ISSN: 2378-3516

Elmajzoup et al. Int J Respir Pulm Med 2018, 5:080
DOI: 10.23937/2378-3516/1410080
Volume 5 | Issue 1
Open Access

International Journal of
Respiratory and Pulmonary Medicine

ORIGINAL ARTICLE

Respiratory Disorders in Aluminum Extrusion Workers

Ammar Awad Elshiekh Elmajzoup[1,2*], Abdel Rouf Ahmed Abbas Elbadawi[1,3] and Faiz Abel Wahab Mohammed[4]

[1]*Biochemistry Department, Faculty of Basic Medical Science, Omdurman Islamic University, Sudan*

[2]*Basic Science Department, AL-Farabi College for Dentistry and Nursing, Saudi Arabia*

[3]*University Director, Open University of Sudan, Sudan*

[4]*King Faisal Specialist Hospital and Research Centre, Saudi Arabia*

***Corresponding author:** *Ammar Awad Elshiekh Elmajzoup, Biochemistry Department, Faculty of Basic Medical Science, Omdurman Islamic University; Basic Science Department, AL-Farabi College for Dentistry and Nursing, P.O.Box: 21512 - Jeddah 45107, Saudi Arabia, Tel: (+966)54-845-6276, E-mail: aelmajzoup@hotmail.com*

Abstract

The present study determined the prevalence of work-induced respiratory symptoms among Sudanese extrusion workers in an aluminum (Al) extrusion plant where the health effects of exposure duration, S-Al, and U-Al concentrations were evaluated. A total of 109 workers were enrolled in our study. Ambient Al fumes was estimated using a flame atomic absorption spectrophotometer (Varian, Spectr AA-250). The respiratory symptoms were reported according to the American Thoracic Society (ATS) Adult Respiratory criteria (Questionnaire (ATS-DLD-78). Results of the study showed concentrations of total airborne Al fumes and Aluminum oxide (Al_2O_3) ranging from 3.08 to 7.12 mg/m^3 (5.05 ± 1.29) and 0.11 to 3.06 mg/m^3 (1.28 ± 0.89) respectively. Higher frequencies of respiratory complains were detected among exposed group.

Keywords

Aluminum fumes, Al_2O_3, Occupational exposure, Respiratory disorders, Asthma, Wheeze

Introduction

Aluminum (Al) is a widespread metal considered as the third most common element in the earth's crust naturally released to the environment from weathering rocks and volcanic activity. Some human activities such as mining also result in the release of Al to the environment. Aluminum levels in environmental media vary widely depending on location and sampling site. In general, background levels of Al in the atmosphere are low, typically ranging from about 0.005 to 0.18 µg/m^3. Much higher levels are routinely observed in urban and industrial locations [1].

Aluminum has been traditionally regarded as non-toxic metal that induces pathological changes only in specific conditions such as long-term dialysis due to renal failure or occupational exposure to Al dust, fumes and its oxides [2].

Occupational exposure to Al occurs during refining of the primary metal and in secondary industries that use Al products. Several studies have reported adverse respiratory tract effects in employees working in Al industry. Abramson, et al. and Kilburn provided evidence suggesting that chronic exposure to Al may cause occupational asthma [3,4]. Additionally, asthmatic reaction was noted following a bronchial provocation test in Al foundry worker and in Al welder [5,6]. Wheezing, dyspnea, or impaired lung function have been reported in potroom workers. However, this has not been consistently viewed across studies and possibly exposure to other compounds may have contributed to observed effects [1].

Röllin and her co-workers reported that the presence of Al in blood serum (S-Al) and urine samples (U-Al) of people working in Al factories is a sign of Al absorption [7]. To assess occupational exposure of workers, measurement of Al concentrations in serum and urine is recommended.

In Sudan, research in environmental and occupational health is generally very limited demonstrated by in-

Citation: Elmajzoup AAE, Elbadawi ARAA, Mohammed FAW (2018) Respiratory Disorders in Aluminum Extrusion Workers. Int J Respir Pulm Med 5:080. doi.org/10.23937/2378-3516/1410080

Accepted: June 12, 2018; **Published:** June 14, 2018

sufficient data concerning levels of Al in human biological samples in addition to lack of studies in assessment of health impact of Al fumes in Al factories workers. This study aims to estimate the incidence of respiratory health complains among workers in an Al extrusion plant.

Materials and Methods

Study design and population

A cross-sectional study was conducted in an aluminum extrusion plant established in 1997 for Al industrial purposes and other applications. The plant occupies 6500 m^2 lot consisting of extrusion line, anodizing unit, powder coating unit, electro-coloring, polishing, brushing, and wrapping unit. Production started in March 2000 with annual capacity of 3000 tons [8]. At the time of this study, the plant had 115 male employees out of which 109 were randomly selected and interviewed. Blood and urine specimens were separately collected from each employee and properly labeled. The 109 workers segregate into 66 workers (Test Group) from the production department and 43 workers (Control Group) from management department, laboratory technicians, quality control, and truck drivers. Due to the nature of their work, members of the Test group were found more exposed to higher concentrations of Al fumes and exhibited respiratory health problems. The average working hours for the Test Group was about 8 hours. During this period, they were in direct exposure to Al fumes. Members of the Control Group did not exhibit any respiratory problems and were not found to experience significant exposure to Al fumes.

A questionnaire was used to collect sociodemographic characteristics, workplace exposure information, occupational history, medical history (current illnesses, health complains, work-related health complains, use of Al containing medications such as Acetaminophen, Aluminum hydroxide, Aspirin and Alginic acid and family medical history) and their personal lifestyle (smoking, exercise and personal hygiene). The questions on the medical history of respiratory symptoms and smoking habits were adapted from the American Thoracic Society (ATS) Adult Respiratory Questionnaire (ATSDLD-78) [9]. Classification of respiratory chronic symptoms was referenced from the guidelines by Robin, et al. and the Modified Medical Research Council (MMRC) dyspnoea scale [10]. Smoking status was classified into three categories, non-smokers, ex-smokers and current smokers. Ex-smokers were defined as those who quit smoking, at least, one month before conducting the questionnaire survey.

Written informed consent (thumbprint in the case of illiterate candidates) was obtained from all participants. The consent form stipulates that the participant has the right to opt out at any time from the study and that collected data may possibly be published. The consent form was approved by the Ethics Review Committee of Omdurman Islamic University Faculty of Basic Medical Sciences (ERC-OIUFBMS).

Air sampling

A flame atomic absorption spectrophotometer (Varian, Spectr AA - 250) was used for measuring Al concentrations on the filters. Air samples were taken from workspaces (1 sample per shift). Time-Weighted Average (TWA) Al concentrations were continuously collected from the workers' breathing zone. Sampling covered at least 7 hours of an 8 h work shift. The amounts of Al fumes were determined gravimetrically and the airborne Al fumes concentrations were calculated as an average of sampled air volumes. Personal air samples were collected using Casella personal sampler pump model AFC123 equipped with a 0.8 µm pore size membrane filter with a 37 mm diameter cellulose membrane filters (Sartorius 11304). Average pump airflow rate during collection was 2 L/min. Samples were collected from extrusion, anodizing, powder coating, electro-coloring, polishing, brushing, and wrapping-in addition to assembly of truck drivers area as a control. After nondestructive analysis, filters were dissolved in concentrated HNO_3 with the National Institute for Occupational Safety and Health (NIOSH) protocols [11].

Biological fluids analysis

A Perkin-Elmer Model 4100L atomic absorption spectrometer with Zeeman-Effect background correction equipped with a Transversely Heated Graphite Atomizer (THGA) was used for detecting Al in serum and urine. The instrument settings and furnace programs for analysis of Al in serum and urine have been described by Röllin, et al. [7].

Blood and urine specimens were obtained from workers in non-fasting state before start of their work shift, wearing their street clothes. Samples were collected under fumes free conditions. Specimens were frozen and stored at -20 °C until analyzed, in accordance with accepted procedures outlined in a previous study [7].

Statistical analysis

Analysis of data was performed using Statistical Package for the Social Sciences (SPSS) software program version 15. Statistical methods were applied including descriptive statistics (mean, standard deviation, frequency distribution, and cross tabulation), significance tests (T-test for quantitative data and Chi-square for categorical data), and logistic regression analysis for evaluating the associations between respiratory symptoms and study groups (exposed and unexposed), and correlations between different variables using Pearson's correlation. A 95% confidence interval (two-sided) was used as the limit of significance.

Results

The questionnaire was completed by 109 partici-

Table 1: Sociodemographic characteristics and the concentrations of S-Al & U-Al (µg/L) of studied workers according to pattern of exposure.

Characteristics	Type of exposure		p-Value*
	Exposed group (N = 66)	Unexposed group (N = 43)	
[2]Age (years) (Mean ± SD)	33.59 ± 9.50	33.83 ± 10.12	0.898
[2]Duration of work (months) (mean ± SD)	41.16 ± 15.79	38.02 ± 12.72	0.255
[1]Educational level No. (%)			
- Illiterate and read and write	9 (13.6)	5 (11.6)	
- Primary and preparatory (5-13 years)	14 (21.2)	10 (23.3)	0.936
- Secondary and university (14-22 years)	43 (65.2)	28 (65.1)	
[1]Residence No. (%)			
- Urban	51 (77.3)	33 (76.7)	0.949
- Rural	15 (22.7)	10 (23.3)	
[1]Personal hygiene No. (%)			
- Good	56 (84.8)	34 (79.1)	0.437
- Bad	10 (15.2)	9 (20.9)	
[1]History of respiratory diseases No. (%)			
- Hasn't a history of respiratory diseases	28 (42.4)	33 (76.7)	0.40
- Has a history of respiratory diseases	38 (57.6)	10 (23.3)	
[1]Smoking habit No. (%)			
- Currently smoker	15 (22.7)	8 (18.6)	0.842
- Ex-smoker	13 (19.7)	8 (18.6)	
- Non-smoker	38 (57.6)	27 (62.8)	
[2]S-Al (µg/L) (mean ± SD)	5.50 ± 1.48	1.03 ± 0.23	0.01**
[2]U-Al (µg/L) (mean ± SD)	97.85 ± 7.76	16.73 ± 3.96	0.01**

[1]Chi Square Test: *significant at P < 0.05, **significant at P < 0.01, ***significant at P < 0.001;

[2]*T-test*: *significant at P < 0.05, **significant at P < 0.01, ***significant at P < 0.001, S-Al: Serum Aluminum; U-Al: Urinary Aluminum concentrations.

Table 2: Frequency of health complains in the Exposed and Unexposed groups.

Health complaints	Exposed group (N = 66)		Unexposed group (N = 43)	
	n	%	n	%
Asthma	16	24.24	2	4.65
Cough	25	37.87	2	4.65
Morning cough with sputum	19	28.78	2	4.65
Phlegm	4	6.06	0	0
Chronic phlegm	5	7.57	0	0
Wheeze	8	12.12	0	0
Respiratory problems (asthma, coughing) caused by current work	7	10.60	2	4.65

pants (exposed: 66; unexposed: 43). Sociodemographic data of studied groups shown in Table 1, where there was no significant difference between exposed and unexposed workers with regards to sociodemographic parameters.

The airborne Al concentrations of total Al fume and Al_2O_3 ranged from 3.08 to 7.12 mg/m^3 (5.05 ± 1.29) and from 0.11 to 3.06 mg/m^3 (1.28 ± 0.89) respectively. The highest air Al_2O_3 concentrations were found at the workplace of workers responsible for extrusion and powder coating lines (2.30 ± 0.28). These concentrations were found above the TLV-TWA of aluminum metal and insoluble compounds (1 mg/m^3) [12].

The mean concentrations of S-Al and U-Al samples are summarized in Table 1. Statistical analysis showed significant difference between exposed and unexposed group (P < 0.001). Significant positive correlation was found between duration of exposure and S-Al (r = 0.735, P < 0.01). Additionally, significant positive correlation was shown between the duration of exposure and U-Al (r = 0.596, P < 0.01).

Prevalence of work-induced asthma, cough, morning cough with sputum, phlegm, chronic phlegm, wheeze and respiratory problems (asthma, coughing) caused by current work were higher in the exposed group (24.24%, 37.87%, 28.78%, 6.06, 7.57, 12.12% and 10.60% respectively) compared to the unexposed group (4.65%, 4.65, 4.65, 0.00%, 0.00%, 4.65% and 4.65% respectively) (Table 2).

Logistic regression analysis was carried out to compare association between study groups and chronic respiratory symptoms adjusted for age, duration of work and Al concentrations in biological samples (blood and urine). The production workers were about seven times more likely to have asthma (OR: 6.56; 95% CI: 1.43-30.20; P < 0.007) compared with unexposed workers.

Table 3: Regression analysis between respiratory problems adjusted with age, duration of work and S-Al/U-Al concentrations.

Respiratory symptoms	OR (95% C.I.)	AOR (95% C.I.)
Asthma	6.56 (1.43-30.20)***	6.58 (1.45-30.26)***
Chronic cough	12.50 (2.78-56.24)***	12.51 (2.79-56.34)***
Morning cough with sputum	8.29 (1.82-37.74)***	7.69 (1.68-35.12)***
Phlegm	1.95 (1.30-2.91)	1.91 (1.26-2.90)
Chronic phlegm	2.43 (0.48-12.30)	2.43 (0.43-10.10)
Wheeze	4.39 (0.89-21.61)	2.24 (0.41-12.17)
Respiratory problems (asthma, coughing) caused by current work	6.21 (2.89-13.36)	6.00 (2.78-12.94)

*Significant at P < 0.05, **significant at P < 0.01, ***significant at P < 0.001, OR: Odd Ratio; AOR: Adjusted Odd Ratio; S-Al: Serum Aluminum; U-Al: Urinary Aluminum concentrations.

Table 4: Comparison of exposure duration in the exposed group between subjects without and with symptoms.

Respiratory chronic symptoms	Exposure duration (months) in the exposed group (Mean ± SD)		p-Value*
	Without symptoms	With symptoms	
Asthma	39.92 ± 15.59	45.06 ± 16.27	0.260
Chronic cough	37.68 ± 15.56	46.88 ± 14.74	0.021*
Morning cough with sputum	39.85 ± 16.03	44.42 ± 15.10	0.291
Phlegm	41.11 ± 15.64	42.00 ± 20.78	0.914
Chronic phlegm	41.75 ± 16.76	34.00 ± 16.12	0.295
Wheeze	41.21 ± 15.26	40.88 ± 20.49	0.956
Respiratory problems (asthma, coughing) caused by current work	39.49 ± 15.63	55.29 ± 8.99	0.011*

T-test: *significant at P < 0.05, ** significant at P < 0.01, *** significant at P < 0.001.

Table 5: Comparison of S-Al concentrations in the exposed group between subjects without and with symptoms.

Respiratory chronic symptoms	S-Al concentrations (µg/l) in the exposed group (Mean ± SD)		p-Value*
	Without symptoms	With symptoms	
Asthma	5.30 ± 1.48	6.15 ± 1.36	0.044*
Chronic cough	5.05 ± 1.41	6.24 ± 1.31	0.001***
Morning cough with sputum	5.33 ± 1.51	5.93 ± 1.37	0.137
Phlegm	5.48 ± 1.50	5.85 ± 1.24	0.633
Chronic phlegm	5.55 ± 1.50	4.98 ± 1.24	0.415
Wheeze	5.45 ± 1.47	5.87 ± 1.80	0.465
Respiratory problems (asthma, coughing) caused by current work	5.32 ± 1.46	7.06 ± 0.29	0.003**

T-test: *significant at P < 0.05, **significant at P < 0.01, ***significant at P < 0.001.

The adjusted OR was slightly increased and was significant (AOR: 6.58; 95% CI: 1.45-30.26; P < 0.016). The concentrations of Al in biological samples (blood and urine) of participants, age, and duration of work were significant predictors (P < 0.001 each) for asthma. Similarly, members of the exposed group were almost thirteen times more likely to suffer a chronic cough (OR: 12.50; 95% CI: 2.78-56.24; P < 0.001) in comparison to unexposed participants. When adjusted, it was still almost thirteen times more (AOR: 12.51; 95% CI: 2.79-56.34; P < 0.001). Duration of work was a significant predictor (P < 0.001) for a chronic cough. Also, exposed participants were eight times more likely to experience a morning cough with sputum (OR: 8.29; 95% CI: 1.82-37.74; P < 0.002) compared with unexposed. On adjustment, AOR slightly decreased but remained significant (OR: 7.69; 95% CI: 1.68-35.12; P < 0.009) indicating age and duration of work were significant predictors (P < 0.001).

Logistic regression analysis compared the association between work-related health complaints (respiratory problems) and type of work performed by each member of the study group. Exposed workers were two times more likely to contract work-induced respiratory problems (asthma, coughing) caused by current work (OR: 2.43; 95% CI: 0.48-12.30; P < 0.029) compared with unexposed workers. However, after adjustment, no association found. Additionally, no association was found between Al plant workers and other respiratory symptoms (phlegm, wheeze, and wheezing with dyspnoea) even after adjustment (Table 3).

Comparison between Al exposure duration and respiratory chronic symptoms revealed statistical significance for a cough (P < 0.021) and respiratory problems (asthma, coughing) caused by current work (P < 0.011) (Table 4).

The association between S-Al concentrations and respiratory chronic symptoms showed a statistically significant difference for work-induced asthma (P < 0.044), cough (P < 0.001), and respiratory problems (asthma, coughing) caused by current work (P < 0.003). There were no statistically significant associations between S-Al concentrations and one another characteristics of respiratory complaints (Table 5).

Table 6: Comparison of U-Al concentrations in the exposed group between subjects without and with symptoms.

Respiratory chronic symptoms	U-Al concentrations (µg/l) in the exposed group (Mean ± SD)		p-Value*
	Without symptoms	With symptoms	
Asthma	96.98 ± 7.64	100.88 ± 7.57	0.073
Chronic cough	95.03 ± 5.64	102.48 ± 8.62	0.001***
Morning cough with sputum	97.19 ± 7.87	99.48 ± 7.43	0.282
Phlegm	97.86 ± 7.71	97.65 ± 9.72	0.957
Chronic phlegm	97.98 ± 7.90	96.23 ± 6.15	0.630
Wheeze	97.42 ± 7.60	100.95 ± 8.74	0.231
Respiratory problems (asthma, coughing) caused by current work	97.01 ± 7.33	104.90 ± 8.26	0.01**

T-test: *significant at P < 0.05, **significant at P < 0.01, ***significant at P < 0.001.

Table 7: Comparison of Al_2O_3 concentrations in the air at workstations in the exposed group between subjects without and with symptoms.

Respiratory chronic symptoms	Al_2O_3 concentrations (mg/m³) in the exposed group (Mean ± SD)		p-Value*
	Without symptoms	With symptoms	
Asthma	1.12 ± 0.81	1.80 ± 0.90	0.006**
Chronic cough	0.99 ± 0.78	1.77 ± 0.82	0.001***
Morning cough with sputum	1.14 ± 0.83	1.64 ± 0.91	0.033*
Phlegm	1.27 ± 0.85	1.35 ± 1.47	0.882
Chronic phlegm	1.32 ± 0.88	0.82 ± 0.80	0.220
Wheeze	1.21 ± 0.85	1.84 ± 0.86	0.054
Respiratory problems (asthma, coughing) caused by current work	1.15 ± 0.79	2.43 ± 0.76	0.001***

T-test: *significant at P < 0.05, **significant at P < 0.01, ***significant at P < 0.001.

Association between U-Al concentrations and work-induced respiratory chronic symptoms revealed statistically higher significance for cough (P < 0.001), wheezing with dyspnoea (P < 0.018), and respiratory problems (asthma, coughing) caused by current-work (P < 0.01). Other respiratory chronic symptoms did not show statistically significant difference when compared to U-Al concentrations (Table 6).

Comparison between current exposure to Al_2O_3 concentrations and respiratory chronic symptoms showed statistically significant difference for worked-induced asthma (P < 0.006), cough (P < 0.001), morning cough with sputum (P < 0.033), and respiratory problems (asthma, coughing) (P < 0.001). Conversely, the differences in the other respiratory chronic symptoms were insignificant (Table 7).

The associations between the total Al airborne concentrations and work-induced respiratory chronic symptoms revealed statistical significant difference for asthma (P < 0.007), cough (P < 0.001), morning cough with sputum (P < 0.018), wheeze (P < 0.042), and respiratory problems (asthma, coughing) caused by current work (P < 0.003), while, the phlegm and chronic phlegm symptoms showed insignificant differences.

Discussion

Due to its high heat and electrical conductivity, light weight and corrosion resistance, Al is widely used in cooking utensils, containers, buildings, airplanes, trains, electric wires and foils [13]. Al has variable toxic effects on the respiratory tract such as pulmonary fibrosis, pulmonary alveolitis, alveolar proteinosis, asthma and chronic bronchitis. Despite enhanced safety measures such as partial protection of production lines and automation of manual work, preventive measures are probably more effective in avoiding respiratory disorders in Al plants workers.

Comparison of health complains results in a group of extrusion workers revealed in our study and data in the literature is rather difficult due to use of different methods for assessing occupational exposure and sometimes combined exposure.

Logistic regression analysis was carried out to compare associations between study members and respiratory symptoms. In our current study, respiratory symptoms: Asthma, cough, and morning cough had significantly higher prevalence in exposed workers compared with unexposed workers. These findings were found consistent with a study conducted in the Netherlands [14].

The results of this study showed that concentrations of Al in biological samples (blood and urine) of production workers were significantly higher than the unexposed workers. Significant relationships were also observed between blood Al and urinary Al concentrations with the number of respiratory symptoms in the group that was continuously exposed to Al fumes for more than 8 h/day. Additionally, significant positive correlation was found between the duration of exposure and Al in biological samples of extrusion workers (blood and urine). This result is in contrast with a cross-sectional study performed in an Al factory in Seydisehir, Turkey, which revealed negative correlation with both exposure time and serum Al [15].

In our study, Al_2O_3 concentrations in the workplace were found higher than the TLV-TWA of aluminum metal and insoluble compounds (1 mg/m^3) according to ACGIH [12], but they were less than (5 mg/m^3) according to NOISH [16] and (Cal/OSHA) [17]. These findings coincide with another previous study of airborne Al exposure in metal inert gas (MIG) welding and grinding shipyard workers in Finland (the welding fumes contained Al_2O_3). The study found that the mean 8 h TWA concentrations measured inside the welding helmet ranged from 0.2 to 10.0 mg/m^3 for total dust and from 0.008 to 2.4 mg/m^3 for Al. When no respiratory protection was used, total dust and Al breathing zone air levels were 1.2-13.6 mg/m^3 and 0.3-6.1 mg/m^3, respectively [18].

A comparison between Al exposure duration time and respiratory chronic symptoms revealed statistically higher significant difference for a cough and respiratory work-induced problems (asthma, coughing) caused by current work. Whereas, the other health complaints were not significant. Furthermore, the association between current exposure to Al_2O_3 concentrations and respiratory chronic symptoms showed statistically significant difference for work induced asthma, cough, morning cough with sputum, and respiratory problems (asthma, coughing) caused by current work. However, the associations between total Al airborne concentrations and respiratory chronic symptoms also revealed statistically significant difference for work-induced asthma, cough, morning cough with sputum, wheeze, and respiratory problems (asthma, coughing) caused by current work. These findings might be attributed to inhalation of Al fumes and other irritant occupational pollutants especially fluorides [19,20] through potentiating oxidative and inflammatory stress leading to functional disturbance of lung epithelium [21].

Results similar to ours were obtained by Chan-Yeung and his colleagues [22], who investigated the prevalence of respiratory symptoms among 1510 employees in an aluminum smelter in British Columbia. The researchers found increased prevalence of a cough (22.6% vs. 14.0%) and wheeze (17.1% vs. 10.5%) in high-exposure group compared with reference group. Comparatively, a cross-sectional study of 316 workers conducted in Machining Industry in Selangor, Malaysia by Liaw, et al. [23], concluded that significantly higher prevalence of daily cough (19.6% vs. 10.6%) and morning cough with sputum (3.6% vs. 0.0%) were associated with occupational exposure to Metalworking Fluid (MWF) aerosol among exposed group compared to unexposed group. Another study performed by Ljiljana [24] on 215 potroom workers from the aluminum factory in Podgorica, Montenegro showed that potroom workers mostly complained of breathlessness associated with the workplace (56.7%) or weather changes (rain, cold, wind, and humidity) (41.9%) and of dyspnoea when climbing stairs (51.2%), but only 22.3% reported using medication to treat these episodes. In our study, Al containing medications were not reported by any member of the study group.

Conclusions

Aluminum is hazardous to both of workers and the community. Based on our findings, workers who are continuously exposed to Al fumes and pollutants for more than 8 h/day, had a higher significant association between biological (serum/urine) Al concentrations and pulmonary complains compared with unexposed workers. Our findings also showed significant associations between respiratory symptoms and Al_2O_3 concentrations in different workstations. These results suggest protective measures are needed, particularly among workgroups with higher exposures or higher prevalence of respiratory symptoms. Accordingly, it is recommended that current control measures should be enhanced such as coolant management program and engineering control through installation of local exhaust ventilation to improve indoor air quality of the plant production site.

It is also recommended that work hours per shift should be reduced in order to avoid over exposure. We also recommend providing Personal Protective Equipment (PPE) to the workers. Mandatory subclinical screening, especially spirometric examination should be integral to the preventive examinations protocol in Al-exposed workers. Finally, workers should be given optimal vacation time to help minimize work-induced Al exposure.

At the community level, voluntary organizations, special interest groups, and non-government organizations should be promoted to educate plant workers, their employers and the general public on the necessity of industrial hygiene practice. Further investigations in health hazards of Al industry will help promulgate the need for greater intervention. All workers deserve workplace environment free from extreme health hazards and unsafe conditions.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgements

The authors gratefully acknowledge the cooperation of all persons who participated in this study which was supported by Omdurman Islamic university. We would like to express our gratitude to management of Aluminum extrusion plant for their assistance with the collection of air samples.

References

1. ATSDR. Toxicological profile for aluminum (2008) U.S. Department for Health and Human Services. Public Health Service Agency for Toxic Substances and Disease Registry.

2. Alfrey AC, LeGendre GR, Kaehny WD (1976) The dialysis encephalopathy syndrome. Possible aluminum intoxication. N Engl J Med 294: 184-188.

3. Abramson MJ, Wlodarczyk JH, Saunders NA, Hensley MJ (1989) Does aluminum smelting cause lung disease? Am Rev Respir Dis 139: 1042-1057.

4. Kilburn KH (1998) Pulmonary and neurological effects of aluminum. In: Rom WN, Environmental and occupational medicine. Philadelphia, PA: Lippincott-Raven, 1065-1073.

5. Burge PS, Scott JA, McCoach J (2000) Occupational asthma caused by aluminum. Allergy 55: 779-780.

6. Vandenplas O, Delwiche JP, Vanbilsen ML, Joly J, Roosels D (1998) Occupational asthma caused by aluminium welding. Eur Respir J 11: 1182-1184.

7. Röllin HB, Theodorou P, Cantrell AC (1996) Biological indicators of exposure to total and respirable aluminium fractions in a primary aluminium smelter. Occup Environ Med 53: 417-421.

8. Giad Aluminum plant (2004) Introduction of Aluminum plant. 4 pp.

9. ATS (1978) American Thoracic Society (ATS) Adult Respiratory Questionnaire (ATS-DLD-78). Recommended Respiratory Disease Questionnaires for Use with Adults and Children in Epidemiological Research.

10. Robins TG, Seixas N, Franzblau A, Abrams L, Minick S, et al. (1997) Acute respiratory effects on workers exposed to metalworking fluid aerosols in an automotive transmission plant. Am J Ind Med 31: 510-524.

11. NIOSH (1994) Manual of Analytical Methods (NMAM). U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, (4th edn), Cincinnati.

12. ACGIH (2007) Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

13. Elinder CG, Sjogren B (1986) Aluminium. In: Friberg L, Nordberg GF, Vouk V, Handbook on the Toxicology of Metals. (2nd edn), Elsevier, Amsterdam.

14. van Rooy FG, Houba R, Stigter H, Zaat VA, Zengeni MM, et al. (2011) A cross-sectional study of exposures, lung function and respiratory symptoms among aluminum casthouse workers. Occup Environ Med 68: 876-882.

15. San LN, Uysal H, Gökbel H, Bediz CS, Sayal A (1998) Pulmonary function of workers in the aluminum industry. Am J Ind Med 33: 305-307.

16. National Institute for Occupational Safety and Health (NIOSH) (2016) NIOSH Pocket Guide to Chemical Hazards. Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health (NIOSH).

17. California Division of Occupational Safety and Health (Cal/OSHA) (2016) Table AC-1, Permissible Exposure Limits (PELs), in California Code of Regulations (CCR) Title 8 Section 5155.

18. Riihimäki V, Valkonen S, Engström B, Tossavainen A, Mutanen P, et al. (2008) Behavior of aluminum in aluminum welders and manufacturers of aluminum sulfate--impact on biological monitoring. Scand J Work Environ Health 34: 451-462.

19. Healy J, Bradley SD, Northage C, Scobbie E (2001) Inhalation exposure in secondary aluminium smelting. Ann Occup Hyg 45: 217-225.

20. Nasiadek M, Sapota A (2004) Toxic effect of dust and fumes of aluminium and its compounds on workers' respiratory tract. Med Pr 55: 495-500.

21. Mazzoli-Rocha F, Dos Santos AN, Fernandes S, Ferreira Normando VM, Malm O, et al. (2010) Pulmonary function and histological impairment in mice after acute exposure to aluminum dust. Inhal Toxicol 22: 861-867.

22. Chan-Yeung M, Wong R, MacLean L, Tan F, Schulzer M, 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: 465-469.

23. liaw Sh, Hashim Z, Lye Ms, Zainuddin H (2014) Respiratory Health and Allergies from Chemical Exposures among Machining Industry Workers in Selangor, Malaysia. Iranian J Publ Health 43: 94-102.

24. KezunoviÄ LC (2008) Prevalence of respiratory symptoms and spirometric values in aluminium potroom workers. Arh Hig Rada Toksikol 59: 89-95.