J Occup Health 2013; 55: 21–28

Journal of Occupational Health

Respiratory Symptoms and Patterns of Pulmonary Dysfunction among Roofing Fiber Cement Workers in the South of Thailand

Phayong THEPAKSORN[1, 2], Sathirakorn PONGPANICH[1], Wattasit SIRIWONG[1], Robert S. CHAPMAN[1] and Surasak TANEEPANICHSKUL[1]

[1]College of Public Health Sciences, Chulalongkorn University, Thailand and [2]Sirindhorn College of Public Health, Trang, Thailand

Abstract: Respiratory Symptoms and Patterns of Pulmonary Dysfunction among Roofing Fiber Cement Workers in the South of Thailand: Phayong THEPAKSORN, *et al.* College of Public Health Sciences, Chulalongkorn University, Thailand—Objective: This study examined the associations between respiratory symptoms and patterns of pulmonary dysfunction of 115 male roofing cement workers compared with 134 unexposed subjects. **Methods**: A cross-sectional study was conducted. Environmental samplings and spirometry measurements were also collected. **Results**: The exposed workers had higher respiratory dust exposure levels (0.65 mg/m^3) compared with the unexposed groups (0.32 mg/m^3). The exposed group had significantly higher prevalence than the unexposed group for shortness of breath (OR=2.19). The exposed group also had higher but insignificant prevalence of chronic cough (OR=1.34), chest tightness (OR=1.64), and wheezing (OR=1.89). The ventilatory respiratory function values (FEV1 and FVC) were slightly lower for the exposed group. **Conclusion**: An association between higher cement dust levels and a decline in ventilatory function among roofing fiber cement workers suggests that the respiratory health of roofing cement workers should be protected through policies or work standards.
(J Occup Health 2013; 55: 21–28)

Key words: Cement dust, Fiber cement, Pulmonary function, Respiratory symptoms

Respiratory health illnesses and symptoms among occupational cement exposure have been well documented and described[1–8]. However, the results concerning adverse respiratory health based on respiratory symptoms and ventilatory function are not entirely consistent. Findings of airway function impairments and respiratory symptoms have been mostly reported in epidemiological studies. The causal associations between cement dust exposure and pulmonary diseases have been studied by epidemiologic and animal studies[9]. The influenced mechanisms of dust deposition are impaction, sedimentation, and diffusion through the respiratory system. Dust greater than 10 μm in aerodynamic diameter are generally captured in the upper respiratory tract, nose and upper airway, whereas smaller particles can penetrate more deeply, reaching the airways and alveoli regions. Particles smaller than 2.5 μm have a greater likelihood of reaching alveoli areas[9]. Fell *et al.* (2010) observed a significantly higher percentage of neutrophils among exposed workers compared with non-exposed workers[16].

There have been a number of studies on effects of cement dust exposure on respiratory symptoms and illnesses[1–8]. In a 4-year prospective cohort study in European countries, Nordby *et al.* (2011) showed elevated relative risks of respiratory symptoms and airflow obstruction (OR=1.2–2.6)[13]. In a follow up study of Zeleke *et al.* (2011) forced expiratory volume in one second (FEV1) and FEV1 per forced vital capacity (FEV1/FVC) were significantly reduced in exposed workers compared with the controls[4]. Neghab and Choobineh (2007) revealed a significant association of respiratory symptoms among exposed cement workers. Similarity, chest radiographs of exposed workers showed various degrees of abnormality[5]. In a cross-sectional study, Mwaiselage *et al.* (2005) observed an annual decline in FEV1 and FVC for cement dust- exposed workers compared to control workers. In addition, cement dust exposed workers were at high risk of developing chronic obstructive pulmonary diseases (COPD)[7, 8]. Noor *et al.* (2000) and Yang *et al.* (1996) showed chronic exposure to cement dust resulted in a greater prevalence of chronic respiratory symptoms and a reduction in ventilatory

Received May 14, 2012; Accepted Oct 20, 2012
Published online in J-STAGE Nov 27, 2012
Correspondence to: S. Pongpanich, College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand (e-mail: sathirakorn.p@chula.ac.th)

capacity in exposed subjects[2, 6]. However, a few studies have found no significant difference in respiratory symptoms and negative impacts on pulmonary impairment indices[14, 15].

The main objective of this study was to investigate the associations between respiratory symptoms, acute respiratory function and patterns of pulmonary dysfunction as well as personal and area dust samplings. The exposure-response relationship between cement dust exposure and respiratory symptoms and pulmonary dysfunction of roofing fiber cement workers has not yet been conducted. Interviews concerning respiratory symptoms among these workers were also conducted and used to explore associations with ventilatory function. The total and respirable dust was examined among exposed workers. The findings concerning ventilatory function and respiratory symptoms among roofing cement workers were compared with those of unexposed groups who were not exposed to cement dust and who were of comparable age and similar socioeconomic status.

Methods

Study design and population

As a part of a study on the respiratory health risk assessment for roofing fiber cement workers, this cross-sectional study was conducted between July 2011 and December 2011 among workers at a roofing fiber cement factory in the South of Thailand.

The sample size was enumerated on the basis of an estimated prevalence of respiratory symptoms from previous studies[3, 8]. A sample size of 110 exposed workers and 110 controls was required to achieve a power of 80%. There were 115 exposed workers and 236 unexposed workers. The exposed group included workers in different parts of a production line, consisting of mixing and pulping (n=7), water injection (n=6), curing (n=9), de-pelleting and skid (n=11), spraying injection (n=6), painting (n=21), quality control (QC; n=7), storage and driving (n=22), maintenance (n=14), and other (n=12). The unexposed group included office workers (n=19) and subcontract workers (n=217). Subcontract workers included those working in accessories and were expected to have low exposure to cement dust. Female workers were excluded due to their small number and significant differences between both groups (unexposed workers; n=102). Therefore, the exposed group included 115 male workers and 134 male unexposed or low- exposed workers. The unexposed subjects were selected from workers who worked with little or no cement dust exposure had no reported current respiratory illness, no history of chronic respiratory diseases and no reported history of working in industries where they could have been exposed to dust, chemicals, fumes or gases. Selection was restricted to male workers with a work history of at least 1 year.

This study was approved by the ethic committee of the Chulalongkorn University Review Board. Permission to conduct the study was granted by the factory manager. All of the participants received a clear explanation of the purpose of this study and agreed to participate via signed consent forms.

Exposure assessment

The factory was established in 1974 as one of five factories in a leading roofing fiber cement company in Thailand. It should be noted that similar materials are used in each factory The compositions of raw material used included potassium/sodium bentonite (2.92%), eucalyptus pulp (0.78%), virgin pulp (8.55%), polyvinyl alcohol (PVA; 5.16%), calcium carbonate (35.67%) and cement (43.92%), respectively. Asbestos use had been phased out since the end of 2011. Asbestos had previously been used in approximately 6% of fiber cement processing. In a roofing fiber cement factory, the work processes consists of cement mixing and pulping, water injection, curing, de-pelleting and skid, spraying injection, painting, quality control testing and storage. According to a preliminary walk-through survey and an existing data records review, this study classified homogenous exposure groups (HEGs)[19, 20] to estimate cement dust exposure levels in different work settings. This was based on the concept that workers working in the same area for similar amounts of time are likely to have similar exposure levels. The workers were classified into three groups of exposed and unexposed workers, including 1) high HEGs (mixing and pulping, water injection, curing, de-pelleting and skid, spraying injection, and painting), 2) low HEGs (quality control, storage and driving and maintenance) and 3) unexposed groups (office and accessory). The authors observed that workers either did not use or did not consistently use personal protective equipment such as protective masks. Most of the workers changed their jobs and did not hold the same job for long periods of time (Table 1). Therefore, individual cumulative duration of work in exposed areas was employed as a surrogated measure of total dust exposure.

Study questionnaire

A questionnaire with modified questions from the Thai Thoracic Society and the American Thoracic Society questionnaire were used to assess respiratory[10, 11]. Face-to-face interviews for both the exposed and control groups were conducted by well-trained occupational nurses. The main questions included those about demographics, work history, use of respiratory protective equipment, smoking habits, and respiratory symptoms. Special attention was given to job title and duration of each job. Smoking was quantified in pack years. Current smokers were those who were smoking for at least 3 months prior to the interview, and nonsmokers were those who had never smoked more than 20 packs of cigarettes in their lifetime. Ex-smokers were those who had quit at least one year before the survey. Pack years were defined as the number of packs (one pack=20 cigarettes) multiplied by the number of years smoked. The principal investigators checked the questionnaire to ensure that the participants completed it.

Spirometric measurements

The ventilatory function testing and results included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and the ratio of forced expiratory volume in one second to forced vital capacity (FEV1/FVC). Pulmonary function was measured using the American Thoracic Society guidelines[11] with a portable spirometer (COSMED Srl, Rome, Italy). The spirometer was tested and calibrated by an authorized service company before conducting the study. Participants did not smoke at least one hour before the test. At least three acceptable efforts were obtained in each participant. Spirometry measured values of FVC and FEV1 were compared with predicted normal values based on the regression equation for Thai men derived by the Thai Thoracic Society[10]. Variations in the two best FVC and FEV1measurements were within 5% of each other. The spirometer was calibrated daily. Standing height and weight were measured using standardized equipment. Expected lung function scores were derived from the Siriraj Equation, which was developed using lung function testing in a healthy nonsmoking Thai population older than 10 years (n=3,654)[12]. In addition, the pulmonary function impairment was calculated according to Thai Thoracic Society guidelines and assigned into four categories from no impairment to severe.

Sampling of the total and respirable dust

A total of 60 respirable dust and 22 total dust measurements were conducted for randomly selected workers from 10 occupational groups whereas 15 respirable dust and 3 total dust measurements were conducted for the unexposed group using a tared 5-μm PVC filter with a closed- faced 37-mm cassette. Millipore samplers (NIOSH method 0500) were used to measure respirable dust using a tared 5-PVC membrane with an aluminum cyclone (NIOSH method 0600)[17]. In total, 5 respirable dust samples and 3 total dust samples were collected during the analyses, as there were unexpected pump stoppages and poor sampling management and procedures. The arithmetic mean of the respirable dust concentration for each occupational group was used in the calculation of cumulative respirable dust exposure. The cumulative respirable dust exposure for representative workers was calculated as the sum of arithmetic means of the respirable dust concentration and the years worked in the work areas, expressed as mg/m^3-years.

Statistical analysis

The data analyses were performed using SPSS *version 18* for Windows (Chicago, IL, USA). Means and SD were used to characterize the difference between exposed and unexposed groups including demographic characteristics, pulmonary function parameters, frequencies and percentages. The chi-square test was used to detect differences in the frequencies of categorical characteristics such as education, cigarette smoking, and mask use between the groups. A *p*-value of less than 0.05 was considered statistically significant. An independent t-test was used to analyze a difference in means for continuous characteristics such as age, height, and weight between the exposure and control groups. Logistic regression was used to determine if the prevalence of chronic respiratory symptoms and patterns of pulmonary dysfunction were different among the exposed and unexposed groups. The independent Student's *t*-test was used to see if the mean values for estimated ventilatory function values differed in exposed versus unexposed groups. A multiple linear regression model was evaluated in which ventilatory function values (FEV1, FVC, and FE1/FVC) were dependent variables and different exposures (cumulative dust) were the primary predictors of interest, after controlling for age, smoking, employment, and tenure as potential confounders.

Results

One hundred and fifteen exposed workers and 134 unexposed subjects were included in this study. The mean age of the exposed group was insignificantly higher than that of the control group (33.1 years old compared to 31.6 years old). The mean height of the exposed group was insignificantly lower than that of the control group, whereas the mean weight of exposed workers was significantly higher than that of unexposed group. The exposed group had a significantly higher education (75%) compared with the unexposed group (42%). Exposed workers had 6.4 years of work experience on average (max=24 years) whereas the unexposed group had 5.1 years of work experience on average (max=15 years). Smoking was significantly lower among exposed workers compared with unexposed workers, and the workers had a similar numbers of pack years-2 pack years on average.

Table 1. Descriptive characteristics of the exposed and unexposed workers at the roofing cement factory

Characteristics	Exposed (n=115)	Unexposed (n=134)	*p* value
Age (years), mean (SD)	33.13 (7.56)	31.67 (10.75)	0.22[a]
Height (cm), mean (SD)	167.17 (5.76)	167.98 (7.91)	0.36[a]
Weight (kg), mean (SD)	65.70 (11.14)	62.66 (10.01)	0.02[a]*
Education (%)			
Primary	0 (0)	23 (17.18)	<0.01[b]*
Secondary	29 (25.22)	54 (40.29)	
Higher	86 (74.78)	57 (42.53)	
Tenure (years), mean (SD)	6.35 (4.86)	5.05 (4.67)	0.05[a]
Maximum range (years)	24	15	
Smoking (%)			
Never	67 (58.26)	58 (43.29)	<0.01[b]*
Current	33 (28.69)	62 (46.27)	
Ex-smoker	15 (13.04)	14 (10.44)	
Pack years, mean (SD)	1.98 (2.92)	2.16 (3.51)	0.77[a]
Current respirable dust (mg/m^3), mean (SD)[c]	0.65 (0.85)	0.32 (0.60)	0.15
Cumulative respirable dust (mg/m^3-yrs), mean (SD)	2.97 (4.01)	0.99 (1.67)	0.05
Personal protective equipment (mask)			
Often	52 (45.22)	45 (33.58)	0.07[b]
Rare	63 (54.78)	89 (66.42)	

[a] Independent Student's *t*-test. [b]Chi-square test. [c]56 samples for the exposed workers and 13 samples for the unexposed workers. *Significant at a *p* value of <0.05.

Table 2. Prevalence of chronic respiratory symptoms in the exposed and unexposed groups at a roofing cement factory

Symptoms	Exposed (n=115)	Unexposed (n=134)	OR[a]	95% CI	*p* value[b]
Coughing	51 (44.34%)	52 (38.80%)	1.34	0.80–2.25	0.26
Chest tightness	22 (19.13%)	17 (12.68%)	1.64	0.82–3.29	0.15
Shortness of breath	24 (20.86%)	15 (11.19%)	2.19	1.08–4.43	0.02*
Wheezing	18 (15.65%)	12 (8.95%)	1.89	0.86–4.11	0.11

[a]Analyzed using logistic regression adjusting for age, tenure, pack years of smoking and education.
*Significant at a *p* value of <0.05.

In the exposed group, 42% of subjects were current or ex-smokers, whereas 57% of the unexposed group were current or ex-smokers. The exposed workers had insignificantly higher levels of current respirable dust (0.65 vs. 0.32 mg/m^3) and respirable cumulative dust (2.97 vs. 0.99 mg/m^3-yrs) compared with the unexposed workers, respectively. More than half of the exposed (55%) and unexposed (66%) groups rarely wore dust masks while working (Table 1). In the logistic linear regression analysis between education and mask use, this study found no significant difference (*p*=0.82).

The exposed group had a significantly higher prevalence than the unexposed group for shortness of breath (OR=2.19; *p*=0.02) and insignificantly higher prevalence than the unexposed group for chronic cough (OR=1.34), chest tightness (OR=1.62), and wheezing (OR=1.67) after adjustment for age, duration of employment, pack years of smoking, and education (Table 2).

The exposed group had a similar prevalence of normal pulmonary function (64%) compared with the unexposed group. The exposed group (32%) had a slightly higher amount of mild pulmonary impairment than the unexposed group (28%) whereas the unexposed group had a slightly higher amount of moderate pulmonary impairment than the exposed group (Table 3).

Table 3. Patterns of pulmonary dysfunction in the exposed and unexposed groups

Pulmonary function	Exposed (n=115)	Unexposed (n=134)	OR[a]	95% CI	p value[b]
Normal	74 (64.33%)	87 (64.92%)	1.02	0.59−1.66	0.93
Mild	37 (32.17%)	37 (27.61%)			
Moderate	4 (3.50%)	10 (7.47%)			

[a] Analyzed using logistic regression adjusting for age, tenure, pack-years of smoking, and education. OR= normal group compared with mild combined moderate groups. No severe cases were found. [b] Significant at a p value of <0.05.

Table 4. Estimated ventilatory function values (FEV1, FVC, and FEV1/FVC) for exposed and unexposed workers

Characteristics	Exposed (n=115)	Unexposed (n=134)	p value[b]
FEV1 (L/s), mean (SD)	3.19 ± 0.45	3.29 ± 0.55	0.32[a]
FVC (L), mean (SD)	3.62 ± 0.52	3.93 ± 0.62	0.34[a]
FEV1/FVC (%), mean (SD)	88.26 ± 4.38	88.37 ± 5.38	0.91[a]

[a] Independent Student's t-test adjusting for age, tenure, pack-years of smoking, and education. [b] Significant at a p value of <0.05.
FEV1=forced expiratory volume in one second. FVC=forced vital capacity.

Table 5. Ventilatory function values (stratifying cigarette smoking habits) for exposed and unexposed workers

Characteristics	Smoking status	Exposed (n=115)	Unexposed (n=134)	p value[b]
FEV1 (L/s)[a], mean (SD)	Never (n=125)	3.06 ± 0.59	3.05 ± 0.71	0.96
	Current (n=95)	3.18 ± 0.49	3.32 ± 0.50	0.21
	Ex-smoker (n=29)	2.95 ± 0.42	3.25 ± 0.53	0.23
FVC (L)[a], mean (SD)	Never (n=125)	3.44 ± 0.66	3.43 ± 0.57	0.99
	Current (n=95)	3.64 ± 0.54	3.76 ± 0.59	0.31
	Ex-smoker (n=29)	3.33 ± 0.44	3.57 ± 0.45	0.31
FEV1/FVC (%)[a], mean (SD)	Never (n=125)	89.20 ± 5.58	88.54 ± 6.23	0.58
	Current (n=95)	87.59 ± 6.16	88.40 ± 5.19	0.49
	Ex-smoker (n=29)	88.46 ± 5.32	90.68 ± 4.35	0.38

[a] An independent t-test. [b] Significant at a p value of <0.05.
FEV1=forced expiratory volume in one second. FVC=forced vital capacity.

The estimated ventilatory function values (FEV1 and FVC) were insignificantly lower for the exposed group compared with the unexposed group whereas the FEV1/FVC in the unexposed group was slightly higher than that in the exposed group (Table 4).

The estimated ventilatory function values for cigarette smoking were similar for current and ex-smokers but the exposed group had lower, but insignificant, FEV1, FVC and FEV1/FVC levels compared with the unexposed group on average. In contrast, there were insignificantly lower FEV1, FVC and FEV1/FVC levels for workers who never smoked in the unexposed group (Table 5).

The high HEGs group (mixing and pulping, water injection, curing, de-pelleting and skid, spraying injection and painting) had insignificant slightly higher respirable cement dust exposure levels (0.617 mg/m^3) than the low HEGs group (quality control, storage and driving and maintenance) (0.607 mg/m^3) and the unexposed group (office and accessory; 0.397, mg/m^3) (p=0.056). The mean FVC, FEV1 and FEV1/FVC levels of the high HEGs exposed group were 87, 86 and 87%, respectively, and those of the low HEGs exposed group were 85, 88 and 90%, respectively,

Table 6. Respirable dust levels and spirometry results for roofing fiber cement workers according to homogenous exposure groups (HEGs)

Descriptive characteristics						
Respirable dust levels (mg/m^3)	No. collected samples	Mean	SD	Max	Min	*p* value[d]
High HEGs[a]	39	0.617	0.887	2.237	0.001	0.056
Low HEGs[b]	17	0.607	0.831	3.107	0.001	
Unexposed[c]	13	0.397	0.677	2.257	0.001	
Pulmonary function tests (PFT %)	No. subjects					
FVC						
High HEGs	25	86.88	9.83	106	63	0.841
Low HEGs	22	85.45	9.43	104	73	
Unexposed	41	86.95	10.68	111	70	
FEV1						
High HEGs	25	86.04	10.61	104	66	0.796
Low HEGs	22	88.27	9.35	113	77	
Unexposed	41	87.10	10.60	108	64	
FEV1/FVC						
High HEGs	25	87.01	5.04	93.41	74.73	0.166
Low HEGs	22	89.69	2.97	95.22	84.32	
Unexposed	41	88.37	5.38	98.51	72.75	

[a] High HEGs (mixing and pulping, water injection, curing, de-palleting and skid, spraying injection, and painting). [b] Low HEGs (quality control, storage and driving, and maintenance). [c] Unexposed (office and accessory). [d] ANOVA analysis adjusting for age, tenure, pack years of smoking and education. Significant at a *p* value of <0.05.

whereas those of unexposed group were 87, 87 and 88%, respectively (Table 6). The FVC (p=0.84), FEV (p=0.79) and FEV1/FVC (p=0.17) levels were insignificantly different among the high HEGs and low HEGs groups as compared with the unexposed group.

Discussion and Conclusions

This is the first epidemiological study of respiratory symptoms and pulmonary dysfunction indices of roofing fiber cement conducted in Thailand. Roofing fiber cement workers were exposed to cement dust during the production processes (mixing and pulping, water injection, curing, de-palleting and skid, spraying injection, painting, etc.). The exposed workers who were directly working in production lines were exposed to higher concentrations of dust compared with others such as office workers. The respirable dust and total dust samples collected showed that dust levels did not exceed the allowable level of exposure in Thailand. The socioeconomic and demographic factors of the cement-exposed and unexposed workers were similar in terms of age, height, and weight, tenure, pack years, current respirable dust, and cumulative dust exposure, with the exception of education background and smoking status.

This study has demonstrated that shortness of breath was significantly different among exposed and unexposed workers, whereas coughing, chest tightness and wheezing were found to be insignificantly different among exposed and unexposed workers. The previous studies on respiratory symptoms and pulmonary function deficits have shown different results. A few studies demonstrated a higher prevalence of respiratory symptoms and varying degrees of pulmonary dysfunction[1–8]. In contrast, some other studies have failed to find any significant differences in pulmonary parameters and respiratory symptoms among cement workers and unexposed workers[14, 15].

Our findings are partly in agreement with previous studies from the United States and Norway[14, 15]. The insignificant reductions in ventilatory function values in exposed workers in this study were in agreement with similar observations by Abrons *et al*. (1988) and Fell *et al*. (2003). In addition, this cross-sectional design could not clearly demonstrate the causal relationship between cement dust exposure and pulmonary reductions and impairments in FVC, FEV1 and FEV1/FVC. The differences in ventilatory function between exposed smokers and nonsmokers did not achieve statistical significance after adjusting for age, height and smoking. Comparing respiratory symptoms and pulmonary dysfunction indices between studies is difficult because many factors vary. In addition, some previous studies did not adjust for possible confounders of respiratory symptoms such as age and smoking status, as was done in this study[1, 2, 6].

The insignificant findings may be due to a number of reasons. Firstly, the effect of dust was probably not observed in workers with low tenure because they had worked in the environment for just a short period of time (average 6.3 years) and were relatively young (average=33 years old) compared with the workers in previous significant studies in which tenure was more than 10 years on average[1, 5, 8, 14]. Secondly, the dust exposure was really low in both the exposed and unexposed groups. Therefore, the ability to detect the effects of dust exposure was likely affected by the low exposure. From our findings and observations in this study, the relationship between cement dust exposure and pulmonary function impairments may be influenced by the healthy worker effect. Since the exposed workers switched jobs often, they were not exposed for long enough to create health effects. Finally, a significantly lower number of smokers was found among exposed workers compared with unexposed workers. This may have caused to be no significant differences between the exposed and unexposed groups. This study found no significant difference between education and mask use (p=0.82). The results also suggest that mask use may not prevent respiratory symptoms and pulmonary reduction, which is similar to the results of previous studies[8, 18].

In conclusion, an association between decline in lung function and cement dust levels among roofing fiber cement workers suggests that the respiratory health of roofing cement workers should be protected. The insignificant difference in dust exposure and pulmonary impairments may be due low tenure and low level of dust exposure as well as the healthy worker effect, which may have occurred. Since more than half of the exposed workers rarely use personal protective equipment (PPE) such as protective masks, they are still at high risk of cement dust exposure. According to a walk-through survey and interviews, it should be noted that the workers felt uncomfortable wearing protective masks for very long. In addition, they thought the cement dust was present at relatively low levels and might not cause any respiratory symptoms and pulmonary impairments. The use of proper PPE while at work and reduction and elimination of smoking by the exposed workers would help to protect them from developing more severe chronic respiratory diseases in the future. However, we strongly recommend use of PPE, such as protective masks, and engineering control for cement dust reduction in the work processes. In addition, the results of ongoing studies of pulmonary radiographs could be used to confirm the possible pulmonary dysfunction and indices among cement workers.

Acknowledgments: The authors would like to thank the manager and workers at the cement factory. The authors also acknowledge the technical assistance of Ms. Aree Khuanet, Thungsong Hospital, in the questionnaire interview and spirometry measurements. The authors would also like to thank Ms. Warinthip Chuchoey for their collaboration and Thaksin University for assistance in sample analysis. The manuscript was edited by Ms. Audrie Chavez. This study was supported by a 90th Year Chulalongkorn Scholarship and partially funded by the Fogarty International Center, National Institutes of Health (D43 TW007849).

References

1) Al Neaimi YI, Gomes J, Lioyd O. Respiratory illnesses and ventilatory function among workers at a cement factory in a rapidly developing country. Occup Med 2001; 51: 367–73.
2) Noor H, Yap CL, Zolkepli O, Faridah M. Effect of exposure to dust on lung function of cement factory workers. Med J Malaysia 2000; 55: 51–7.
3) Zeleke ZK, Moen BE, Braviet M. Cement dust exposure and acute lung function: a cross shift study. BMC Pulmonary Medicine 2010; 10: 19.
4) Zeleke ZK, Moen BE, Braviet M. Lung function reduction and chronic respiratory symptoms among workers in the cement industry: a follow up study. BMC Pulmonary Medicine 2011; 11: 50.
5) Neghab M, Choobineh A. Work related respiratory symptoms and ventilatory disorders among employees of a cement industry in Shiraz, Iran. J Occup Health 2007; 49: 273–8.
6) Yang CY, Huang CC, Chiu HF, Chiu JF, Lan SJ, Ko YC. Effects of occupational dust exposure on respiratory health of portland cement workers. J Tox Environ Health 1996; 49: 581–8.
7) Mwaiselage J, Bråtveit M, Moen B, Mashalla Y. Cement dust exposure and ventilatory function impairment: an exposure-response study. J Occup Environ Med 2004; 46: 658–67.
8) Mwaiselage J, Bråtveit M, Moen B, Mashalla Y. Respiratory symptoms and chronic obstructive pulmonary disease among cement factory workers. Scand J Work Environ Health 2005; 31: 316–23.
9) The Institute of Medicine (IOM). [Online]. 2010 [cited 2010 Sept 10]: Available from: URL: http://www.iom.edu/About-IOM.aspx
10) The Thoracic Society of Thailand. [Online]. 2010 [cited 2010 Apr 10]: Available from: URL: http://www.thaithoracic.or.th/knowledge/download/GuidelinePFT.pdf.
11) American Thoracic Society (ATS). Diagnosis and initial management of nonmalignant diseases related asbestos AM J Respir Crit Care Med 2004: 170:

691–715.
12) Desomritrutai W, Nora A, Mararetra H, et al. Reference Spirometric values for healty lifetime smoker in Thailand. J Med Assoc 2000; 83: 457–66.
13) Nordby KC, Fell AK, Noto H, et al. Exposure to thoracic dust, airway symptoms and lung function in cement production workers. Eur Respir J 2011; 38: 1278–86.
14) Fell AK, Thomassen TR, Kristensen P, Egeland T, Kongerud J. Respiratory symptoms and ventilatory function in workers exposed to Portland cement dust. J Occup Environ Med 2003; 45: 1008–14.
15) Abrons HL, Petersen MR, Standerson WT, Engelberg, Harber P. Symptoms, ventilator function, and environmental exposures in Portland cement workers. British J Indus Med 1988; 45: 368–75.
16) Fell AK, Sikkedland LI, Svendsen MV, Kongerud J. Airway inflammation in cement production workers. J Occup Environ Med 2010; 67: 395–400.
17) NIOSH Manual of Analytical Methods (NMAM), Fourth Edition [Online]. 2003 [cited 2010 Apr 10]: Available from: URL: http://www.cdc.gov/niosh/docs/2003-154/
18) AbuDhaise BA, Rabi AZ, Zwairy MAA, Hader AFE, Qaderi SE. Pulmonary manifestations in cement workers in Jordan. Int J Occup Med Environ Health 1997; 10: 417–28.
19) Burdorf A, Vantonggeren M. Variability in Workplace Exposures and the Design of Efficient Measurement and Control Strategies. Ann Occup Hyg 2003; 47: 95–9.
20) Kromhout H, Symanski E, Rappaport SM. A comprehensive evaluation of within- and between-worker components of occupational exposure to chemical agents. Ann Occup Hyg 2003; 37: 253–70.