RESPIRATORY EFFECTS AMONG SMELTERS EXPOSED TO METAL FUME AND REPARABLE DUST IN A FACTORY IN EASTERN THAILAND

Ananmai Thetkatuek[1]*, Tanongsak Yingratanasuk[1], Teerayuth Sa-ngiamsak[1], Wiwat Ekburanawat[2], Wallop Jaidee[3], Saksith Kulwong[1]

[1] Department of Industrial hygiene and safety, Faculty of Public health, Burapha University, Chonburi 20131, Thailand
[2] Health Promotion & Occupational Medicine Center, Bangkok Rayong Hospital, Rayong 21000, Thailand
[3] Department of Public Health Foundations, Faculty of Public Health, Burapha University, Chonburi 20131, Thailand
*For correspondence; Tel. + (66) 38-102740 Email: anamai@buu.ac.th

ABSTRACT: *Exposure to metal fume and respirable dust may be related to a respiratory health effect. The objective of this study was to examine the relationship between a metal fume (trade secret), and respirable dust exposure and respiratory health among the smelters. Exposure monitoring was conducted by area sampling. Inquiries on symptoms of the respiratory system as well as chest radiograph and lung function tests were conducted. In regards to FEV1 (% predicted), we found that 2.5% had an obstructive abnormality. When assessing FVC (% predicted), 2% had restrictive ventilator impairment. Regarding chest radiograph of the 397 subjects, 3% had fibrosis, in which 3 cases had a fibrotic band at the right upper lobe, 1 case had diffuse pleural thickening in the area of both sides of the lower lung (0.83 mm). The results revealed that cough symptom was related to smoking history (OR 1.97, 95% CI 1.009, 3.847. For the respirable dust exposed group, the OR (95% CI) among the smokers was 1.708 (95% CI 1.033, 2.825).*

Keywords: respiratory effect; smelters; metal fume; respirable dust; Thailand

1. INTRODUCTION

Metal manufacturing increases around the world, especially in developing countries where products from metals such as aluminum, beryllium, brass, and brass alloys are in high demand [1]. 260 industrial smelting factories are found in many provinces across Thailand [2]. The manufacturing process comprises many departments, such as casting, hot rolling, cold rolling, and finishing and office departments. If the concentration of this kind of metal fume (trade secret) and respirable dust exceed the limits for 8 working hours [3-4], the occupational health of smelters could be harmed. Exposure to metal fume and respirable dust during working hours could cause illness, for example, pot room asthma [5-7]. The symptoms can develop to be a chronic lung disease with chest pain and wheezing [5-6], pulmonary fibrosis, pneumoconiosis, lower pulmonary function [8,9] indicated by FEV1 and abnormal chest X-ray test result [10].

Factors affecting smelters' health exposed to metal fume and respirable dust include metal fume concentration and respirable dust concentration in the smelting process [11], exposure frequency, and exposure time [11,12]. The personal factors such as age and smoking history also play a part. A study found that the pulmonary function of each person is different according to age, exposure period to the metal fume (trade secret), and smoking history. The pulmonary function could be reduced through the employment period [13]. Rare usage of personal protective equipment is another factor making smelters more exposed to metal fume and dust [14].

Early protection against illness resulting from exposure to the metal fume (trade secret) and respirable dust can be achieved by monitoring the work environment to ensure that the metal fume and respirable dust do not exceed the limits [3-4]. Medical check in workplaces performed to monitor the occupational health should include pulmonary function tests [13] chest radiograph [9] and assessment of abnormalities with a questionnaire [15]. In the past decade, researchers around the world have studied the effects of the metal fume (trade secret), such as pot room asthma [5-7], chronic lung diseases, pulmonary fibrosis, pneumoconiosis, lung cancer [11,13,16] and lower pulmonary function [8]. However, in Thailand, there is no study on how this kind of metal fume (trade secret) and respirable dust would cause respiratory system abnormalities among smelters. The research aims to explore the relationship between the metal fume (trade secret), and respirable dust exposure and respiratory system abnormalities among the smelters in a metal (trade secret) manufacturing factory in Eastern Thailand.

2. METHODOLOGY

This was a cross-sectional study. The researcher collected data from 10 January 2018 – 30 April 2018.

2.1 Study Population

The study pertains to the workers in a smelting factory in Eastern Thailand. There were 399 employees in 4 departments which included casting, hot rolling, cold rolling, and office departments.

2.2 Sample Size

The sample size calculation method was based on logistic regression analysis [17]. The researcher conducted a literature review [18] which reported the frequency of wheezing among smelters exposed to metallic fume in pot rooms. Hence, the study subjects consisted of 399 employees. The number of metal fume and respirable dust samples in the work environment was calculated in accordance with the recommendation of the American Industrial Hygiene Association, which emphasized proper sample size for daily chemical exposure assessment [19]. The collection of airborne workplace contaminants consisted of 45 samples of a metal fume (trade secret) and 46 samples of respirable dust.

2.3 Research Ethics

The study was approved by the Committee for Research Ethics in Humans at Burapha University, Chonburi, Thailand.

2.4 Tools and Data Collection

The researcher explained the research purposes, data collection method and asked for his permission to conduct the study, as follows;

2.4.1 Questionnaire: The questionnaire comprised 4 parts including demographic information, smoking, and alcohol drinking history, employment period, symptoms of the respiratory system. The interview covering 4 parts lasted approximately 15-minutes/interviewee.

2.4.2 Air Samples: Exposure monitoring was conducted by area sampling. The Similar Exposure Group (SEG) was established based on a walk through a survey. 6-10 full-shift air samples for the metal fume and respirable dust were collected in each department. The sampling and analytical methods of the metal fume and respirable dust were conducted according to NIOSH method 7013 [20], and 0600, respectively [21]. 45 samples of the metal fume and 46 samples of respirable dust were collected from 4 departments which included welding, hot rolling, cold rolling, and the office. The sampling media were routinely transported to the laboratory for chemical analyses.

2.4.3 Pulmonary Function Test: The spirometer used in this study was Datospir-120 P/ N 511-800-Mu2, in compliance with the minimum criteria according to the ATS guideline in 1994[22]. The results were interpreted according to the criteria set by the Occupational Health Division of the Occupational and Environmental Diseases Association of Thailand [22].

2.4.4 Chest X-Ray (CXR): CXR was conducted by the occupational physicians and radiologists to acquire the chest x-ray images of the employees receiving the health check in the health check-up van. The abnormal chest x-ray images were read by the radiologists based on the International Labor Organization (ILO) criteria to determine the abnormalities, such as fibrosis.

2.4.5 Data Analysis The researcher entered variables with details. 1) Multiple linear regression analysis included independent variables, as follows; Gender, years of smoking, drinking history, usage of respiratory protective equipment, with air conditioner, metal fume concentration (Trade secret; mg/m3), or concentration of respirable dust (mg/m3). The dependent variable was the pulmonary function indicated by FEV1 and FVC. 2) Multiple logistic regression analysis included independent variables, as follows; gender, age, smoking and alcohol drinking history, medical history, years of employment periods, daily working hours, usage of respiratory protective equipment, exposure concentrations of the metal fume, and respirable dust (mg/m3). The dependent variable was respiratory system abnormalities, covering a cough, secretion, chest tightness, wheezing and nasal congestion.

3. RESULTS AND DISCUSSION

3.1 Demographic information

According to the demographic data, 399 subjects covered both males and females. Most of the subjects were of working age, with average ages of 25.78 (SD 4.67) years for males and 28.24 (SD 5.33) years for females. The highest educational level for both male and female subjects was a diploma level. The majority was single. The smoking percentage of male subjects was higher than the female counterparts. 25.9% of the male subjects smoked, while the female subjects never smoked. The average smoking period was 5.7 (SD 4.46) years. 85.2% of males and 57.1% of female subjects drank alcohol.

3.2 Employment Period

80.9% of male subjects and 82.5% of female subjects never worked in another factory. 36.6% of working in the casting department were male. All subjects working in the office were female. The average employment period of male subjects was 2.23 (SD 1.14) years, while the average employment period of females was 2.22 (SD 1.31) years. 87.5% of male subjects and 47.6% of female subjects wore respiratory protective equipment. As for the work environment, 48.8 of the male subjects worked in the area with electric fans, while 95.2% of the female subjects worked in the air-conditioned room.

3.3 Concentrations of the metal fume and respirable dust

It was found that the geometric mean concentration of the metal fume was 0.003 (GSD 3.525) mg/ m3 and the respirable dust was .576 (GSD 0.003)(mg/ m3), and did not exceed the ACGIH TLV-TWA [4], as shown in Table 1.

3.4 Pulmonary function tests

It was found that the subjects of the office department have the lowest average FVC rate. 40.36 of employees in the office department were female and they have the average pulmonary function at 3.53 (SD 0.717) and the lowest average FEV1 rate at 3.45 (SD 0.836). The subjects in the cold rolling department have the lowest FEV1/ FVC result which is 85.70 (SD 5.07) as shown in Table 2.

3.5 Chest X rays

Two of the 399 subjects did not allow the chest X-ray test. Among 397 subjects, 3% have abnormal chest x rays result, as follows; 3 subjects have upper lobe fibrosis, 1 subject has fibrosis, opaque line, and upper lobe nodule. The subjects have fibrosis, but no pneumoconiosis.

3.6 Conditions of the respiratory system

According to the interview, 50% of 244 subjects exposed to metal fume and respirable dust, had chest tightness, and 48% of 244 of them had coughing as shown in Table 3.

3.7 Factors affecting pulmonary function

Regarding variables affecting FVC and FEV1 in male smelters exposed to fume of metal, according to multiple linear regression analysis with 6 independent variables (age, smoking period (years), alcohol drinking history, usage of respiratory protective equipment, working in the workplace with air-conditioner, the concentration of a kind of metal fume (trade secret), and change of FVC and FEV1 rate), it is found that, when other variables were under control, no independent variable affects the change of FVC and FEV1 rate, as shown in Table 4.

Regarding variables affecting FVC in smelters exposed to respirable dust, according to multiple linear regression analysis with 6 independent variables, and concentration of respirable dust (mg/m3), and change of FVC) it is found that, when other variables were under control, the 6 independent variables affect the change of FVC rate at a moderate level ($R = 0.447$, $R2 = 0.22$). The independent found that, when other variables were under control, the independent variables affect the change of FEV1 rate at a moderate level ($R = 0.427$, $R2 = 0.182$). The independent variables affect the change of FEV1 rate for 18.2 % with a statistical significance of 0.05. When considering the regression coefficient, it is found that, when other variables were under control, alcohol drinking history and usage of respiratory protective equipment affect the change of FEV1 rate with a statistical significance of 0.05, as shown in Table 5.

Table 1. The concentration of metal fume and respirable dust

Department	N	Mean	SD	GM	GSD	Min	Max
Metal fume (mg/m^3)							
Welding	29	0.0138	0.008	0.011	2.081	0.001	0.40
Hot rolling	2	0.0015	0.0007	0.001	1.633	0.001	0.002
Cold rolling	2	0.015	0.0056	0.014	1.472	0.001	0.019
Office	1	<0.001	-	0.001	1.000	0.001	0.001
Average	34	0.01	0.008	0.003	3.525	0.001	0.04
Respirable dust (mg/m^3)							
Welding	29	0.325	0.289	0.255	2.127	0.050	0.93
Hot rolling	8	0.26	0.1017	0.245	1.438	0.150	0.440
Cold rolling	7	0.244	0.110	0.220	1.672	0.10	0.390
Office	2	0.245	0.134	0.226	1.784	0.150	0.34
Average	46	0.30	0.18	0.5765	.003	0.05	0.93

Table 2. Lung function capacity (%)

Department	n	Mean	SD	Median	Min	Max
FVC						
Welding	123	4.11	0.473	4.09	3.0,5.50	5.50
Hot rolling	56	4.081	0.547	4.08	2.55	5.16
Cold rolling	65	4.01	0.458	3.95	0.312	5.54
Office	153	3.530	0.717	3.58	2.11	5.11
FEV_1						
Welding	123	3.53	0.434	3.48	2.37	4.85
Hot rolling	56	3.52	0.445	.445	2.31	4.43
Cold rolling	65	3.45	0.386	3.39	2.79	4.47
Office	153	3.52	0.63	3.11	1.64	4.46
FEV_1/ FVC						
Welding	123	85.870	5.49	85.90	67.50	100
Hot rolling	56	86.46	4.37	86.30	74.30	95.40
Cold rolling	65	85.70	5.07	85.50	69.70	95.90
Office	153	86.36	5.45	86.30	72.80	99.50

Table 3. Respiratory system disorder symptoms

Respiratory system disorder symptoms	**Exposed group** (n = 244)	**Non-exposed group** (n = 155)	**Total** (n = 399)
Coughing	118 (48.40)	69 (44.5)	187 (46.90)
Phlegm	99 (40.60)	64 (41.3)	163 (40.90)
Chest tightness	122 (50.00)	81 (52.3)	203 (50.90)
Wheezing	54 (22.10)	22 (14.2)	76 (19.00)
Nasal congestion	97 (39.80)	80 (51.6)	177 (44)

Table 4. Factors and metal fume concentration associated with FVC and FEV1 among male workers

Variables	Adjust FVC				Adjust FEV_1			
	Unstandardized coefficients: B	p-value	Lower CI	Upper CI	Unstandardized coefficients: B	p-value	Lower CI	Upper CI
Constant	3.868	0.013	0.867	6.868	3.846	0.001	1.657	6.035
Gender (Year)	0.049	0.338	-0.054	0.152	0.017	0.643	-0.058	0.092
Years of smoking (year)	0.007	0.857	-0.07	0.084	0.031	0.271	-0.025	0.087
Drinking history\(No/ Yes)	-0.566	0.184	-1.417	0.285	-0.564	0.074	-1.184	0.057
Usage of respiratory protective equipment (No/ Yes)	0.035	0.819	-0.279	0.35	-0.04	0.722	-0.269	0.189
With air conditioner (No/ Yes)	-0.196	0.395	-0.66	0.269	-0.07	0.677	-0.408	0.269
Metal fume concentration (Trade secret; mg/m^3)	7.535	0.672	-28.55	43.62	18.875	0.153	-7.449	45.199

Table 5. Factors and respirable dust associated with FVC and FEV1 among male workers

Variables	Adjust FVC				Adjust FEV_1			
	Unstandardized coefficients: B	p-value	Lower CI	Upper CI	Unstandardized coefficients: B	p-value	Lower CI	Upper CI
Constant	5.32	0	3.952	6.688	4.614	0	3.497	5.731
Gender) Year(	-0.006	0.749	-0.043	0.031	-0.014	0.365	-0.044	0.016
Years of smoking)year(	-0.005	0.776	-0.038	0.029	0.007	0.591	-0.02	0.035
Drinking history)No /Yes(	-0.686	0.009	-1.193	-0.179	-0.524	0.014	-0.938	-0.11
Usage of respiratory protective equipment (No /Yes)	0.166	0.009	0.043	0.29	0.119	0.021	0.019	0.22
With air conditioner) No/ Yes)	0.095	0.429	-0.143	0.334	0.082	0.406	-0.113	0.276
Respirable dust concentration)mg/m^3(	-0.196	0.693	-1.179	0.788	-0.287	0.478	-1.09	0.515

3.8 Factors affecting respiratory system abnormalities of smelters in an industrial smelting factory

According to the analysis of 7 variables (gender, age, smoking history, alcohol drinking history, employment period, usage of respiratory protective equipment, the concentration of the metal fume (trade secret), which affect 5 symptoms in the respiratory system, it is found that subjects with smoking history have cough 1.97 times more than non-smoking subjects. OR (95% CI) = 1.97 (1.009, 3.847). Subjects with alcohol drinking history have cough 2.039 times more than non-drinking subjects. OR (95% CI) = 2.039 (1.074, 3.872). Subjects with 4-10 years of employment period have phlegm 1.979 times more than subjects with 1-3 years of the employment period. OR (95% CI) = 1.979 (1.04, 3.766). Female subjects have nasal congestion 2.156 times more than male subjects. OR (95% CI) = 2.156 (1.096, 4.241), as shown in Table 6.

Table 6. Factors and metal fume concentration associated with respiratory system disorders (Trade secret: mg/m^3)

Factors	N (%)	Coughing aOR (95%CI)	Phlegm aOR (95%CI)	Chest tightness aOR (95%CI)	Wheezing aOR (95%CI)	Nasal congestion aOR (95%CI)
Gender (Female)	63 (22.7)	1.056 (0.531,2.101)	0.721 (0.358,1.455)	1.306 (0.667,2.56)	1.059 (0.4,2.801)	2.156 (1.096,4.241)
Age (>37 Years)	15 (5.4)	0.629 (0.195,2.031)	0.838 (0.274,2.564)	0.458 (0.148,1.424)	00.378 (0.047,3.069)	0.572 (0.183,1.788)
Smoking history (Yes)	49 (17.6)	1.97 (1.009,3.847)	1.264 (0.654,2.444)	0.853 (0.445,1.637)	0.711 (0.299,1.688)	1.039 (0.537,2.011)
Alcohol drinking history (Yes)	216 (77.7)	2.039 (1.074,3.872)	0.992 (0.529,1.858)	1.066 (0.564,2.016)	1.45 (0.605,3.476)	1.153 (0.621,2.14)
Years of employment periods (4-10 Years)	53 (19.1)	1.391 (0.727,2.66)	1.979 (1.04,3.766)	1.066 (0.564,2.016)	1.09 (0.454,2.617)	1.41 (0.743,2.676)
Usage of respiratory protective equipment (No)	69 (24.8)	0.634 (0.347,1.155)	0.737 (0.403,1.349)	1.057 (0.59,1.896)	0.33 (0.136,0.799)	0.978 (0.542,1.766)
Metal fume concentration (>0.0145mg/m^3)	38 (13.7)	0.755 (0.385,1.479	0.668 (0.335,1.332)	0.676 (0.348,1.313)	0.825 (0.361,1.885)	0.861 (0.438,1.695)

References: Gender (Male); Age (<=37 Years); Smoking history (No); Alcohol drinking history(No); Years of employment periods (1-3 Years); Usage of respiratory protective equipment (No); Metal fume concentration (mg/m^3)(< = 0.0145)

According to the analysis of 7 variables (gender, age, smoking history, alcohol drinking history, employment period, usage of respiratory protective equipment, the concentration of respirable dust), which affect 5 symptoms in the respiratory system, it is found that subjects with smoking history have cough 1.708 times more than non-smoking subjects. OR (95% CI) = 1.708 (1.033, 2.825). Female subjects have nasal congestion 2.412 times more than male subjects. OR (95% CI) = 2.412 (1.26, 4.615), as shown in Table 7.

Work conditions

In smelting factories, a large number of chemicals, such as metal fume and metallic respirable dust and many kinds of gases contaminate in the air [23]. Exposure to of such chemical affects the respiratory system of smelters, for example, an abnormal respiratory system of smelters in the pot room of smelting factories [24]. This study does not classify the components of metallic chemicals.

The study assesses the concentrations of the metal fume and respirable dust in the work environment of the 4 departments. The concentrations of metal fume and respirable dust do not exceed the ACGIH-TLV TWA [4] and are lower than the level in the study of Godderis et al. [23] which indicated the total inhalable fume exposure at 4.37 mg/m3. However, both studies applied different analysis techniques [23].

Chest x-ray

This study, conducted a chest x-ray for 397 subjects. It is found that 4 male subjects have fibrosis in their lung. The previous study attested that exposure to the metal fume (trade secret) will lead to respiratory system diseases, including pulmonary fibrosis) [13,16,24,25]. The long exposure will result in chronic pulmonary disease [13]. Two of 4 subjects with fibrosis have 1-3 years of employment period; another two subjects have more than 3 years of the employment period. According to the previous study, smelters having more than 18 years of employment period in a smelting factory of the metal, had chest pain, relapse of right pneumothorax and upper lobe fibrosis [26]. However, the mentioned study applied another analysis technique different from this study. Therefore, the causes of fibrosis cannot be determined, although the previous study attested that respirable dust accumulated in the lungs will lead to pulmonary fibrosis [27-30].

Factors affecting respiratory disorders

1. Factors affecting FVC and FEV1 among smelters in a smelting factory

This study is found that the majority of the sample group have normal pulmonary function results. It is found that alcohol drinking history affects the change of FVC and FEV1. On the contrary, smoking history does not affect the change of FVC and FEV1. The finding is in line with the previous study attesting that heavy alcohol drinking, together with smoking, causes a negative effect on the pulmonary function of smokers [31].

This finding contradicts with the previous study of Radon et al. [32] attesting that smokers in the pot room tended to have a lower pulmonary function, compared to a controlled group. Moreover, it contradicts the previous study indicating that the high prevalence of smoking of industrial populations [33] is a variable of lower pulmonary function [34]. Hence, smelters, as a risk group, were recommended to avoid alcohol drinking and smoking, even they were exposed to the low concentration of the metal fume (trade secret) and low concentration of respirable dust. This study found that FVC and FEV1 of smelters wearing respiratory protective equipment are higher different from that of workers not wearing respiratory protective equipment. It is well known that airway protection can reduce exposure to respirable dust in a polluted area.

However, such abnormalities were jointly caused by other variables as well, such as types of furnaces, wear and tear of furnaces, type of respiratory equipment used [14,35]. This finding was in line with the research of Kongerud and Rambjør [36] studied efficiency of Racal airstream helmet respirator as part of the improvement of personal protective equipment (PPE) to reduce respiratory system abnormalities. Although we cannot find that exposure to the metal fume and respirable dust is related to the pulmonary functions, the factory should keep on controlling the exposure concentrations below the standards. Exposure to metal fume and respirable dust of low concentration could lead to high risk if it was a long-term exposure, similar to the effect of smoking [37].

As for the gender variable, 15.8% of the sample group is female. All of them work in the office. Therefore, to analyze the variables affecting the changes of FVC, the test results of female subjects are separated from the test results of male subjects. In general, the gender variable affects the abnormalities of pulmonary capacity. Males and females were differently sensitive to chemical hazard owing to different lung capacity [38].

2. Factors affecting the abnormalities of the respiratory system

According to the interview regarding respiratory conditions of smelters exposed to the metal fume (trade secret) in a casting factory, it was found that 48.40% of smelters in the casting department and 44.5% of employees in the office had a cough. 22.10% of the smelters in the casting department and 14.2% of employees in the office have to wheeze. The result confirms the study of Chan-Yeung et al [9] regarding respiratory symptoms among casting smelters of the metal in British Columbia.

Smoking: This study found that workers with smoking history, when exposed to the metal fume (trade secret), and respirable dust were at risk of cough than non-smoking smelters. It was well-known that smoking results in respiratory system abnormalities [39]. If future research conducts a study of non-smokers only, it may discover risk factors of respiratory system abnormalities upon exposure to chemicals in the air, such as metal fume and metallic respirable dust.

Employment Period: According to the test results of smelters, it was found that the employment period affects phlegm symptoms. According to the study of Bradshaw LM et al. [8], a cumulative exposure index to welding fume relates to chronic bronchitis. Likewise, Kusaka et al. [40] indicated experience of hard metal exposure as a risk factor of asthmatic symptoms.

Gender: It was found that female subjects exposed to the metal fume (trade secret) have nasal congestion 2.156 times more than male subjects. This finding contradicts the study of Van Rooy et al. [11]. However, Van Rooy's methodology [11] was different from the methodology of this study.

Research Strength: The researcher chose the area where smelters were exposed to the same chemicals, for the sampling. Their x-ray images were interpreted by physicians specialized in radiology and experts of pneumoconiosis resulting from inorganic dust, certified by the International Labor Organization, (ILO). Research Weakness: As it was a cross-sectional study, respiratory system abnormalities might have started even before the study, or not caused by work-related conditions.

4. CONCLUSIONS

In the case of FEV1, we found that 2.5% had an obstructive abnormality. When assessing FVC, 2% had restrictive ventilator impairment. Regarding chest radiograph of the 397 subjects, 3% had fibrosis, in which 3 cases had a fibrotic band at the right upper lobe, 1 case had diffuse pleural thickening in the area of both sides of the lower lung (0.83 mm). The results revealed that cough symptom was related to smoking history. Although we could not find that exposures to the metal fume and respirable dust were related to respiratory health among the smelters, lung function tests should be conducted as health surveillance, especially among the workers who had smoking history, being female, drinking alcohol, had work experience > 3 years. Particular attention should be paid to variables increasing risks against pulmonary function.

5. REFERENCES

[1] Yokel RA, Anke MM, Inhat M, Stoeppler M. (eds) (2004). Elements and their compounds in the environment (2nd ed.). Weinheim, Germany: Wiley-VCH.

[2] Division of the Industrial factory. Department of Industrial Works. [Serial online] (2016). Available from: URL: [3] http://www.diw.go.th/hawk/content.php?mode=data1search.

[3] Department of Labor Protection and Welfare, Ministry of Labor: Chemical Concentration Limit of Dangerous

Chemical. [Serial online] (2016). Available from: URL:http:/ / www.ratchakitcha.soc.go.th/ DATA/ PDF/ 2556/ E/ 185/ 42.PDF. [Cited 2018 June 1]
[4] ACGIH. TLVs and BEIs based on the documentation of the threshold limit values for chemical substances and physical agents & biological expose Indices (2017). United States.
[5] Gibbs GW. (1985). Mortality of aluminum reduction plant workers, 1950 through 1977. J Occup Med; 27(10):761-770.
[6] Larsson B, Karlsson JE, Nielsen J. (2007). Respiratory and ocular symptoms in workers exposed to potassium aluminium-tetrafluoride soldering flux. Int Arch Occup Environ Health; 80(7):627-633 9.
[7] Leira HL. (2008). Occupational asthma in Norway. Tidsskr Nor Laegeforen; 128(23):2719-2721.
[8] Bradshaw LM, Fish wick, D, Slater T, Pearce N. (1985). Chronic bronchitis, work related respiratory symptoms and pulmonary function in welders in New Zealand. Occup Environ Med; 55(3):150-154.
[9] Chan-Yeung M, Wong R, MacLean L, Tan F, Schulzer M, Enarson D, et al. (1983). Epidemiologic health study of workers in an aluminum smelter in British Columbia. Effects on the respiratory system. Am Rev Respir Dis; 127(4): 465-469.
[10] Leo F, Venissac N, Drici MD, Mouroux J. (2005). Aluminium and primary spontaneous pneumothorax. A suggestive but unconfirmed hypothesis. Interact Cardiovasc Thorac Surg; 4(1): 21-22.
[11] van Rooy FG, Houba R, Stigter H, Zaat V, Zengeni MM, Rooyackers JM. et al. (2011). A cross-sectional study of exposures, lung function and respiratory symptoms among aluminium cast-house workers. Occupational and environmental medicine; 68(12): 876-882.
[12] Fishwick D, Bradshaw L, Slater T, Curran A, Pearce N. (2004). Respiratory symptoms and lung function change in welders: are they associated with workplace exposures? N Z Med J; 7(117): U872.
[13] Chattopadhyay BP, Saiyed HN, Roychowdhury A, Alam J. (2007). Pulmonary function in aluminium smelter and surrounding community-a case study. J Environ Sci Eng; 49(4): 309-316.
[14] Bhumika N, Prabhu GV, Ferreira AM, Kulkarni MK, Vaz FS, Singh Z. (2012). Respiratory morbidity among welders in the shipbuilding industry, Goa. Indian J Occup Environ Med; 16(2):63-5. doi: 10.4103/0019-5278.107069.
[15] American Thoracic Society. Standardization of spirometry. (1995). Update. American Journal of Respiratory and Critical Care Medicine; 152:1107-1136.
[16] Abbate C, Giorgianni C, Brecciaroli R, Tringali MA, D'Arrigo G. (2003). Spirometric function in non-smoking workers exposed to aluminum. American Journal of Industrial Medicine; 44(4):400-404.
[17] Hsieh FY, Bloch DA, Larsen MD. (1998). A simple method of sample size calculation for linear and logistic regression. Stat Med; 17(14):1623–1634.
[18] Kongerud J, Søyseth V. Respiratory disorders in aluminum smelter workers. (2014). J Occup Environ Med; 56(5 Suppl):S60-70. doi: 10.1097/JOM.0000000000000105.
[19] Hawkins NC, Norwood SK, Rock JC. (1991). A strategy for occupational exposure assessment. American Industrial Hygiene Association, Akron, Ohio, U.S.A.
[20] NIOSH: NIOSH Manual of Analytical Methods (NMAM), Fourth Edition. [Serial online] 2003. Available from URL:https://www.cdc.gov/niosh/docs/2003-154/pdfs/7013.pdf. [Cited 2018 October 22]
[21] NIOSH: Particulates not otherwise regulated, respirable 0600. [Serial online] 2003. Available from: URL:https://www.cdc.gov/niosh/docs/2003-154/method-cas0.html. [Cited 2018 October 1]
[22] The Association of Occupational and Environmental Diseases of Thailand: Guideline for Standardization and Interpretation of Pulmonary Function Test by Spirometry in Occupational Health Setting. [Serial online] 2011. Available from: URL: http://www.summacheeva.org/documents/book_spirometry.pdf. [Cited 2018 October 1].
[23] Godderis L, Vanderheyden W, Van Geel J, Moens G, Masschelein R, Veulemans H. (2005). Exposure and inhalation risk assessment in an aluminium cast-house.J Environ Monit;7(12):1359-63.
[24] KL. (2008). Prevalence of respiratory symptoms and spirometric values in aluminium potroom workers. Arhiv za higijenu rada i toksikologiju; 59(2): 89-95.
[25] Elserougy S, Mahdy-Abdallah H, Hafez SF, Beshir S. (2015). Impact of aluminum exposure on lung. Toxicology and industrial health; 31(1):73-78.
[26] Inuzuka K, Yasui M, Waseda Y, Takato H, Ichikaw Y, Fujimura M. (2010). A case of repeated bilateral pneumothorax associated with upper lobe predominant fibrosis in an aluminum processing worker. Nihon Kokyuki Gakkai Zasshi; 48(7):492-6.
[27] Jindal SK, Aggarwal AN, Gupta D. (2001). Dust-induced interstitial lung disease in the tropics. Curr Opin Pulm Med; 7(5):272-7.
[28] Crystal RO, Oadek JE, Ferrans VJ, Fulmer J.D, Line BR, Hunninghake OW. (1981). Interstitial lung disease: current concepts of pathogenesis, staging and therapy. Am J Med; 70: 542-568.
[29] Snider OL. (1983). Interstitial pulmonary fibrosis-which cell is the culprit. Am Rev Respir Dis;127: 535-539.
[30] Devuyst P, Dumonier P, Schandene L, Estcnne M, Verhest A, Yernault JC. (1987). Sarcoidlike lung granulomatosis induced by aluminium dust. Am Rev Respir Dis; 135: 493-497.
[31] Frantz S, Wollmer P, Dencker M, Engström G, Nihlén U. (2014). Associations between lung function and alcohol consumption – Assessed by both a questionnaire and a blood marker. Respiratory Medicine; 108 (1): 114-121.
[32] Radon K, Nowak D, Szadkowski D. (1999). Lack of combined effects of exposure and smoking on respiratory health in aluminium potroom workers. Occup Environ Med; 56: 468-472.

[33] Covey LS, Wynder EL. (1981). Smoking habits and occupational status. J Occup Med; 23: 537-542.

[34] Sato K, Shibata Y, Inoue S, Igarashi A, Tokairin Y, Yamauchi K, Kimura T, Nemoto T, et al. (2018). Impact of cigarette smoking on decline in forced expiratory volume in 1s relative to severity of airflow obstruction in a Japanese general population: The Yamagata-Takahata study. Respir Investig; 56(2):120-127.

[35] Soyseth V, Kongerud J. (1992). Prevalence of respiratory disorders among aluminium potroom workers in relation to exposure to fluoride. British journal of industrial medicine; 49(2):125-130.

[36] Kongerud J, Rambjør O. (1991). The influence of the helmet respirator on peak flow rate in aluminum potroom. Am Ind Hyg Assoc J; 52:243-248.

[37] Roto P. Smelting and Refining. Works. [Serial online] 1980. Available from: URL:http://www.iloencyclopaedia.org/part-xiii-12343/metal-processing-and-metal-working-industry/smelting-and-refining-operations/135-smelting-and-refining-operations/smelting-and-refinin. [Cited 2017 October 1]

[38] Prasongwattana S, Maruo S, Punpakdee O, Kalampalakorn S. (2010). Respiratory Symptom and Pulmonary Function of Home Based Garment Workers: A Case Study in Bansang Community, Bangpa-in District, Phra Nakhon Si Ayitthaya Province.Journal of Public Health Nursing; 24 (2):34.

[39] Tynes T, Løvseth EK, Johannessen HA, Sterud T, Skogstad M. (2018). Interaction of smoking with respiratory effects of occupational dust exposure: a prospective population study among Norwegian men. ERJ Open Res; 26;4(2). pii: 00021-2018. doi: 10.1183/23120541.00021

[40] Kusaka Y, Iki M, Kumagai S, Goto S. (1993). Epidemiological study of hard metal asthma. Occup Environ Med; 53(3): 188-193.Gondal, M. A., Drmosh, Q. A., Yamani, Z. H., Saleh, T. A., “Synthesis of ZnO2 nanoparticles by laser ablation in liquid and their annealing transformation into ZnO nanoparticles” *Applied Surface Science*, **256**: 298-304(2009).