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Effects of Air Pollution Related Respiratory Symptoms in Schoolchildren in Industrial Areas Rayong, Thailand

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Abstract

The chronic effects of air pollution in school children living near industrial sites were investigated. There spiratory symptoms of 806 school children aged 9-12 years were examined by the American Thoracic Society's Division of Lung Diseases (ATS-DLD-78-C) questionnaire during February-August 2013. The selected elementary schools in this survey was based on the distance from Map Ta Phut Industrial Estate, area A within 1 km., area B 5 km. and area C 10 km. Logistic regression techniques were used to assess the association between prevalence of respiratory symptoms and independent variables. The average 24 hrs PM_{10} and VOCs concentrations from 2011-2014 in area A were significantly higher than in area C *($p<0.05$)*. Relatively, the prevalence of respiratory symptoms in area A were high with odds ratios (OR) = 3.41, (95% confidence intervals (CI) = 1.70-6.85) and in area B with OR = 1.36, (95% CI = 0.54-3.45), in comparison to area C. The prevalent of non-specific respiratory diseases (NSRD) and Persistent Cough and Phlegm (PCP) in boy student were higher than girls students with OR=2.17, (95% CI=1.33-3.53), whereas those factors such as age, residential years, home size, parental smoking habits, use of air conditioners and domestic pets were not associated. Exposure to particulate matter and volatile organic compounds arising from Industrial sites was associated with worse respiratory impairments in children.

Keywords: air pollution; respiratory symptoms; industrial area; children health

1. Introduction

Industry related air pollutants exert its adverse impacts on human health, particularly respiratory system. Exposure to PM_{10} could effect on breathing, damage lung tissue, cause lung cancer and premature death (EPA, 1995). High level of Volatile organic compounds (VOCs) associated to increasing of asthma and high levels of the inflammatory marker nitric oxide in the exhaled breath in children (Rumchev *et al*., 2002; 2004). Toxic VOCs, 1,3 butadiene, 1,2 dichloroethane and benzene were classified as carcinogenic in human (EPA, 2000).

Previous epidemiological studies have suggested relatively consistent associations between ambient air pollutions and human health (Pascal *et al*., 2013). To illustrate, its effects on respiratory symptoms from traffic related air pollutions were reported in school children (Langkulsen *et al*., 2006) or traffic policemen (Tamura *et al*., 2003; Karita *et al*., 2004); health effects caused by $PM_{2.5}$, PM_{10}, SO_2 (Aekplakorn *et al*., 2003; Peled *et al*., 2005) and NOx from power plant were also reported by Yogev-Baggio *et al*. (2010). Furthermore, respiratory symptoms among residents exposed to petrochemical pollution were previously reported in China (Wilson *et al*., 2008) and in Argentina (Wichmann *et al*., 2009).

Our study area, Map Ta Phut Municipality covered 165.575 km^2, 38 communities around the Map Ta Phut Industrial Estate (MTPIE) and 58,245 registered populations (MTP Municipality, 2014). The Map Ta Phut area is influenced by the sea wind which sweeps from the southwest to the northeast with a wind speed below $6ms^{-1}$ (Pimpisut *et al*., 2005). Many heavy industries and Petrochemical related manufactures were located in MTPIE, Rayong province and high level of air pollutions such as PM_{10} and VOCs in this area were recorded (www.aqnis.pcd.go.th, 2015). Comparison of data from each monitoring site indicated that PM_{10} and VOCs across sites were different from their major species and their concentrations which might be influenced by nearest potential emission sources. These conditions prompted us to investigate the extent of respiratory symptoms and their potential risk factors. Hence, the objective of this study was to assess the respiratory health effects on children exposed to PM_{10} and VOCs living in the different distance from industrial sites by the epidemiological cross-sectional method.

2. Materials and Methods

2.1. Study area and population

The study areas were selected based on the ambient air quality levels and the distance from industrial sources in MTPIE. Fig. 1 illustrated the three areas, distanced from MTPIE, 1 km.(A), 5 km.(B) and 10 km.(C). The ambient air pollution levels in these studied areas were compared in Table 1 and 2. Four selected schools located in area A, two schools in area B and another two schools in area C respectively (Fig. 1). Schoolchildren aged 9-12 from these eight governmental primary schools volunteered to involve in this survey were 2,145.

2.2. Air pollution monitoring

Air quality data from 2011 to 2014 were obtained from the Air Quality and Noise Management Bureau (AQNIS), Pollution Control Department (PCD), Thailand (www.aqnis.pcd.go.th, 2015) and Map Ta Phut Industrial estate (MTPIE, 2014). Air pollution concentrations were measured following the standard methods, PM_{10} by Beta attenuator air sampling and volatile organic compounds (VOCs) were collected using canisters and were analyzed by gas chromatography /mass spectrophotometer (GC/MS) following the US.EPA TO15 procedure. Composite samples taken over a 24-h period were collected monthly. The air quality monitoring stations were located within the studied areas as shown in Fig. 1. The 24 hour average concentrations of PM_{10}, in 2011-2013 from station Mc, Nf, Tk, 29T, 74T and 30T were compared in Table 1. VOCs concentrations in 2012-2014 were obtained from MC, NF, TK, MT and NJ monitoring stations, Table 2.

2.3. Respiratory Questionnaires

American Thoracic Society's Division of Lung Diseases (ATS-DLD-78-C) questionnaire is a standard questionnaire using in NSRD and respiratory symptom study. The questionnaire consists of general information (13 items), respiratory symptoms (20 items), and family history (7 items) as details in (ATS-DLD, 2015). The analysis of the questionnaires was followed the epidemiology standard method, Ferris, 1978. The criteria of analysis were summarized in Table 3. Questionnaires randomly administered to 1500 students from total 2145 students in eight schools. The number of delivered questionnaires was higher than 10% precision level of sampling size, recommended 525 (Yamane, 1973). The survey was conducted during February - August 2013. This study was approved by Ethics Review Committee for Research Involving Human Research Subject, Health Science Group, Chulalongkorn University.

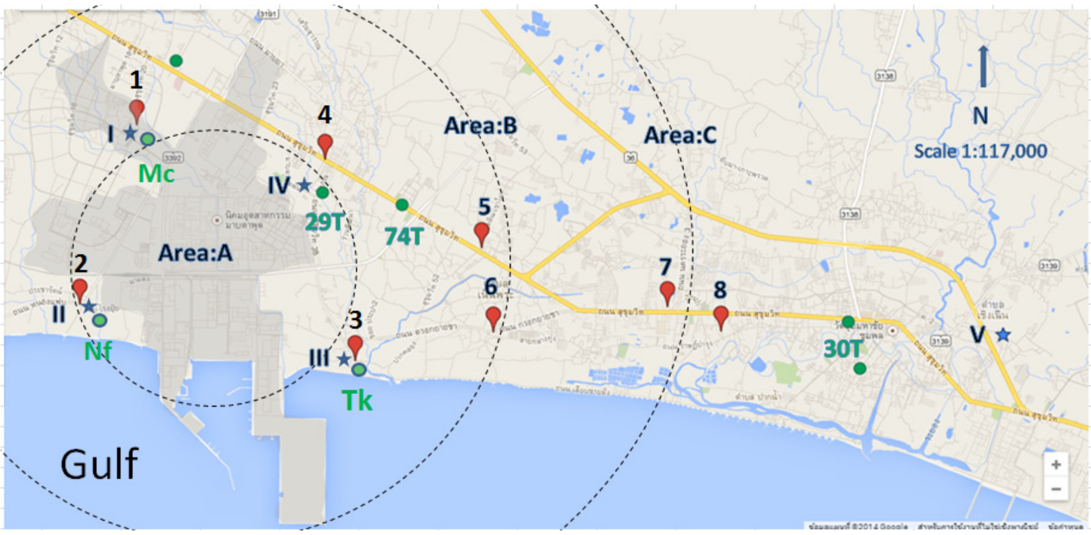

Figure 1. Study sites distance further from petrochemical industries: -------- area A within 1 km, area B 5 km and area C 10 km ★ VOCs monitoring stations: I = MC, II = NF, III = TK, IV = MT, V = NJ ● PM_{10} monitoring stations: Mc, Nf, Tk, 29T, 74T, 30T Elementary schools: area A (1 = Wat Map-cha-lood, 2 = Ban Nong-fab, 3 = Wat Ta-kurn, 4 = Ban Map-ta-phut), area B (5 = Wat Khot-hin-mit-tra-phap, 6 = Wat Trok-yay-cha) and area C (7 = Wat Nong-snom, 8 = Wat Nuen-phra)

Table 1. Area characteristics, distance from MTPIE and 24 hrs average concentration of PM_{10}, in 2011-2013

Area	Characteristic	PM_{10} (µg/m^3)			
		Range	Average	Frequency of exceeding standard	*P*
A	Surrounded area within 1 km.				A *VS* B ns
	Station Mc	0-3471	38.81	-	A *VS* C *
	Station Nf	0-668	35.00	-	
	Station Tk	0-578	40.68	-	
	Station 29T	5-209	44.85	24/885 (2.7%)	
	Average	-	39.84	-	
B	Residential area within 5 km.				
	Station 74T	11-107	35.55	0/725 (0%)	B *VS* C ns
C	Residential area within 10 km.				-
	Station 30T	4.4-107	27.45	3/928 (0.3%)	

* $p < 0.05$ by one-way ANOVA
Data from the www.aqnis.pcd.go.th (2015) and MTPIE (2014)

2.4. Data analysis

A nonparametric method (Mann-Whitney U-test) was used to compare the levels of VOCs. Differences in the health-related parameters among the areas A, B and control area C were compared using Yates' chi-squared test. Logistic regression techniques were used to assess the association between prevalence of respiratory symptoms and independent variables such as gender, age, residential years, residential areas, home size, family members, parental smoking habits, use of air conditioners and having domestic pets. The odds ratios (ORs) and 95% confidence intervals (CIs) were obtained as the outcome variables and precision weighting was applied to estimate the degree of association in this study. All statistical analyses were performed using the Statistical Package for Social Science (IBM SPSS Statistics 19; SPSS Inc, Chicago, IL, USA, 2010).

Table 2. Annual average concentration of VOCs in 2012-2014: Industrial Area (A) and Reference area (C)

Area	Air monitoring station	VOCs (µg/m^3)									
		VinylChloride	1,3 Butadiene	Dichloromethane	Chloroform	1,2 Dichloroethane	Benzene	Trichloroethylene	1,2 Dichloropropane	Tetrachloroethylene	Total VOCs
A	MC	0.21	0.18	0.97	0.16	0.35	1.23	0.27	0.11	0.14	3.61
	NF	0.06	0.29	0.66	0.29	0.30	1.37	0.16	0.23	0.13	3.49
	TK	0.18	0.86*	0.92	0.12	0.28	2.33	0.17	0.11	0.14	5.11*
	MT	0.93	0.69*	1.00	0.15	1.21	2.60	0.18	0.11	0.16	7.03*
	Total	0.35	0.51	0.89	0.18	0.54	1.88	0.78	0.14	0.14	4.81
C	NJ	0.05	0.05	0.41	0.12	0.20	1.90	0.17	0.10	0.14	3.13
Annual avg. standard		10	0.33	22	0.43	0.4	1.7	23	4	200	

**$p < 0.05$*, Mann-Whitney U test,
The underline values are exceed the National Ambient Air Quality Standard (NAAQS),
Data from www.aqnis.pcd.go.th (2015)

Table 3. Definition of respiratory symptoms in ATS-DLD-78-C Questionnaire

Respiratory symptom		Definition
Non-Specific Respiratory Diseases: NSRD	Chronic Bronchitis (CB)	phlegm production from the chest two times/day for 4 days/week for 3 months/year for at least 3 years
	Bronchial Asthma (BA)	doctor diagnosed asthma and still have asthma
	Dyspnea and Wheezing (D&W)	wheezing or whistling in the chest apart from cold on most days or nights
Persistent Cough and Phlegm: PCP	Persistent Cough	cough apart from cold on most days more than 4 days/week for 3 months/year for at least 1 year
	Persistent Phlegm	congested in the chest or bring up phlegm, sputum, or mucus apart from cold on most days more than 4 days/week for 3 months/year for at least 1 year

3. Results and Discussion

3.1. Air quality and health effects

The air quality data in Map Ta Phut area were obtained from Pollution Control Department (PCD), Thailand. The VOCs and criteria air pollutants PM_{10}, SO_2, NO_2, CO and O_3 were recorded. The concentrations were different across monitoring sites. In this study we investigated the effect from two major pollutants, PM_{10} and VOCs since the other gaseous pollutants average concentrations were not exceeded the NAAQS. PM_{10} and VOCs in area A were found higher than that of area B and C (Table 1 and 2). Particularly, concentrations of PM_{10} in area A were 2.7% frequency exceeded the standard level (Table 1) and three carcinogenic VOCs namely 1,3 butadiene, 1,2 dichloroethane and benzene were exceeded the NAAQS (Table 2). These could associate with the high prevalence of respiratory symptoms in area A, B and C, 18 %, 8% and 5% respectively, $p < 0.05$, Table 4. Details of NSRD and PCP prevalence in each school and each area were included in Table 5. Total PCP prevalence in area A were higher than in C significantly. Our results indicated the association between respiratory prevalence in children and air pollutions which was in the same trend as previous studies in adult and pregnant subjects (Tanyanont *et al*., 2012; Kongtip *et al*., 2013; Phatrabuddha *et al*., 2013). In addition, Thepanondh *et al*. (2011) reported that high concentration of benzene and 1,3 butadiene were detected at the stations near factories and the main roads, 1,2 dichloroethane observed near monitored site close to the plastic factories. Potentially, both stationary and mobile sources contributed to high level of VOCs.

Table 4. Air pollution in 2011-2014 and respiratory symptoms in schoolchildren (n=806)

Pollutant/ respiratory Symptoms	Area A	Area B	Area C	(A and C) *p-value*
PM-10 (mean, $\mu g/m^3$)	39.84	35.55	27.45	*< 0.05*
VOCs (mean, $\mu g/m^3$)				
1,3 butadiene	0.51	-	0.05	
1,2 dichloroethane	0.54	-	0.20	
benzene	1.88	-	1.90	
total VOCs	4.81	-	3.13	
Prevalence (%)				
- Persistent Cough	4.5	2.3	0.8	*< 0.05*
- Persistent Phlegm	3.3	0.7	0	*< 0.05*
Any one of the respiratory Symptoms				
-Individual basis	**58(14)**	**9(7)**	**12(5)**	***< 0.05***
-Symptoms basis	**77(18)**	**11(8)**	**12(5)**	***< 0.05***
History of allergic diseases, n (%)				
Dust and Other chemical	96(22.8)	15(11.4)	47(18.5)	
Past illness, n (%)				
Respiratory Symptoms	116(27.6)	31(23.5)	40(15.7)	

Table 5. Number and prevalence (%) of respiratory symptoms in school children (n=806)

Area [a]	School	NSRD			PCP			Any one of the respiratory symptoms	
		CB	BA	D and W	Persistent Cough	Persistent phlegm	Both PCP	Individual basis	Symptoms basis
A n=420	MC	2(1.9)	7(6.6)	10(9.4)	9(8.5)	6(5.7)	2(1.9)	24(23)	34(32)
	NF	0	2(3.6)	6(10.7)	2(3.6)	3(5.3)	1(1.8)	10(18)	13(23)
	TK	0	3(3.6)	3(3.6)	0	2(2.4)	0	7(8)	8(10)
	MT	2(1.1)	4(2.3)	5(2.8)	8(4.6)	3(1.7)	1(0.6)	17(10)	22(13)
	total	4(0.9)	16(3.8)	24(5.7)	**19(4.5)***	**14(3.3)***	**4(0.9)**	**58(14)***	**77(18)***
B n=132	KH	1(1.7)	2(3.3)	2(3.3)	2(3.3)	1(0.7)	1(1.7)	6(10)	8(13)
	YC	0	2(2.8)	0	1(1.4)	0	0	3(4)	3(4)
	total	1(0.7)	4(3.0)	2(1.5)	3(2.3)	1(0.7)	1(0.7)	9(7)	11(8)
C n=254	NS	0	1(1.0)	3(3.1)	1(1.0)	0	0	5(5)	5(5)
	NP	0	2(1.3)	4(2.5)	1(0.6)	0	0	7(4)	7(4)
	total	0	3(1.2)	7(2.7)	2(0.8)	0	0	12(5)	12(5)

*$p < 0.05$ by chi-squared test compared with area C

3.2. Respiratory symptoms and Questionnaire analysis

Response completed 806 questionnaires were administered by parent (60% from mother). All subjects had lived in the study sites for at least 1 year. The demographic and subject characteristics were analyzed resulting in Table 6. From questionnaires analysis, children living in area A were found high prevalence of respiratory symptoms than B and C. For instance, history of allergic disease (dust and chemical) in area A, B and C were 22.8%, 11.4% and 18.5% respectively. Past illness, sinus trouble, asthmatic bronchitis and other respiratory in area A, B and C were 27.6%, 23.5% and 15.7% respectively.

Parental smoking habit had no association with respiratory symptoms of the children but smoking parent shared room with children were significantly associated with respiratory symptoms, OR= 2.01 (95% CI = 1.2-3.5). Parents in area C were found higher educated level than parents in area A and B. However, in this study, the level of education has no correlation with their children's respiratory symptoms.

The prevalence of respiratory symptoms of schoolchildren in area A, B and C were compared in Table 5. The respiratory symptoms, chronic bronchitis (CB), bronchial asthma (BA), dyspnea and wheezing (D and W), persistent cough, and persistent phlegm were higher in area A than in B and C. However, the persistent cough and persistent phlegm were significantly higher in children in area A compared with those in area C *($p < 0.05$)* Table 5. The results of the logistic regression analyses are shown in Table 7. The children in area A have significantly increased prevalence of respiratory symptoms compared with those living in the area C (OR=3.41, 95% CI=1.70-6.85).

The environmental factors outside the studied school including industrial sources and traffic pollution were examined. In general, PM_{10}, benzene and 1,3 butadiene were considered as the traffic related pollutions. However, our school sites, MT (area A), KH (area B) and NS (area C) are located along the main road and close to the intersections which were commonly suffering from constant heavy traffic jams. Nevertheless, students living in area C had the least respiratory symptoms compared to those of MT (area A) and KH (area B). This finding suggested that the distance from the industrial zone accounted to the prevalence of respiratory symptoms of school children in this area.

Gender has the association with the prevalence of respiratory symptoms and interestingly prevalence of respiratory symptoms of the boys significantly higher than the girls (OR=2.17, 95% CI=1.33-3.53). Other factors such as age, residential years, home size, family members, parental smoking habits, use of air conditioners and domestic pets were not different among the areas. In this study, boys have a higher risk of the respiratory symptoms than girls 2.17 times. This could be associated to children's daily activity. Potentially, boy could enjoy outdoor rather than indoor functions, thus increasing more opportunities of pollutants exposure higher than girls. Our result is consistent to the findings of Moraes *et al*. (2010) who examined the association between wheezing in children and adolescents living downwind of dispersion plum emitted from petrochemical complex in Brazil. Even with low levels of pollutants, the prevalence of wheezing in male was higher in female 2.5 times. Liu *et al*.(2014) examined the association between outdoor and indoor air pollution and respiratory diseases among children aged 6 to 13 years living in a heavy industrial

Table 6. Demographic and risk factor characteristics of children included in the analysis, (n=806)

Parameter	Elementary student included in the analysis		
	Area A n=420	Area B n=132	Area C n=254
Mother responder, n (%)	268(63.8)	89(67.4)	150(59.0)
Boys, n(%)	165(39.3)	66(50.0)	118(46.4)
Mean age ± SD (years)	11.0 ± 0.9	10.8 ± 0.8	10.6 ± 0.9
Mean height ± SD (cm.)	144.1 ± 9.1	140.7 ± 8.7	144.1 ± 9.9
Mean weight ± SD (kg.)	38.7 ± 11.3	37.0 ± 11.6	39.3 ± 12.5
BMI ± SD	18.35 ± 3.83	18.43 ± 4.15	18.57 ± 4.32
Total born in Rayoung (%)	242(57.6)	67(50.7)	140(55.1)
Residential years, n(%)			
≤ 5	110(26.2)	53(40.2)	103(40.6)
6-10	211(50.2)	63(47.7)	109(42.9)
> 10	91(21.7)	16(12.1)	42(16.5)
History of allergic diseases, n(%)			
Dust and Other chemical	96(22.8)	15(11.4)	47(18.5)
Past illness, n(%)	274(65.2)	68(51.5)	110(43.3)
Respiratory Symptoms*	116(27.6)	31(23.5)	40(15.7)
- Sinus trouble	25(6.0)	0	8(3.1)
- Asthmatic bronchitis	58(13.8)	20(15.2)	13(5.1)
- Other Respiratory	33(7.9)	11(8.3)	19(7.5)
Other			
- Measles (not German)	50(11.9)	11(8.3)	17(6.7)
- Pneumonia	19(4.5)	5(3.8)	6(2.4)
- Whooping cough	19(4.5)	3(2.3)	7(2.8)
- Bronchitis	57(13.6)	14(10.6)	34(13.4)
- Bronchiolitis	13(3.1)	4(3.0)	6(2.4)
Home size, room, n(%)			
1	154(36.7)	37(28.0)	61(24.0)
2-5	256(61.0)	91(68.9)	181(71.3)
>5	3(0.7)	1(0.7)	9(3.5)
Family members, n(%)			
1-5	340(81.0)	104(78.8)	198(78.0)
6-10	73(17.4)	22(16.7)	51(20.1)
>10	3(0.7)	1(0.8)	2(0.8)
people share his/her bedroom smoke cigarettes	89(21.2)	23(17.4)	37(14.6)
Cooking in home			
Gas	347(82.6)	90(68.2)	158(62.2)
Electricity	11(2.6)	5(3.8)	19(7.5)
Charcoal	13(3.1)	7(5.3)	1(0.4)
Other	48(11.4)	29(22.0)	75(29.5)
Use of air conditioners, n(%)	85(20.2)	26(19.7)	136(53.5)
Domestic pet, n(%)	232(55.2)	73(55.3)	117(46.1)
Parental smoking habits, n(%)	181(43.1)	53(40.2)	96(37.8)
Socioeconomic status			
Father' Education			
No formal education	2(0.5)	2(1.5)	0
Primary school	157(37.4)	45(34.1)	49(19.3)
High school	127(30.2)	39(29.6)	69(27.2)
≥ Bachelor's Degree	40(9.5)	12(9.1)	75(29.5)
Mother' Education			
No formal education	9(2.1)	5(3.8)	1(0.4)
Primary school	171(40.7)	47(35.6)	60(23.6)
High school	155(36.9)	46(34.9)	90(35.4)
≥ Bachelor's Degree	26(6.2)	11(8.3)	48(18.9)

*From Table 4

Table 7. Multiple logistic regression analyses for the association between some independent variables, any of the respiratory symptoms among school children in Map Ta Phut, Thailand

Independent variables	Children (n=806) Any of the respiratory symptoms OR (95% CI)
Gender (ref: girls)	2.17 (1.33-3.53)**
Age (ref: 9 year)	
10 year	2.36 (0.52-10.63)
11 year	1.99 (0.44-9.03)
12 year	1.74 (0.37-8.13)
Residential years (ref: 0-5 year)	
6-10 year	0.80 (0.46-1.40)
>10 year	0.85 (0.40-1.82)
Family members (ref: 1-5)	
6-10 member	1.08 (0.56-2.06)
Parental smoking habits	1.45 (0.89-2.36)
Use of air conditioners	1.00 (0.55-1.81)
Domestic pets	0.96 (0.58-1.57)
Areas [a] (ref: area C)	
A	3.41 (1.70-6.85)*
B	1.36 (0.54-3.45)

*$p < 0.001$, ** $p < 0.002$

province of China and they found that the prevalent rates of asthma and asthma related symptoms in male were significantly higher than that in female *($p< 0.05$)*.

4. Conclusions

Children living near industrial areas particularly with high level of PM_{10} and VOCs are at risk of chronic bronchitis, bronchial asthma, dyspnea and wheezing, persistent cough and persistent phlegm. The results suggested a need for environmental policies to control industrial pollution and reduce the resident exposure. Further investigations regarding health effects of Cohort exposure to air pollutants in this area are recommended.

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