318	−0.1958
FEV1 (Percentage)	−0.1835	−0.3184	−0.2872

Similar to Hong Kong study, five disease-related questions were included in the questionnaire. Logistic regression model was further applied for respiratory illnesses. Nine independent variables were included gender, weight, height, mode of transportation to school, keep furry pet at home in last 12 months, family member smoking inside home, incense burning at home, mosquito repellent burning, and mould on wall for logistic regression model development.

Positive coefficient was found on the factor which implies keeping pet at home has higher chance to suffering from asthma. A significant impact was found for indoor living conditions on incense burning at home and keeping furry pet at home have the incidence of suffering from allergic rhinitis. The results were different from Hong Kong and Nepal, as they showed that the sampled students that had experienced incense burning at home had a higher chance of suffering asthma and allergic rhinitis. The coefficients of each logistic model are shown in Table 36.

Table 36: Logistic regression model for respiratory illnesses (Vietnam)

Dependent variable	Significant independent variable	Partial regression coefficients	Odds Raito
Suffered asthma in the last 12 months	Constant	0.276	1.318
	Incense burning at home	0.313	1.368
Sinusitis	No significant variables were included in model		
Allergic rhinitis	Constant	0.017	1.017
	Incense burning at home	0.214	1.239
	Keeping furry pet at home in last 12 months	0.446	1.562
Bronchitis	No significant variables were included in model		
Pneumonia	No significant variables were included in model		

Note: Significant at the 0.05 level (2-tailed).

5.4 Comparison between cities

Questionnaire survey

Similar questionnaire surveys were carried out in three Asian cities. In Hong Kong, the largest number of the students went to school on foot (about 45% of total sampled students). Similar to Hong Kong, 85.5% students in Nepal were found to travel to school on foot. However, only 23% of students went to school on foot in Vietnam, but over 70% of students in Vietnam went to school by motorcycle. This large difference may relate to the governments' policies and the lifestyle habits in different countries.

Besides the different transportation modes to school, a large difference was also found between the cities in the percentages of families keeping pets at home. In Hong Kong, only 13% of sampled students reported keeping pets at home, which was the lowest percentage of three cities; Nepal reported the highest percentage with 42.6%, and Vietnam reported around 37.5% of sampled students keeping pets at home.

The presence of tobacco smoking parents at home was reported to have a significant impact on children's pulmonary function in previous research. In our survey, we found that only 27.3% of children reported having tobacco smoking parents. The results from

Hong Kong and Vietnam were similar to each other but higher than Nepal's: 40.3% and 44.6%, respectively.

Measurement survey

The indoor and outdoor air quality data were recorded for the three sampled cities. The CO and TVOC readings for Hong Kong were nearly 90% higher than those for Vietnam. Hanoi, Vietnam reported the best air quality of the three cities and Kathmandu, Nepal came next.

The pulmonary function value data from the three cities were combined and statistical ANCOVA were performed for testing for significant differences. The ANCOVA results together with the significance values are shown in Table 37. The results show that a significant difference occurred for gender and family member smoking inside home. This result is similar to pervious researches that have found that boys have a significantly better value for pulmonary function than girls. Besides, students from family that having member smoke inside home has significant poor value for both FVC and FEV1.

Table 37: ANCOVA results for different factors (all three cities)

Dependent variable	Factor	ANCOVA (significant value)
FVC	Gender	0.009*
	Keeping furry pet at home in last 12 months	0.081
	Family member smoking inside home	0.000*
FEV1	Gender	0.042*
	Keeping furry pet at home in last 12 months	0.723
	Family member smoking inside home	0.000*

* Significant at the 0.05 level (2-tailed).

Statistical ANCOVA was further carried out between the three sampled cities for pulmonary function. The results showed that there is a significant difference (p-value: 0.000 for both FVC percentage and FEV1 percentage) in the mean pulmonary function value between these three cities. The mean plots of these three cities for FVC percentage and FEV1 percentage are shown in Figures 34 and 35. The results show that Hong Kong had the best lung function performance for both FVC and FEV1 percentage. In contrast, Nepal had the poorest performance for children’s lung function. According to World Bank (2013), the GDP per capita is 51,946, 1,484 and 3,635 international dollars for Hong Kong, Nepal and Vietnam, respectively. Nepal has the lowest GDP of the three countries and it also recorded the poorest performance for children’s lung function.

Figure 40: Plot of mean FVC percentage value of the three cities

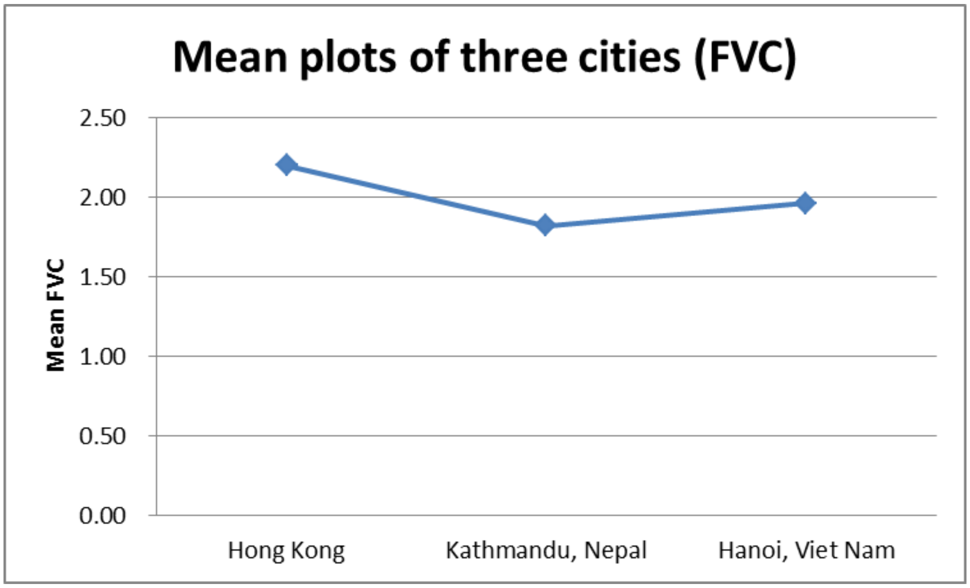
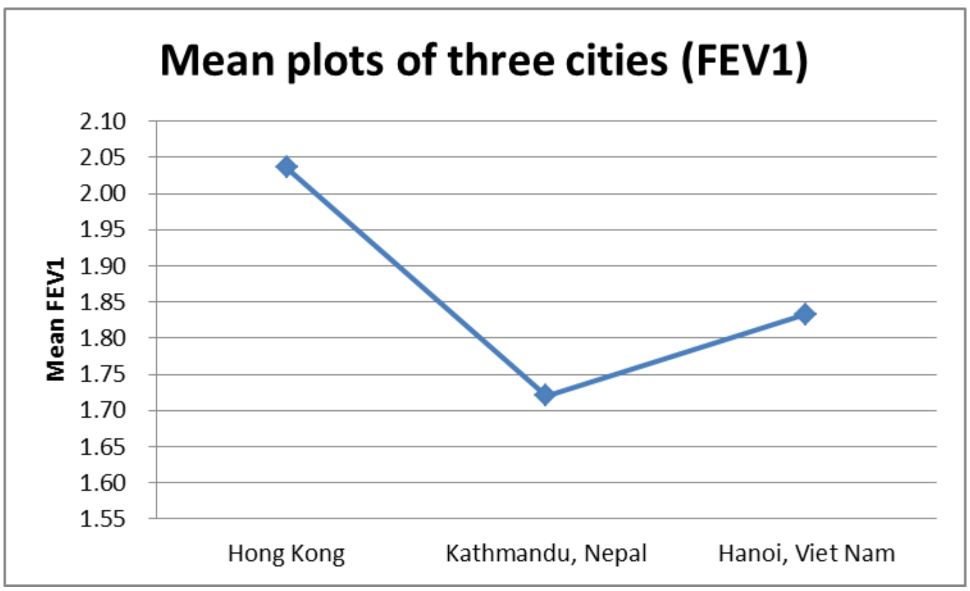


Figure 41: Plot of mean FEV1 percentage value of the three cities



6. Conclusions

6.1 Conclusions

This study relates the pulmonary function of school children to the air quality they are exposed to inside and outside classrooms as well as on route to school using various public transport modes and walking in three Asian cities. The study focuses on primary Grades 5 and 6 pupils from schools in Hong Kong, Kathmandu, Nepal and Hanoi, Vietnam.

In Hong Kong, Significant differences were obtained for three factors: gender, mode of transportation and family member smoking inside home for both FVC and FEV1 by ANCOVA. Boys had a better lung function than girls, i.e., 9.11% and 6.57% better for FVC and FEV1 respectively. Furthermore, family member smoking inside home had a significant relationship with poor lung function in children. Children with smokers at home performed 4.94% and 4.86% worse than children with no smokers at home for FVC and FEV1, respectively. Students who travel by school bus have the poorest pulmonary function, probably because of the poor air quality of the school bus. The best air quality of the five sampled transport modes was found inside the trains. Children who travelled by rail to school have the best pulmonary function.

In Nepal, a significant difference was obtained in gender for both FVC and FEV1, similar to Hong Kong. Boys performed better than girls for both FVC and FEV1. Furthermore, a significant difference was obtained among schools. A negative linear relationship was obtained between the lung function value and indoor air quality for CO and TVOC.

In Vietnam, the results were similar to Nepal in that a significant difference was found in pulmonary function (FEV1) among the sampled schools and children keeping furry pet at home in the last 12 months. The pulmonary function and indoor air quality for all indoor sampled air pollutants (PM10, CO and TVOC) was found negatively correlated, indicating the air quality had significant adverse impacts on children's pulmonary function.

The results of the three cities showed that indoor conditions such as family member smoking inside home and incense burning at home have significant adverse relationships with one or more pulmonary diseases as revealed in the statistical logistic model. In Hong Kong, allergic rhinitis was found to have a significant negative correlation with "family member smoking inside home". Besides this, no significant impact was found for the other diseases. In Nepal study, "keeping pet at home" was found to have a significant adverse relationship with Sinusitis. Positive coefficient was found on the factor which implies keeping pet at home has higher chance to suffer from sinusitis. In Vietnam study, it was found that “keeping pet at home” has higher chance of suffering from asthma. “Incense burning at home” and “keeping furry pet at home” leaded to higher chance of contracting allergic rhinitis. In the case of Hong Kong and Nepal, students experienced incense burning at home had a higher chance of suffering from asthma and allergic rhinitis.

The data were further grouped together for comparison between cities, “gender” and “family member smoking inside home” were found to have significant differences in lung function using statistical ANCOVA. Nepal was found to have the worst performance in pulmonary function among the three cities.

6.2 Limitations

In this study, only 10 to 12 primary schools were sampled for study in each city. The sample size is relatively small mainly because of the limited availability of equipment and manpower. In Hong Kong, due to the absence of responses from some schools, there was only one school in the main urban areas.

The numbers in the samples of various transport modes were not evenly distributed. This numbers of pupils taking school bus, railway and private car were small. Furthermore, the air quality measurement in the transport modes was conducted in Hong Kong only. Although the results showed significant differences in air quality in transport modes, conclusive results cannot be drawn for all Asian cities.

Both indoor and outdoor air quality sampling were carried out at each sampled schools. However, only four hours of sampling were allowed at each time. The derived correlation between air quality and children's pulmonary function value can only be indicative.

For the Nepal study, extremely high percentage on prevalence of pneumonia in the past year was recorded in our survey. Accordingly to our best knowledge, the sampling city did not struck by an epidemic. The unexpected high percentage may relate to the understanding of prevalence of pneumonia when the question was translated to local language.

Lastly, this study was carried out over a period of more than two years. The air quality measured at each school may have had seasonal fluctuations which would have affected the overall correlation analysis in connection with the air quality impact on the pulmonary functioning of the children.

6.3 Suggestions for further research

This study found that the sampled children from Nepal have the poorest lung function value compared to the Hong Kong and Vietnamese children. We suspect that the lung function value may relate to the development of the country. The lung function values are indeed in the order of the per capital gross domestic product (GDP). Nepal has the lowest per capita GDP of the three sampled countries and the Nepalese children have the weakest lung function. However, no conclusion can be drawn with significant level of confidence because only three cities have been studied. In order to help further the understanding of the relationship between children's lung function value and economic development, further studies in more cities are suggested.

Appendix: Questionnaire on home air quality and health record of children

Air Pollution Exposure and Health Survey

Name of School : ____

Grade: ____________ Age: ______________ Gender: ___________

Height: ___________ (m) Weight: ________________ (kg)

Address: ____

How long have you been living at your current address?_____________

Section A – Indoor Environment

Please tick the appropriate box.

You may select more than one answer.

Which of the following pets have you kept inside your home *in the last 12 months*?

☐ Dog ☐ Cat ☐ Bird ☐ Other furry pets ☐ Others:______________ ☐ None

Has any family member smoked inside your home *in the last 12 months*?

☐ Yes ☐ No

If yes, how many cigarettes in total are smoked per day in your home?

☐ Less than 10 cigarettes ☐ 10 -20 cigarettes ☐ More than 20 cigarettes

Which fuel have you used for cooking *in the last 12 months*?

☐ Electricity ☐ Town Gas ☐ LPG ☐ Coal or Wood ☐ Others:_____________

Have you had the following indoor conditions *in the last 12 months*?

☐ Incense burning ☐ Indoor plants ☐ Mosquito repellent burning

☐ Air purifier

☐ Odoriferous chemical vapour ☐ Dehumidifier

☐ No

Has your apartment had mould/mildew on the walls or ceilings *in the last 12 months*?

☐ In the rainy season only ☐ When continuously raining

☐ On most days of the year

☐ When humidity level is high ☐ No

Section B – Child Health Record

1. Has a doctor ***ever*** said that your child has asthma? ☐Yes ☐ No

If yes, how old was he/she ? ________ years old

2. Has your child suffered from the following illnesses *in the last 12 months*?

☐ Sinusitis ☐ Allergic rhinitis ☐ Bronchitis

☐ Pneumonia ☐ Asthma ☐ None of these illnesses

Section C – Travel Pattern

1. How do you travel from your home to school?

☐ By foot ☐ School Bus ☐ Private Car ☐ Bus

☐ Public Light Bus ☐ Tram/ Railway ☐ Motor Cycle

2. How long does it take for you to travel from your home to school?

____________ minutes

3. How do you travel from school to your home?

☐ By foot ☐ School Bus ☐ Private Car ☐ Bus

☐ Public Light Bus ☐ Tram/ Railway ☐ Motor Cycle

4. How long does it take for you to travel from school to your home?

____________ minutes

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