EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/ea/index.html
EnvironmentAsia 9(2) (2016) 178-185
DOI

Lung Function Testing of School Children Living near Industrial Areas in Rayong, Thailand

Paradee Asa [a] and Wanida Jinsart [b]

[a] *Interdisciplinary Program on Environmental Science, Graduate School, Chulalongkorn University, Thailand*
[b] *Environmental Science Department, Faculty of Science, Chulalongkorn University, Thailand*

Abstract

Lung functions of children exposed to air pollutions around industrial areas in Rayong Thailand were tested. 806 elementary students aged 9-12 years performed Spirometric measurements during February-August 2013. Eight volunteer schools were selected based on the distance between schools and Map Ta Phut Industrial Estate (MTPIE). The study sites were divided into 3 groups: A - 4 schools located within 1 kilometer from MTPIE, B - 2 schools located in 1-5 kilometers from MTPIE and C - 2 schools at 5-10 kilometers from MTPIE. The lung function impairments of subjects in group A, B and C were statistically analyzed by Binary Logistic Regression. According to the study, the low lung functions were found in group A with the distance near industrial sites, odds ratios (OR) = 1.66 (95% confidence intervals (CI) 1.06-2.62). Comparing the area B to that of C, the lung functions were found different but not significant, OR = 0.66, (95% CI = 0.34-1.29). Comparing the PM_{10} level to the reference group, children exposed to particulate matter $PM_{10} < 37\ \mu g/m^3$, their lung function potentially reduced with OR = 1.77 (95% CI = 1.25-2.51). The impaired lung function in school children was associated with the level of air pollution and the distance from industrial sites.

Keywords: air pollution; respiratory; lung function; industrial area; schoolchildren

1. Introduction

Children are a sensitive group and more susceptible to the toxic agents than adults. Particularly, when they are exposed to air pollution, its effects may harm their respiratory organs. Their lung growth can be influenced by various factors, including developmental, genetic and environment ones (Kotecha, 2000; Gauderman *et al*., 2004). Several studies have found the associations between air pollution and pulmonary functions in children. For example, Langkulsen *et al*. (2006) reported that school children living by the roadside of Bangkok and exposed to the traffic air pollutions had higher prevalence of respiratory symptoms than those living suburban and rural areas. Wichmann *et al*. (2009) studied the health effects of children living near the petrochemical plant in La Plata, Argentina in 2005-2006. The subjects were found more respiratory symptoms and lower lung functions than those living in different areas. Tabaku *et al*., 2011 reported that the pulmonary functions of children living in urban area of Tirana city in Albania were lower than those living in suburban area. Pascal *et al*. (2013) reviewed the epidemiological methods of the study health impacts from industrial air pollutions in France. Morbidity was investigated through crosssectional surveys on the respiratory health of children. The study areas were based on the distance to the industrial plants located from < 2 km to > 20 km from the schools. Nevertheless, this study lacks the environment data and the authors suggest to improve assessment methods and define the criteria of site selection.

In this study, the pulmonary functions of the school children living around Map Ta Phut Industrial Estate (MTPIE), Rayong, Thailand were compared. The MTPIE was established in 1989 as the eastern seaboard industrial area in Thailand. A number of heavy industries and petrochemical factories are situated in this area (http://www.mtpie.com/prfl/mn_prfl.htm). Nevertheless, air quality data from Pollution Control Department indicated high pollution levels around this industrial site (AQNIS, 2015). Indeed, recently health effects and areas with potential risk in Map Ta Phut have been investigated (Thepanondh *et al*., 2011; Tanyanont and Vichit-Vadakan, 2012; Kongtip *et al*., 2013). Those studies reported the association between air pollution and respiratory health in adults and identified certain risk areas. This study performed the initial test for lung functions of children in this area. Children are particularly vulnerable population because they spend most of their time outdoors, thereby having higher ventilation rates and lung per body surface area more than adults (Gauderman *et al*., 2000; Salvi, 2007). Children have limited ability to metabolize and detoxify environmental agents and their airway epithelium is more permeable to inhale air pollutants (Schwartz, 2004). Due to their high exposure pollutants, children have higher possibility of different responses more than in adults. However, the chronic effects from air pollution exposure in children remain unclear, particularly in industrial areas. The epidemiological cross-sectional research could be one of the tools in the study of prevalence of respiratory effects from industrial air pollution exposure. In our previous study, the respiratory health questionnaires were employed to investigate its effects, (Asa and Jinsart, 2016) and we have found the prevalence of respiratory illness in school children living near industrial sites. In this paper, we report the quantitative analysis of school children's lung function abnormality associated with the distance from industrial sites where air pollution level is high.

2. Materials and Methods

2.1 Subjects and study sites

The volunteer schools and children in this work were selected by taking the distance from schools to MTPIE industrial site into consideration, (Pascal *et al*., 2013; Nirel *et al*., 2015). Thus, we obtained the subject schools, which could be divided into 3 groups: < 1 km (A- 4 schools), 1-5 km (B- 2 schools) and 5-10 km (C- 2 schools) from plants, respectively (Fig.1). The criteria of school selection are based on the location with different distance from industrial source, close to the monitoring stations, near the roadside and within the resident area. Total subjects from eight selected schools were 2,145 students. Ten percent precision level of minimum sampling size for 2,145 students was 525, calculated from Yamane (1973), equation 1. In this study, lung functions were measured in 806 students aged 9-12 years.

$$n = N / 1+N(e)^2 \qquad \text{equation 1.}$$

n = Sample size, N = Population size and e = Level of precision

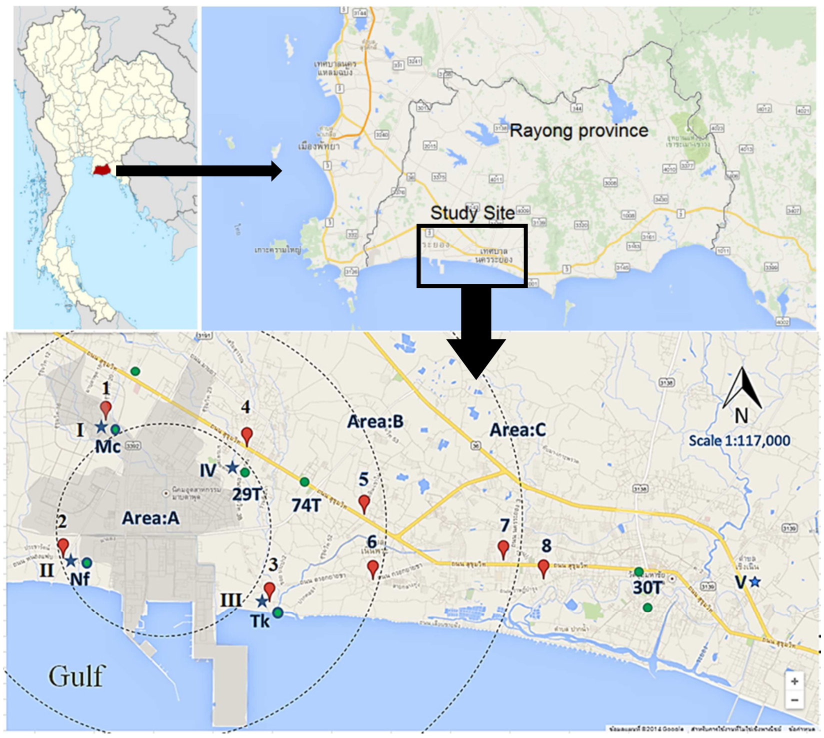

Figure 1. Illustrates the distance from the study site to MTPIE: area A 1 km, area B 5 km and area C 10 km

- VOCs monitoring stations: area A (station I, II, III, IV), area C (station V)
- PM_{10} monitoring stations: Map-cha-lood station (Mc), Nong-fab station (Nf), Ta-kurn station (Tk), Map-ta-phut station (29T), Nuen-phra station (74T) and Tha-pradu station (30T)
- Elementary schools: area A; 1 = Wat Map-cha-lood (MC), 2 = Ban Nong-fab (NF), 3 = Wat Ta-kurn (TK), 4 = Ban Map-ta-phut (MT): area B; 5 = Wat Khot-hin-mit-tra-phap (KH), 6 = Wat Trok-yay-cha (YC) and area C; 7 = Wat Nong-snom (NS), 8 = Wat Nuen-phra (NP)

All of the volunteer schools in this study were under Rayong Primary Education Service and the schoolchildren subjects were confirmed by their teachers that they were not involved with smoking or narcotic drugs.

2.2 Air quality monitoring data

The ambient air quality data year 2011-2014 were provided by Pollution Control Department Thailand (PCD, 2015; MTPIE, 2014). The annual average of criteria air pollutants, particulate matter with aerodynamic diameter less than 10 μm (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and total volatile organic compounds (TVOCs) were compared among different sites in Table 1. Area A has the highest air pollution level in comparison to that in area B and C. To illustrate, according to the data from 2011 to 2013 PM_{10} in area A was 39.84 $\mu g/m^3$, and in area B was 35.55 $\mu g/m^3$ and in area C was 27.45 $\mu g/m^3$, respectively.

2.3 Questionnaires

ATS-DLD-78-C questionnaire, American Thoracic Society's Division of Lung Diseases number 78 for children was used in screening the tested subjects. Questionnaires were randomly distributed to 1500 students in eight schools. Either their parents or caregivers completed the information in the questionnaire. Descriptive data, including age, gender, residential areas, residential years, family members, home size, parental smoking habits, domestic pets and use of air conditioners were recorded. The subjects not completing questionnaires, living in the area less than one year or lung history illness were excluded. The questionnaires analysis was based on the epidemiological standard method (Ferris, 1978).

2.4 Lung function test

Children lung function were tested at schools, using American Thoracic Society criteria, using automated spirometer (CHESTGRAPH HI-101, CHEST, Japan) following the parameters and reference values for Thai population (Dejsomritrutai *et al*., 2000). The spirometers were previously calibrated by American Thoracic Society standard method (Miller *et al*., 2005). Each subject was asked to perform at least three maximal forced expiratory flow-volume graphs. Forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and FEV_1/FVC was recorded. The graph with the highest sum of FVC and FEV_1 was chosen for further analysis. Test acceptability was determined by examining the flow and volume time curve as recommended by ATS. The criteria for impaired lung function by Specified ratio for FEV_1/FVC % were less than 75% and FVC% predicted was less than 80% (Fig. 2). The lung function tests in this study were conducted by the license medical workers and their professional team, using method of AOED Thailand (2014).

2.5 Statistical analysis

Binary Logistic regression methods were used to assess the association between lung functions and independent variables. The odds ratio (OR) and 95% confidence intervals (CI) were obtained as the outcome variables and the precision weighting was applied to evaluate the degree of the associations. Statistical processing of the data was analyzed using Statistical Package for Social Science (SPSS statistics 19; SPSS Inc., Chicago IL, USA, 2010).

Table 1. Area characteristics, distance from MTPIE, average concentration of PM_{10} data in 2011-2013 and SO_2, NO_2, CO, O_3, TVOCs data in 2012-2014

Area	Characteristic	Air pollutants					
		PM_{10} ($\mu g/m^3$)	SO_2 (ppb)	NO_2 (ppb)	CO (ppm)	O_3 (ppb)	TVOCs ($\mu g/m^3$)
A	Surrounded area within 1 km.						
	Station Mc	38.81	-	-	-	-	3.61
	Station Nf	35.00	-	-	-	-	3.49
	Station Tk	40.68	-	-	-	-	5.11
	Station 29T	44.85	6.97	14.97	0.50	21.9	7.03
	Average	39.84					4.81
B	Residential area within 5 km.						
	Station 74T	35.55	3.67	13.40	0.68	23.5	-
C	Residential area within 10 km.						
	Station 30T	27.45	2.31	10.67	0.85	24.1	3.13
Standard		50	40	30	-	-	-

Data from AQNIS (2015) and MTPIE (2014)

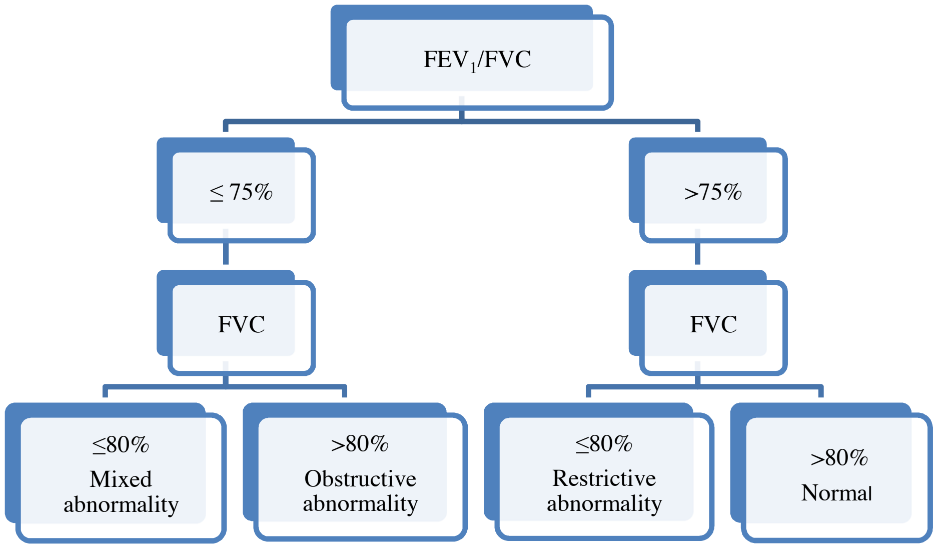

Figure 2. Criteria flow chart of lung function analysis (AOED Thailand, 2014)

3. Results and Discussion

3.1 *Questionnaires*

The 1500 Questionnaires were randomly distributed to students in eight schools. There were 1167 responded questionnaires, accounting for 77.8%, which were completed by students' parents or caregivers. After exclusion of the incomplete questionnaires, 877 subjects were given the pulmonary function tests. Of 877, there were only 806 subjects compatible with the Spirogram Standard criteria. The independent variables associated with the impaired lung functions, such as age, gender, residential areas, residential years, family members, home size, parental smoking habits, domestic pets and use of air conditioners were evaluated. Data from of a total of 806 children (349 boys and 457 girls) were analyzed. According to the analysis, all subjects had lived in the study sites for at least 1 year and 149 subjects had lived in this area for more than 10 years. Characteristic and demographic information were compared for the risk factors. Considering the personal characteristics, there were no significant differences in among three groups. The mean age of the children ranges from 10.6 - 11.0 years old. The risk factors based on the characteristic and demographic information of 806 children were analyzed and reported in our previous work, Asa and Jinsart (2016). The prevalence of respiratory symptoms in schoolchildren area A were higher than those in area C with OR= 3.41, (95% CI=1.70-6.85), respectively. The prevalent of (NSRD) non-specific respiratory diseases and (PCP) persistent cough and phlegm in boy students was found higher than the girl students with OR=2.17, (95% CI=1.33-3.53); however, the factors, e.g., age, residential years, home size, parental smoking habits, domestic pets and use of air conditioners were not associated.

3.2 *Lung function test*

Lung functions of the children living in area A, % predicted FEV_1, % predicted FVC and % FEV_1/FVC were less than other subjects in area B and C (Table 2). The impaired lung functions of children in area A, B and C were 25.24 %, 12.12 % and 15.35 %, respectively. The major lung abnormality was mild restrictive. The selected eight schools were located in the different distances from Map Ta Phut Industrial Estate (MTPIE) with < 1 km. (A- 4schools), 1-5 km. (B- 2 schools) and 5-10 km. (C-2 schools). The school location areas were significantly associated with impaired lung functions. Children studying at the schools in area Aare potentially exposed to higher level of pollution than in the area of B and C (Table 1). Data of impaired lung function abnormality and odd ratio in comparison among eight schools were summarized in Table 2.

The number of children with impaired lung functions in area A was significantly higher than those in area C. The results of each school analysis indicated significant health risk associations between ILF and school locations. Three schools in area A namely, MC, NF and TK had OR=3.76 (95%CI= 2.24-6.31), OR=2.02 (95%CI= 1.02-3.99) and OR=2.38 (95% CI= 1.33-4.24), respectively (Table 3).

Table 2. Lung function test of school children in Area A, B and C

	Area A (n=420)	Area B (n=132)	Area C (n=254)
Lung function [a]			
% predictedFVC	89.09 (13.13)	95.45 (13.92)	91.37 (12.46)
% predicted FEV_1	92.34 (19.28)	102.09 (22.45)	96.79 (18.02)
% FEV_1/FVC	92.13 (5.28)	92.89 (5.36)	93.50 (5.34)
Total lung function test, n	420	132	254
Normal	314	116	215
Impaired lung function[b], n (%)	106(25.24%)	16(12.12%)	39(15.35%)
Mild Obstructive	2	1	0
Mild Restrictive	101	13	38
Moderate Restrictive	3	2	1

a: presented as group means (±SD)
b: obstructive ventilatory (%FEV_1/FVC ≤75), restrictive ventilatory (FVC% predicted ≤80)

3.3 Impaired lung function and independent variables

Table 4 shows the results of other factors from binary logistic regression analysis. The impaired lung functions of students in area A were higher than those in other areas with odds ratios (OR) = 1.66, (95% CI = 1.06-2.62) and in area B with OR = 0.66, (95% CI = 0.34-1.29), in comparison to area C. The independent variables e.g., age, gender, residential years, family members, home size, parental smoking habits, domestic pets and use of air conditioners were not associated. The level of PM_{10}, SO_2 and TVOCs in area A was significantly higher than those in area C. In Table 1, children's lung functions were found related to the distance from MTPIE and PM_{10} level. Children living close to the industrial site in area A were potentially exposed to a high level of air pollutants. They were found high impaired lung functions more than those in area B and C (Table 3 and 4). Exposure to particulate matter PM_{10} significantly reduced lung functions with OR = 1.77 (95% CI = 1.25-2.51). PM_{10} and too ther chemicals resulting in toxicity to cells and ability to deposit in the low respiratory tract (Kulkarni and Grigg, 2008). Short-term increase in ambient particulate matter concentrations are associated with the change of the lung functions (Ward and Ayres, 2004). TVOCs concentrations were not directly associated with lung functions at OR = 0.75 (95% CI = 0.51-1.11). This could result from limited VOCs monitoring data in the area. However, from previous studies, Wichmann *et al.* (2009) and Rumchev *et al.* (2004) found that VOCs had directly associated with lung functions and respiratory systems of children. Therefore, all criteria air pollutants and hazardous air pollutants in MTPIE areas are suggested to be continued monitored.

Table 3. Area comparison of crude odds ratios (OR) of impaired lung function (ILF) of eight schoolchildren

Area	School	n	ILF, (%)	ILF abnormality: Obstructive mild	Restrictive mild	Restrictive moderate	OR (95% CI)
A	1MC	106	43 (40.6)	1	42	0	3.76 (2.24-6.31)**
	2NF	56	15 (26.8)	0	15	0	2.02 (1.02-3.99)*
	3TK	83	25 (30.1)	0	22	3	2.38 (1.33-4.24)**
	4MT	175	23 (13.1)	1	22	0	0.83 (0.48-1.45)
	Total	420	106 (25.2)	2	101	3	
B	5KH	60	6 (10.0)	0	5	1	0.61 (0.25-1.52)
	6YC	72	10 (13.9)	1	8	1	0.89 (0.42-1.88)
	Total	132	16 (12.1)	1	13	2	
C	7NS	97	14 (14.4)	0	14	0	
	8NP	157	25 (15.9)	0	24	1	
	Total	254	39 (15.4)	0	38	1	#Ref.

* *p<.05*, ** *p<0.005*

3.4 Children health and air pollution

Children are vulnerable to the damaging effects of air pollution since their lungs are in the course of growing and their innate defending against inhaled pollutants may be less than adults (Gauderman *et al*., 2000). Exposure to a high level of air pollution could influence lung growth development. (Rojas-Martinez *et al*., 2007). Inhalation of particulate matter and gases pollutants from fuel combustion harms the lung functions of normal children (Gauderman *et al*., 2004). Health effects related to industrial air pollutants in this area had been studied and the associations in the same trend were also found, such as the report from Asa and Jinsart (2016); Kongtip *et al*., (2013); Tanyanont and Vichit-Vadakan (2012). Our study reported on the impaired lung functions of children age 9-12 years old from eight schools near industrial site MTPIE. Cross sectional lung function tests in this study aimed to raise the awareness of children growing up in high pollution areas. They could potentially suffer morbidity and mortality if they develop serious conditions of pulmonary diseases.

4. Conclusions

This study is preliminary lung function field surveillance among schoolchildren subjects in this area. The results suggest that children residing near industrial sites with high PM_{10} level tend to suffer relatively from impaired lung functions. In this work, the source of exposure was considered as a single center model. Schoolchildren's Morbidity was found associated with the level of air pollution and the distance from the plants. This single industrial site, MTPIE, is based on the petrochemical complex factories. For further study, the exposure assessment in the future could be improved by including industrial sites with different natures. The multicenter studies should be promoted which the criteria of additional industries should be defined. Nevertheless, we hope that our findings would encourage the industrial pollution control and increasing the awareness of residential health risk.

Abbreviations

CI: Confidence Intervals
FEV_1: Forced Expiratory Volume in 1 second
FVC: Forced Vital Capacity
ILF: Impaired Lung Function
NSRD: Non-Specific Respiratory Diseases
OR: Odds Ratios
PCP: Persistent Cough and Phlegm
PM_{10}: Particulate Matter less than 10 μm in diameter
TVOCs: Total Volatile Organic Compounds

Acknowledgements

This work was supported by the National Research Council of Thailand 2014, grant number GRB_APS_20572304 and Graduate School, Chulalongkorn University. The authors are grateful to all volunteer parents and children who participated in this study.

Table 4. Adjusted odds ratios of impaired lung function and independent variables (*n=806*)

Independent variables	Impaired lung function Adjusted OR (95% CI)
Gender (ref: boy)	0.75 (0.52-1.07)
Age (ref: 9 year)	
10 year	1.19 (0.43-3.29)
11 year	2.67 (0.99-7.21)
12 year	2.61 (0.95-7.18)
Residential years (ref: 0-5 year)	
6-10 year	1.29 (0.84-1.98)
>10 year	1.07 (0.63-1.83)
Family members (ref:1-5)	
6-10 member	0.88 (0.54-1.44)
>10 member	0.64 (0.07-5.93)
Parental smoking habits	1.22 (0.85-1.75)
Use of air conditioners	1.30 (0.83-2.04)
Domestic pets	0.90 (0.63-1.30)
Areas (ref: area C)	
area A	1.66 (1.06-2.62)*
area B	0.66 (0.34-1.29)
PM_{10} (ref: <37 μg/m^3)	1.77 (1.25-2.51)**
TVOCs (ref: < 4.3 μg/m^3)	0.75 (0.51-1.11)

* *p< 0.05* , ***p< 0.005*

References

Air Quality and Noise Management Bureau (AQNIS). [homepage on the Internet]. Thailand: Pollution Control Department, Ministry of Natural Resources and Environment; 2015 [Cited 2015 January 22]. Available from: www.aqnis.pcd.go.th.

Asa P, Jinsart W. Effects of air pollution related respiratory symptoms in schoolchildren in industrial areas Rayong, Thailand. EnvironmentAsia 2016; 9(1): 116-23.

Association of Occupational and Environmental Diseases of Thailand (AOED). Guideline for standardization and interpretation of pulmonary function test by spirometry in occupational health [monograph on the Internet]. Thailand: 2014 [Cited 2014 Dec 20]. Available from: http://www.summacheeva.org/documents/share_meeting_spirometry.pdf

Dejsomritrutai W, Nana A, Maranetra KN, Chuaychoo B, Maneechotesuwan K, Wongsurakiat P, Chierakul N Charoenratanakul S, Tscheikuna J, Juengprasert W, Suthamsmai T, Naruman C. Reference spirometric values for healthy lifetime nonsmokers in Thailand. Journal of the Medical Association of Thailand 2000; 83(5): 457-66.

Ferris BG. Epidemiology standardization project (American Thoracic Society). The American Review of Respiratory Disease 1978; 118: 1-88.

Gauderman WJ, McConnell R, Gilliland F, London S, Thomas D, Avol E, Vora H, Berhane K, Rappaport EB, Lurmann F, Margolis HG, Peters J. Association between air pollution and lung function growth in Southern California children. American Journal of Respiratory and Critical Care Medicine 2000; 62(4 Pt1): 1383-90.

Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, McConnell R, Kuenzli N, Lurmann F, Rappaport E, Margolis H, Bates D, Peters J. The effect of air pollution on lung development from 10 to 18 years of age. The New England Journal of Medicine 2004; 351(11): 1057-67.

Kongtip P, Singkaew P, Yoosook W, Chantanakul S, Sujiratat D. Health effects of people living close to a petrochemical industrial estate in Thailand. Journal of the Medical Association of Thailand 2013; 96 (Suppl 5): S64-72.

Kotecha S. Lung growth for beginners. Paediatric Respiratory Reviews 2000; 1(4): 308-13.

Kulkarni N, Grigg J. Effect of air pollution on children. Paediatrics and Child Health 2008; 18(5): 238-43.

Langkulsen U, Jinsart W, Karita K, Yano E. Respiratory symptoms and lung function in Bangkok school children. European Journal of Public Health 2006; 16(6): 676-81.

Map Ta Phut Industrial Estate (MTPIE). [homepage on the Internet]. Thailand: Industrial Estate Authority of Thailand; 2014 [Cited 2014 Nov 12]. Available from: www.mtpie.com

Map Ta Phut Industrial Estate (MTPIE). [homepage on the Internet]. Thailand: Industrial Estate Authority of Thailand; 2016 [Cited 2016 May 17]. Available from: www.mtpie.com/prfl/mn_prfl.htm

Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, Crapo R, Enright P, van der Grinten CPM, Gustafsson P, Jensen R, Johnson DC, MacIntyre N, McKay R, Navajas D, Pedersen OF, Pellegrino R, Viegi G, Wanger J. Series "ATS/ERS task force: standardisation of lung function testing" (Standardisation of Spirometry). European Respiratory Journal 2005; 26(2): 319-38.

Nirel R, Maimon N, Fireman E, Agami S, Eyal A, Peretz A. Respiratory hospitalizations of children living near a hazardous industrial site adjusted for prevalent dust: a case-control study. International Journal of Hygiene and Environmental Health 2015; 218(2): 273-79.

Pascal M, Pascal L, Bidondo ML, Cochet A, Sarter H, Stempfelet M, Wagner V. A review of the epidemiological methods used to investigate the health impacts of air pollution around major industrial areas. Journal of Environmental and Public Health 2013; 2013 (Article ID 737926): 1-17.

Rojas-Martinez R, Perez-Padilla R, Olaiz-Fernandez G, Mendoza-Alvarado L, Moreno-Macias H, Fortoul T, McDonnell W, Loomis D, Romieu I. Lung function growth in children with long-term exposure to air pollutants in Mexico City. American Journal of Respiratory and Critical Care Medicine 2007; 176(4): 377-84.

Rumchev K, Spickett J, Bulsara M, Phillips M, Stick S. Association of domestic exposure to volatile organic compounds with asthma in young children. Thorax 2004; 59(9): 746-51.

Salvi S. Health effects of ambient air pollution in children. Paediatric Respiratory Reviews 2007; 8(4): 275-80.

Schwartz J. Air pollution and children's health. Pediatrics 2004; 113: 1037-43.

Tabaku A, Bejtja G, Bala S, Toci E, Resuli J. Effects of air pollution on children's pulmonary health. Atmospheric Environment 2011; 45(40): 7540-45.

Tanyanont W, Vichit-Vadakan N. Exposure to volatile organic compounds and health risks among residents in an area affected by a petrochemical complex in Rayong, Thailand. The Southeast Asian Journal of Tropical Medicine and Public Health 2012; 43(1): 201-11.

Thepanondh S, Varoonphan J, Sarutichart P, Makkasap T. Airborne volatile organic compounds and their potential health impact on the vicinity of petrochemical industrial complex. Water, Air and Soil Pollution 2011; 214(1): 83-92.

Ward DJ, Ayres JG. Particulate air pollution and panel studies in children: a systematic review.Occupational and Environmental Medicine 2004; 61(4): 1-12.

Wichmann FA, Müller A, Busi LE, Cianni N, Massolo L, Schlink U, Porta A, Sly PD. Increased asthma and respiratory symptoms in children exposed to petrochemical pollution. The Journal of Allergy and Clinical Immunology 2009; 123(3): 632-38.

Yamane T. Statistics: an introductory analysis. 3rd ed. New York: Harper and Row. 1973.

Received 19 May 2016
Accepted 15 June 2016

Correspondence to
Professor Wanida Jinsart
Environmental Science Department,
Faculty of Science,
Chulalongkorn University,
Phayathai Road, Bangkok 10330
Thailand
Tel: +662 218 5181-3
Fax: +66 2218 5180
Mobile: 66-81-8375127
E-mail: jwanida@chula.ac.th